Biopac Student Lab *PRO*® Manual

For Life Science Educational Applications

Data Acquisition and Analysis with BIOPAC MP Systems
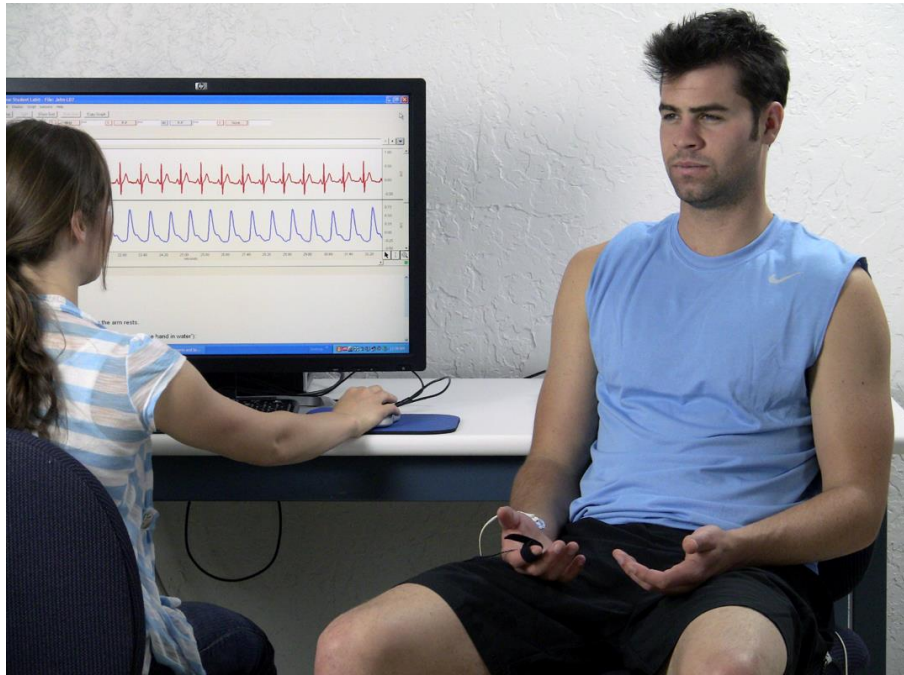
Reference Manual for
Biopac Student Lab 4.1.3 Software & MP36/MP35 & MP45 Hardware
on Windows® 10, 8, & 7, Mac OS® 10.10-10.13

BIOPAC
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Preface to Biopac Student Lab *PRO* Manual

Welcome

Welcome to the Biopac Student Lab *PRO* Manual. The Biopac Student Lab PRO system includes both hardware and software for the acquisition and analysis of life science data.

BSL *PRO* software not only makes data collection easier, but also performs analyses quickly and easily that are impossible on a chart recorder. Easily edit data, cut and paste sections of data, perform mathematical and statistical transformations, and copy data to other applications for reports and publication.

The MP System (MP36, MP35 or MP45 hardware) with BSL *PRO* is compatible with Windows® 10, 8, & 7 or Mac OS 10.10-10.13*.

This manual covers use of BSL *PRO* software with an MP System and details BIOPAC equipment available for a variety of applications. If a desired application is not addressed, please visit the BIOPAC web site at www.biopac.com to download one of our many Application Notes, or call to request a hard copy or talk to an Applications Specialist.

See also:

É BIOPAC Installation Guideô packed with the software installation disc.

É BIOPAC Hardware Guide.pdfô available under the Help menu and installed to the User Support folder. Provides details on MP System transducers, electrodes, etc., and setup and calibration.

É BIOPAC Catalogs

Supported Platforms

BSL *PRO* is supported on the following:

Operating Systems	MP Devices
Windows 10, 8, or 7	MP36/35/45
Mac OS 10.10 ó 10.13	
(10.13 is macOS High Sierra)	

What's new for BSL 4.1.3 *PRO*

The following features have been introduced since BSL 4.1.2 was released.

Bug fixes

macOS High Sierra support (10.13)

Chinese Traditional language support for BSL Lessons

Dropbox Version 2 support

Analysis Shortcuts—allows easy access to specialized analysis options from within a data channel

Enhanced Lesson Preferences offering easy access to *PRO* menu functionality and other custom features

The following features have been introduced since BSL 4.1.1 was released.

Bug fixes

macOS Sierra support (10.12)

Arbitrary Wave Output Control

Lesson videos can now be played back without Flashplayer

Updated Lessons and *PRO* Lessons

The following features have been introduced since BSL 4.1 was released.

Bug fixes

Windows 10 and Windows 8 support

Japanese language support for BSL Lessons

Collapsible channels — quickly hide and unhide single or multiple channels with one click

Updated Lessons and *PRO* Lessons

The following features have been introduced since BSL 4.0.3 was released.

FIR Filter Calculation Channel — apply high quality FIR filters in real time

Slew Rate Limiter — precise real-time or offline tool for denoising and removing motion artifact

Event-based Rate Measurements — extract the mean, median and standard deviation of online and offline Rate outputs

Support for four new transducers — (OUT4 Visual Stimulator Controllable LED, SS57LA for EDA, SS25LB Hand Dynamometer, STIMHUM Human-safe Stimulator)

Elapsed timers — stopwatch, elapsed timers and alarm to time experiment protocols

Embedded PDF Integration — embed PDFs of procedures, analysis, etc. into graph files and journals

Dropbox Integration — copy and store data files to Dropbox account directly from BSL application

Simplified User Interface and UI updates

Append event boundaries now appear in graph for easier viewing

New Analysis menu features — Locate Animal ECG Complex Boundaries, Correlation Coefficient, Ensemble Average, Epoch Analysis, define Focus Areas between events or appended segments, and Waterfall Plot

Curriculum Manager — Instructors may customize analysis procedures, data reports, lesson introduction, recording procedure and onscreen instructions and broadcast the customized content to all student workstations (Licensed Functionality)

Preset transducer detection — presets automatically check to see if correct transducer is connected

Simplified calibration for selected presets

New sample data files

New Lesson 11A for measuring visual stimulus reaction time

Updated *PRO* Lessons with *PRO* Lesson PDFs now embedded in graph template file

Bug fixes

The following features have been introduced since BSL 4.0 was released.

Consolidated hardware support

Single executable launches application for all supported hardware types

Rate detector enhancements

Adjustable baseline window width

Adjustable averaging output modes

Customizable Rate õsignal typeö presets

Textual values display and toolbar

Tabbed graph interface (shows multiple graphs in single window)

Focus areas for indicating areas of data to be analyzed by the Cycle Detector

Selection palette toolbar button

Show most recent data only in XY mode

Configurable measurement columns

Linked media files can be imported from BSL 3.x files (Windows only)

Screencast radio button in Startup Wizard and Help menu

Journal hyperlinks

Application preference to show/hide individual lessons or *PRO* lessons

Horizontal split view ó allows viewing of two independent horizontal axis areas in same graph

BSL *PRO* Windows included the following new features since BSL *PRO* 3.7.7 was released. If upgrading from an older version of BSL *PRO*, see the "BSL 3.7.7 *PRO* Manual" for a more complete list of features.

Analysis Packages

Histogram

Power Spectral Density

FFT/IFFT

Find Cycle

Find Rate

Detect and Classify Heartbeats

Locate Human ECG Complex Boundaries
Locate Animal ECG Complex Boundaries
Heart Rate Variability

Correlation Coefficient

Digital Input to Stim Events

Ensemble Average

Epoch Analysis

Focus Areas (define events)

Waterfall Plot

Multichannel Event Marking System

Event marking system is now combined with Cycle/Peak Detector, allowing automated measurements around specific events and additional event marking based on measurements taken. For example, mark when a dose or task occurs and automatically measure and mark the maximum response.

Cycle (Peak) Detector interface
Advanced Cycle/Peak Detector combines with powerful new Event Marking System. Perform amplitude, time, or event-based measurements. New output options for measurements, averaging, events, and 3D surface (cycle data, histogram, and FFT).

Transformations
Most recently used files, transformation and analysis
Delay transformation
Cubic spline resampling options
Spectrum analyzer/real-time FFT

Calculation Channels
Calculation metachannelsô daisy-chain calculations, such as Filter and Difference, on one channel
Dynamic digital filter options

Measurements
Expression enhancementsô online and post-acquisition
Interpolated measurements
New measurement options to optimize event marking system

User Interface – Display and control of data
Text annotationsô add zest to publication screen shots or annotate the file beyond event notes
Print functionsô adjust data range for printing; print waveform data in black; print file to PDF
Adaptive scalingô vertical scale updates in real time to optimize data display
Gridsô Friendly grid scaling; Flexible grid options Grid Tool
Balloon Help
Multiple levels of Undo
Jump tool
Rescale operations
Selection paletteô place cursors at specific time points
Mouse scrollwheel support
Keyboard Shortcuts added (accelerator keys)
Replay data

Data processing
Large file support
Batch acquisitions
Multithreaded operation

File Formats
Excel Export (for reports with tabular data)
Save Selection As moved to File menu and added = Wav, EDF, JPEG; removed = Metafile (*.WMF)
Open Mac Biopac Student Lab 3 Graph
BSL file import
EDF file import and export
Igor Pro Experiment import/export
WAV file format import/export

Using this Manual

The BSL *PRO* Manual is divided into four parts:

Part A *Getting Started*

Please review *Getting Started* whether new to computer-based data acquisition systems or an old hand at physiological monitoring. Use this section to become acquainted with how the system works and the most frequently used features.

Part B *Acquisition Functions*

Explains data acquisition features and gives a detailed summary of different acquisition parameters. Provides an in-depth description of the commands used to determine acquisition rate, acquisition duration, and specialized functions such as triggering, averaging, and online calculation of different values.

Part C *Analysis Functions*

Details information on analysis features; covers the range of post-acquisition analysis functions and transformations available with the MP System. Describes how to edit data, take measurements and perform basic file management options (save, print, etc).

Part D *Appendices*

Answers frequently asked questions, offers hints for working with files, includes information on upgrading from previous versions, provides technical information about the MP System and other information about the BSL *PRO* software.

See also:

BIOPAC Installation Guide

This guide was included with the software CD. It contains full instructions for hardware and software installation, and how to be up and running with the MP System in just a few minutes.

BSL Hardware Guide

BIOPAC MP Hardware Guide.pdf is available under the Help menu. It gives practical examples of how the MP data acquisition unit is used with different components for common types of data acquisition, and includes sample results and applications for widely used test procedures. This guide provides instructions for connecting external devices to the MP36, MP35 or MP45, electrodes, transducers etc.

User Support

User Support files can be found in the following hard drive location; BIOPAC Systems, Inc/BSL PRO 4.0/User Support in the Program Files or Applications folder.

■   BSL *PRO* Manual.pdf is the software support document

■   BSL Hardware Guide.pdf is the hardware guide (with specifications)

The User Support files can also be opened directly from the CD.

The files are in PDF format, and can be read by Adobe Acrobat Reader.

- Adobe Acrobat Reader can be downloaded for free at www.adobe.com under the Adobe Acrobat Reader site.

The Samples folder in the BIOPAC program folder contains sample files, graph template, Lesson and *PRO* Lesson files for a variety of applications. These templates establish the channel setup and acquisition parameters required for a variety of applications.

- To open sample files from the Startup Wizard, choose õOpen a graph File, choose the õSample data fileö radio button and select the desired folder. From within the application, go to File > Open then Browse to the BIOPAC Samples folder.

- To open a graph template file from the Startup Wizard, choose õCreate and/or record a new experimentö, choose the õSample graph templateö radio button and select the desired folder. From within the application, choose File > Open then Browse to the BIOPAC Samples folder (be sure to select/enable the desired file type).
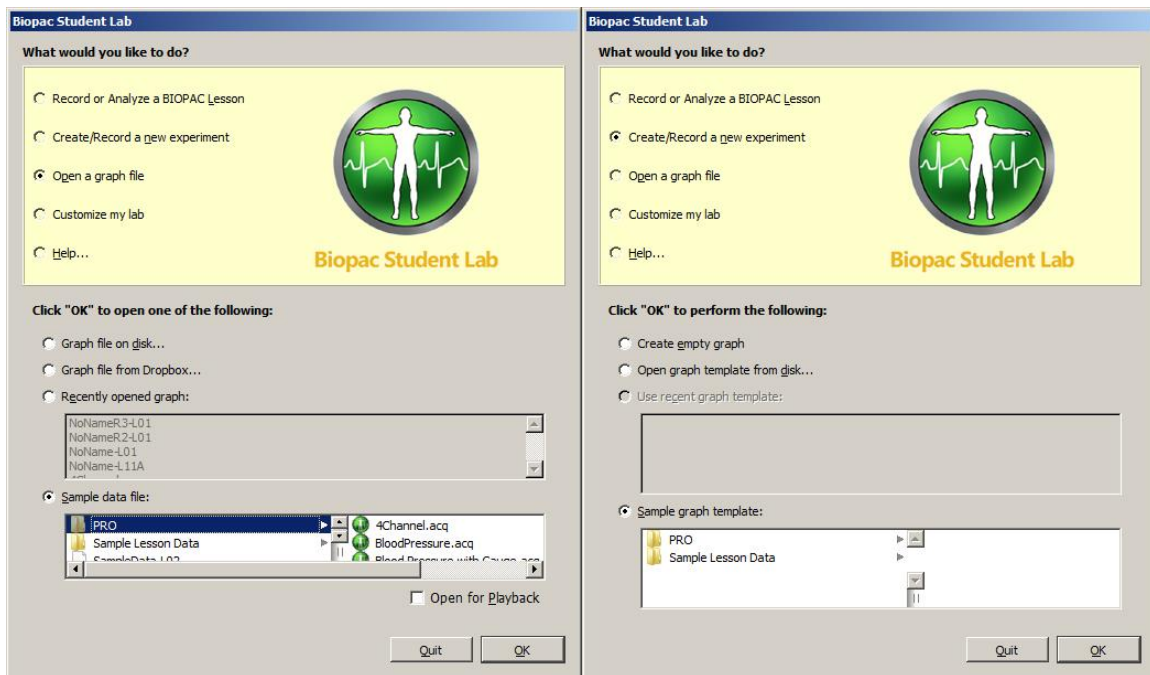
Where do I find help?

The Introductory sections are intended to provide enough information to get up and running with the MP System, and become familiarized with some basic BSL *PRO* functions. There are far more features than described in the first few pages, so here is a guide for how to continue using this manual.

➢ *Help menu*

The software Help menu includes basic information about standard BSL *PRO* functions and links to the tutorial, manual and hardware guide for online searchable Help while running BSL *PRO*, plus links to the BIOPAC web site.

➢ *Application Notes*

The BIOPAC web site at http://www.biopac.com has more than 50 available Application Notes. Download the desired Application Note or call to request a hard copy.

➢ *Acquiring data*

For more specific information on different types of acquisitions, see Part Bô *Acquisition Functions*. It covers basic acquisition parameters in detail, and describes some acquisition features (such as *peak detection* techniques and *online Calculation channels*) not covered in the Getting Started section.

➢ *Analysis*

Information about how to edit, display and transform data can be found in Part Cô *Analysis Functions*. It explains how to import and export data, how to save files, and other file management commands. This section also explains how to use all of the post-acquisition features of the BSL *PRO* software.

➢ *Connecting input devices*

To find out how specific modules connect to the MP data acquisition unit, turn to the *BIOPAC MP Hardware Guide* PDF file. This section describes how to connect signal-conditioning modules to the MP data acquisition unit and how to connect electrodes and transducers to the modules.

➢ *Working with large files*

Many users need to perform high speed (i.e., fast sampling rates) or long duration acquisitions. These types of acquisitions tend to generate large (several megabytes) data files that can be difficult to load, store, and view. The MP System can handle such acquisitionsô see the Appendices for information on how to optimize setup for these types of acquisitions.

➢ *Troubleshooting*

Includes a list of the most frequently asked questions regarding the MP System. Check this section (Appendix B) for commonly encountered problems and solutions.

IMPORTANT SAFETY NOTICE

BIOPAC Systems, Inc. instrumentation is designed for educational and research-oriented life science investigations. BIOPAC Systems, Inc. does not condone the use of its instruments for clinical medical applications. Instruments, components, and accessories provided by BIOPAC Systems, Inc. are not intended for the diagnosis, mitigation, treatment, cure, or prevention of disease.

The MP data acquisition unit is an electrically isolated data acquisition system, designed for biophysical measurements.

Exercise extreme caution when applying electrodes and taking bioelectric measurements while using the MP System (MP36, MP35 or MP45) with other external equipment that also uses electrodes or transducers that may make electrical contact with the Subject. Always assume that currents can flow between any electrodes or electrical contact points.

Extreme caution is also required when performing general stimulation (electrical or otherwise) on a subject. Stimulation currents should not be allowed to pass through the heart. Keep stimulation electrodes far from the heart and located close together on the same side of the subject's body.

It is very important (in case of equipment failure) that significant currents are not allowed to pass through the heart. If electrocautery or defibrillation equipment is used, it is recommended that all BIOPAC Systems, Inc. instrumentation be disconnected from the Subject.

Human Anatomy & Physiology Society Position Statement on Animal Use

(Adopted July 28, 1995, Modified January 2001, Approved April 29, 2012)

It is the position of the Human Anatomy and Physiology Society (HAPS) that dissection and the manipulation of animal tissues and organs are important elements in scientific investigation that introduce students to the excitement and challenge of their future careers. HAPS supports the use of biological specimens as part of a program of study, provided their use is in strict compliance with federal legislation and the guidelines of the National Institutes of Health and the United States Department of Agriculture, and that such use fulfills clearly defined educational objectives.

The mission of the Human Anatomy and Physiology Society (HAPS) is to promote excellence in the teaching of anatomy and physiology. A fundamental tenet of science is the ordered process of inquiry requiring careful and thoughtful observation by the investigator. As subdivisions of biology, both anatomy and physiology share a long history of careful and detailed examination, exploration and critical inquiry into the structure and function of the human and animal body.

Consistent with the origins and nature of scientific inquiry, HAPS endorses the use of animals as part of the laboratory experiences in both human anatomy and human physiology.

Historically, an important tool of investigation in human and animal anatomy has been dissection. A complete anatomy learning experience that includes dissection goes beyond naming structures and leads the student to conclusions and insights about the nature and relatedness of living organisms that are not otherwise possible. To succeed in their future careers, students must become thoroughly familiar with anatomical structures, their design features and their relationships to one another. Dissection is based on observational and kinesthetic learning that instills a recognition and appreciation for the three-dimensional structure of the animal body, the interconnections between organs and organ systems, and the uniqueness of biological material. Dissection conveys the inherent variability of living organisms not otherwise observable in simulations and models. Physiology experiments involving humans and live animals provide an excellent opportunity to learn the basic elements specific to scientific investigation and experimentation. It is here that students pose questions, propose hypotheses, develop technical skills, collect data, analyze results and develop and improve critical thinking and problem solving skills

Since effective teaching requires a diversity of strategies and approaches, HAPS endorses the use of computer atlases and simulations, modeling, and video programs to meet educational objectives and the needs of students. Science educators choosing not to use animals or biological specimens should choose alternatives that are able to convey equivalent anatomical and physiological intricacies to meet their educational objectives.

Science educators have in common a respect and reverence for the natural world and therefore have a responsibility to share this with their students. They must communicate the importance of a serious approach to the study of anatomy and physiology. HAPS also encourages educators to be responsive to student concerns regarding use of animals and to provide students who object to animal use with alternative learning materials.

HAPS contends that science educators should retain responsibility for making decisions regarding the educational uses of animals and other strategies and techniques for the betterment of their students' learning. Furthermore, it opposes any legislation or administrative policy that would erode the educator's role in decision making or restrict dissection and animal experimentation in biology.

Used with permission of:
The Human Anatomy & Physiology Society (HAPS)
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800-448-HAPS (4277)   Fax: (706) 883-8215   www.hapsweb.org

Part Aô Getting Started
Chapter 1   MP Systems Overview

Part A - *Getting Started* covers the basics of data acquisition and analysis with an MP System (MP36, MP35 or MP45). All of the material in this section is covered in more detail in subsequent sections (see *Using this Manual, page 15*).

Overview

The MP System is a computer-based data acquisition system that performs many of the same functions as a chart recorder or other data viewing device, but is superior to such devices in that it transcends the physical limits commonly encountered (such as paper width or speed). Data collection generally involves taking incoming signals (usually analog) and sending them to the computer, where they are (a) displayed on the screen and (b) stored in the computerøs memory (or on the hard disk). These signals can then be stored for future examination, much as a word processor stores a document or a statistics program saves a data file. Graphical and numerical representations of the data can also be produced for use with other programs.

The MP System utilizes the same hardware, excepting the computer interface. The software has the same õlook and feelö on computers running Windows® or Mac® OS.

The MP System consists of several major components, including hardware and software. The BSL *PRO* software included with the MP system allows full control over editing data, the way it appears on the screen, and performs four general functions:

> (a) Control the data acquisition process;
> (b) Perform real-time calculations (such as digital filtering and rate detection);
> (c) Perform post-acquisition transformations (such as FFTøs and math functions);
> (d) Handle file management commands (saving, printing, and the like).

The heart of the MP System is the MP data acquisition unit, which converts incoming physiological data into digital signals that can be processed and displayed on a computer interface. The MP3x and MP45 systems connect via USB 2.0.

A wall transformer is included with the MP System to convert AC mains power into DC power suitable for system operation and safety.

MP36/MP35 support

The MP36/MP35 is a four-channel data acquisition unit designed to work with BSL *PRO*. BSL *PRO* support for the MP36/MP35 unit includes:

- Standard data acquisition and data acquisition features (triggering, multiple channels, variable sampling rate, input values)
- Output control functionality for controlling stimulators, digital channel, and channel redirection to output.
- Standard analog presets for all SS series transducers
- Electrode Check support
- Control channel support for changing digital output lines based on calculation channel analysis

MP3x Notes The computer sleep mode should be disabledô if the computer goes to sleep while BSL *PRO* is running, communication with the MP36 may be lost and the application may freeze. To prevent this from occurring, modify the computer settings to prevent the computer from going to sleep.

- If sleep mode is enabled and causes the application to freeze, force quit the application and ÷power cycleø the MP unit to re-establish communication.

- During an unresponsive period, the ÷Connect Hardwareø dialog may display odd characters in place of the MP serial number or the computer, upon waking up, may generate aõDriver irql not less or equalö error dialog.

  Mac OS users: Connect the MP3x directly to the computer, do not connect MP36 via hub or keyboard.

MP System Requirements

Suggested minimum system requirements are detailed below. Recommendations are included to optimize system performance; more memory and a faster system will enhance MP System performance. If planning to acquire data for more than a few hours and/or are sampling at more than 1,000 samples per second, see the Disk Space note.

Windows	For BSL *PRO*
OS	Requires Windows 10/8/7 or Mac OS 10.10-10.13
Port	MP36/MP35 and MP45 require USB.
Hard Disk	Requires 1 GB to store the software and online manuals; additional 1 GByte recommended for data storage
RAM	1 GB recommended
Processor	PC: Pentium 4 or higher Mac: Intel Core Duo or higher

MP45 Support

The MP45 is a two-channel data acquisition unit designed to work with BSL *PRO*. Like the MP36/MP35, the MP45 connects via the USB port but uses the computerøs audio card as a signal processing source. The MP45 functionality is more limited than the MP36/MP35, as triggering, digital channels, Electrode Checker and certain Output Controls are not supported.

Sound Errors for MP45 Users

▪ **Audio Properties**

BIOPAC MP45 USB Data System must be selected as the default device from the Sound Playback menu (Control Panel > Sound) in order for sound to be heard. If the Sound/Audio Properties are not setup properly, no sound will be heard; no warning prompts will appear if set incorrectly.
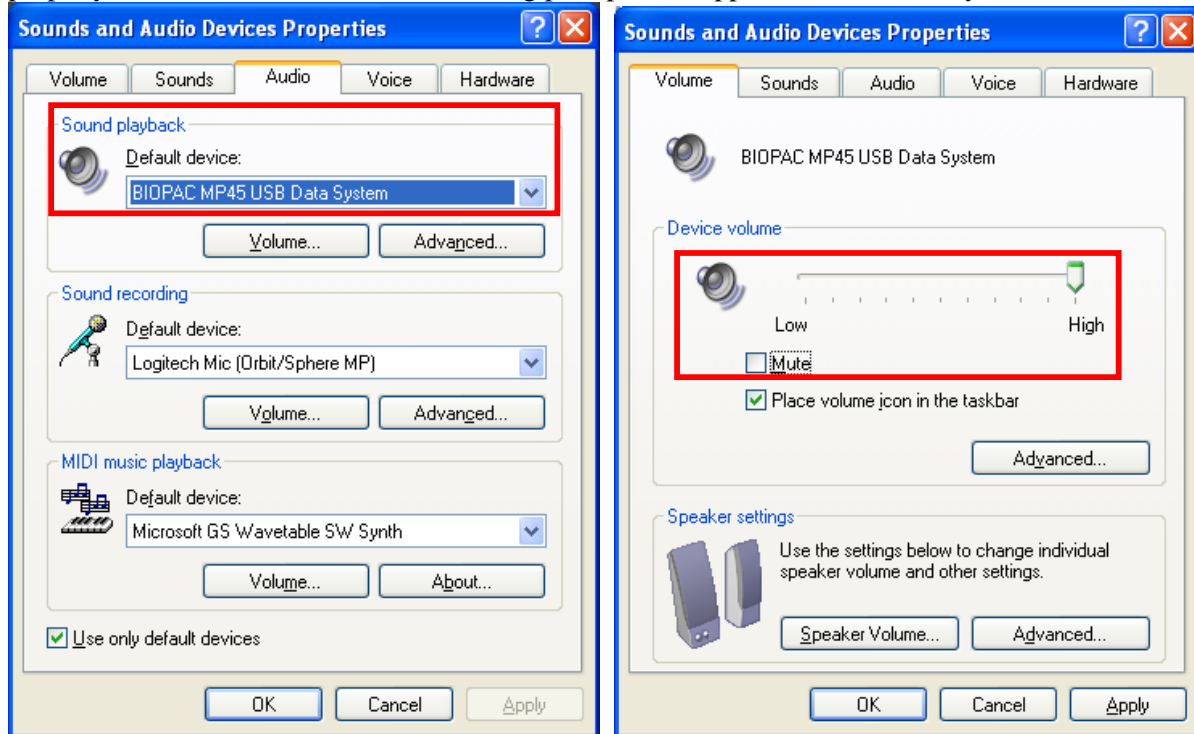
▪ **Device Volume**

The Device volume slider must be set to õHighö and õMuteö must not be enabled.

Disk Space

With any program, adequate disk space is necessary for storage of data files. Although BIOPAC saves files in a format as compact as possible, some users may generate data files of several dozens of megabytes. To acquire data for long periods (more than a few hours) while sampling at relatively fast rates (more than 1,000 samples per second), as much disk space as possible should be available. (A removable drive may also be used). See the Appendices for hints on working with large files.

MP System Features

The MP System (MP36, MP35 or MP45) is a complete system for acquiring almost any form of continuous data, whether digital or analog. The MP System can perform a range of recording tasks, from high-speed acquisitions to long duration acquisitions. Generally speaking, for physiological applications, the MP System is limited only by processor speed and available memory or disk space. Features of the MP System include:

Easy to use	The MP System offers the same convenient and easy-to-use features which computer users are accustomed to. Since the MP System software runs under these Windows and Mac OS environments, other applications can be running while collecting data. In terms of hardware setup the MP System uses simple plug-in connectors and standard interface cables.
Flexible	The MP System can be configured for a wide variety of applications. Control the length of acquisition, the rate at which data is collected, how data is stored, and more...all with a few mouseclicks.
Menu flexibility	Easily customize menu displays to show only necessary functions, thereby reducing the risk of error or confusion in the lab. It is also useful for teaching applications where instructors can hide unnecessary menu items. *See* Appendix Dô Customizing Menu Functionality.
Calculation Channel Presets	Customize the recording for specific measurements.
Template files	BSL *PRO* Lesson templates are available for over 30 lessons. Just open the template file and start the acquisitionô appropriate settings are established for the selected application.
Online Calculation	Although the MP System provides an extensive array of measurements and transformations to apply to collected data, sometimes itøs necessary to perform computations *while* data is being collected. The online Calculation functions supports calculation of new channels based on incoming signals. For example, this feature will extract BPM based on raw ECG data.
Online filtering	Many times, it is preferable to filter data as it is being collected, rather than having to wait until after the fact, so filters can be applied to incoming data and the results viewed in real time.
Online measurements	The MP System can instantly compute over a dozen measurements and computations for any given data point(s). These options are available from pull-down menus and include mean, peak-to-peak, value, standard deviation, frequency, and BPM.
Measurement Validation	Validate measurements with the ValidateMeasurements.acq sample file included with the software. The measurement definitions (page 89) include measurement formulas and õ*Sample data file*ö explanations.
Previewing data	Similar to chart recorders, the MP System allowsmodification of both the vertical and horizontal scale. Change the amplitude scale or the time scale to any custom value, or have BSL *PRO* automatically scale them.
Simplified editing	Delete unimportant sections of data with a keystroke, or õpasteö together sections from different waves, or simply edit out noise spikes from individual waves.
Append mode	For some applications, data only needs to be recorded during some portions of a long experiment. BSL *PRO* has an õAppendö mode that allows pausing of the acquisition for as long necessary, and resumes the acquisition as many times as needed. Appending data saves on storage space and processing time for transformations.

Digital filtering	Reduce or eliminate that error by using the included digital filters and smoothing transformations. Smooth data across any number of samples, or filter out noise from virtually any frequency or bandwidth.
Digital Output	Control external devices when an input or calculation channel meets specified trigger conditions. Use the Control channels to output a pulse when the signal on an analog channel falls above or below a given threshold.
X/Y plotting	View and acquire data in the form of an X/Y plot, with one channel on the horizontal axis and another on the vertical axis. This allows exploration of relationships between different channels and opens up a whole range of applications, from chaos plots to respiration analysis to vectorcardiograms.
Histogram function	Easily examine the variability and the measures of central tendency of any waveform data with the histogram function. Set the plotting options to suit or let the software determine the õbest fitö for graphing data.
Math functions	In many cases, simply collecting raw data is not enough. BSL *PRO* has an array of built-in mathematical functions ranging from simple absolute value to computation of integrals, derivatives, and operations involving multiple waveforms (such as subtracting one wave from another). Chain multiple functions together to form complex equations or expressions.
Annotation	BSL *PRO* has a Journal for adding comments about the data, either online or after the fact. This is especially useful for noting the characteristics of an acquisition (what was involved, what manipulations took place, and the like) for future reference. *See also*: Text annotation, page 56.
Triggering	To measure response times or start data collection only after a specific event has occurred, BSL *PRO* supports triggering an acquisition in a number of different ways. Trigger on the level of a signal, or with an external synchronizing trigger. (Triggering is not supported in MP45 hardware.)
Event marker	Many times, especially during a long acquisition or in a laboratory setting, it is useful to make a note of when specific events occurred so that these events (such as when a manipulation occurred) can be recorded and any changes in the data can be noted. The event function supports the insertion of symbols in the record and the adding of text for each event. These can be added either while data is being collected or after the fact. Event functionality can be automated for sequential application or customized for Function keys.

File compatibility	Data can be saved in a number of different formats. For word processor programs like Microsoft Word®, use Copy to Clipboard and then paste into the document. Use Save as Excel for Microsoft Excel®. Data can be outputted in text or graphical form, and BSL *PRO* can even read-in raw data from a text file. Open (import) or save as (export) MATLABÎ and Igor Pro Experiments, or raw (binary) data for low level exchange.
Pattern recognition	Using an advanced pattern search/recognition algorithm, the MP System can automatically find a specific pattern within waveforms. This is useful for finding abnormal waveforms (such as irregular ECG waves) within a data file.
Cycle/Peak detection	BSL *PRO* has a built-in algorithm to find cycle data, such as positive or negative peaks, from any size data file. Search for all the cycles/peaks with one command and automatically log statistics like time and area to the journal.
Printing	The MP System provides a range of printing options, and allows a wide range of formatting options. Print several graphs per page, even for one-channel recordings.
Report generation	BSL *PRO* has many features to simplify report generation. Use the Journal for notes and quickly copy and paste graph data or measurements to the journal or to another program. Cascade event markers to prevent print overlap and select the range of data to print and which options to display (measurements, eventss, etc.). Use the Playback mode to simulate acquisition for presentations.
User Support	Have a question about compatibility with existing equipment or need to develop a specialized measurement device? BIOPACøs Applications Department can address the problem.

MP System (MP36, MP35 or MP45) Application Notes

BIOPAC has prepared a wide variety of application notes as a useful source of information concerning certain operations and procedures. The notes are static pages that provide detailed technical information about either a product or application. A partial list of Application Notes follows. View or print application notes directly from the *Support* section of the BIOPAC website www.biopac.com.

Chapter 2   BSL *PRO* Overview

Overview
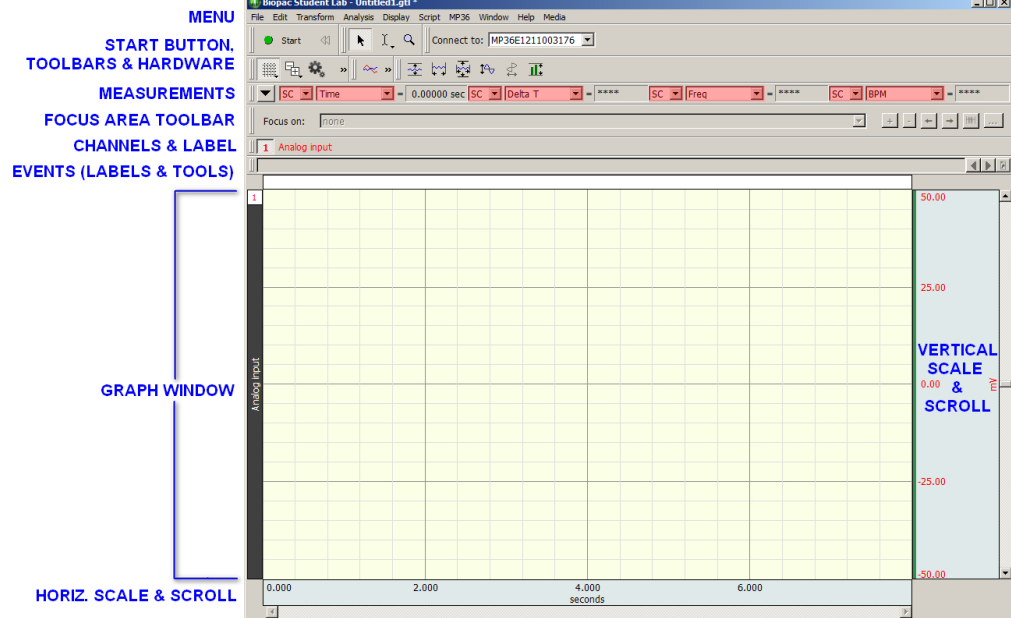
The full version of Biopac Student Lab 4.1 software is called BSL *PRO* and performs two basic functions: acquisition and analysis. The acquisition settings determine the basic nature of the data to be collected, such as the amount of time data will be collected for and at what sample rate the data will be collected. Parameters can be found under the MP menu. The other menu commands pertain to analysis functions such as viewing, editing, and transforming data.

Note: Some very minor differences exist between the Windows and Mac OS screen displays and keystroke/mouse functionality. These differences are noted throughout this section.

Menu	Functionality	See Page
File	New, Open, Open Recent, Open for Playback, Close, Save, Save As, Save Selection As, Save Journal Text As, Send Email as Attachment, Copy to Dropbox, Open from Dropbox, Logout from Dropbox, Page Setup, Print, Go to Startup Wizard, Quit	220
Edit	Undo, Cut, Copy, Paste, Clear/Clear All, Remove Last Appended Segment, Insert Waveform, Duplicate Waveform, Select All, Remove Waveform, Clipboard (Copy Measurement, Copy Wave Data, Copy Graph, Copy Acquisition Settings, Copy Data Modification History for All Channels, Copy Data Modification History for Selected Channels, Copy Focus Area Summary, Copy Event Summary), Journal (Paste Measurements, Paste Wave Data, Paste Acquisition Settings, Paste Modification History for All Channels, Paste Modification History for Selected Channels, Paste Focus Area Summary, Paste Event Summary, Manage PDFs, Show Journal)	241
Transform	*operations that primarily modify the data in the graph* Recently Used, Digital Filters, Math Functions, Template Functions, Integral, Derivative, Integrate, Smoothing, Difference, Resample Waveform, Resample Graph, Expression, Delay, Rescale, Waveform Math, Slew Rate Limiter	250
Analysis	*operations that derive data & measurements from the graph* Recently Used, Histogram, Power Spectral Density, FFT/IFFT, Find Cycle, Find Rate, Detect and Classify Heartbeats, Locate Human ECG Complex Boundaries, Locate Animal ECG Complex Boundaries, Heart Rate Variability, Correlation Coefficient, Digital Input to Stim Events, Ensemble Average, Epoch Analysis, Focus Areas (define events), Waterfall Plot	276

Menu	Functionality	See Page
Display	Tile Waveforms, Autoscale Waveforms, Optimize Ranges, Overlap Waveforms, Compare Waveforms, Autoscale Horizontal, Show All Data, Show Default Scales, Zoom back/forward, Reset Chart Display, Reset Grid, Adjust Grid Spacing, Set Wave Positions, Set Channel Visibility, Wave Color, Horizontal Axis, Show, Customize Toolbars, Channel Info, Preferences, Size Window, Cursor Style, Split View, Create Data View, Create Focus Area, Load All Data Into Memory	314
MP36/35/MP45*	Set Up Data Acquisition , (Channels, Length/Rate, Event Marking, Segment Labels, Stimulator, Trigger, Sound Feedback), Show Input Values, Output Control, Show Gauge, Electrode Checker, Auto Plot, Scroll, Warn on Overwrite, Organize Channel Presets, Exit Playback Mode, Manage Hardware Connections	99
Playback	Replaces the MP menu when Playback mode is active (use File > Open for Playback and Playback > Quit playback to toggle playback and acquisition modes)	37
Window	Controls the position of windows on the monitor	341
Help	Provides online support files (PDF format and web links).	341
Media	Capture or Playback media files(.avi, .wmv, or mpg) and synchronize with .acq data	343

*Triggering and Electrode Checker are not supported in MP45 hardware.

Launching the BSL *PRO* software

The first step is to launch the software by double-clicking the Biopac Student Lab desktop icon. If a hardware prompt appears after launching BSL *PRO,* there are two possibilities: The cable connections are faulty or the MP unit has not been properly powered on. Either of these conditions will generate the following warnings:
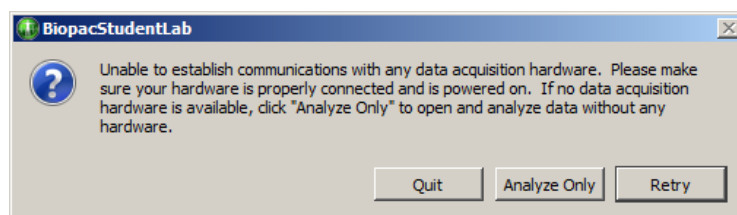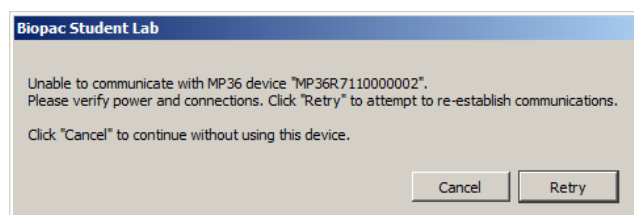
➤ To use BSL *PRO* without an MP data acquisition unit, click the õAnalyze Onlyö button. Click õDo not ask me againö or set õPreferences > Hardwareö to õAlways work with no data acquisition hardware connected.ö
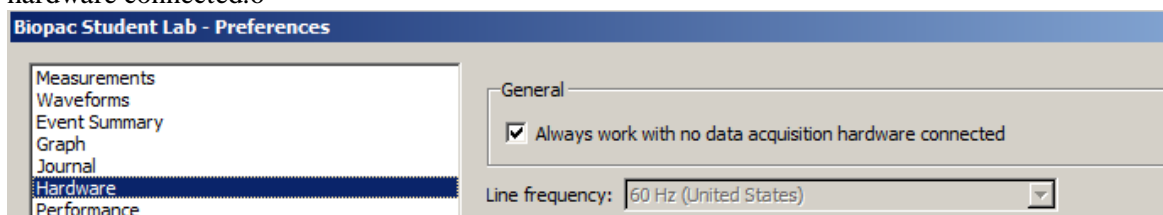
Assuming everything is properly connected and there are no conflicts, the Startup Wizard will appear. Use this wizard to choose whether to create a new experiment, open a saved graph for analysis or access the Help and support files.
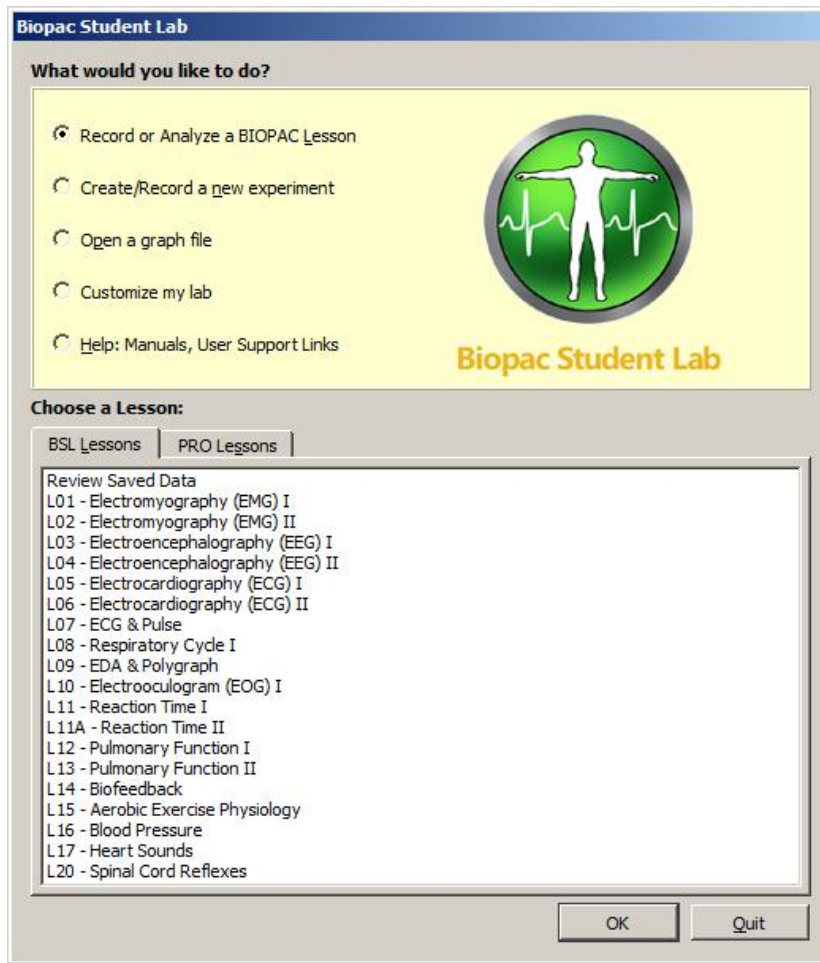
Startup Wizard	Functionality
Record or Analyze a BIOPAC Lesson	Displays the BSL Lessons and *PRO* Lessons menus. This is the default view presented when launching the Wizard.
Create/Record a new experiment	Displays options to create a BSL *PRO* new graph, or open an existing graph template or sample graph template. (*.gtl file)
Open a graph file	Displays options to launch existing data graph files by browsing, or selecting from a list of recently-opened graphs. Sample data files also accessible from this view.
Customize my lab	Displays options for customizing standard or *PRO* Lesson procedures and onscreen instructions with the Curriculum Manager (licensed feature). For more information on the Curriculum Manager, see Chapter 18.
Help: Manuals, User Support Links	Offers Help and Support options, including a link to Web Tutorial Screencasts.
Quit/OK buttons	Cancels or confirms selected operation.

NOTE: The Startup Wizard can be disabled in the Preferences, if desired. (Display > Preferences > Other)
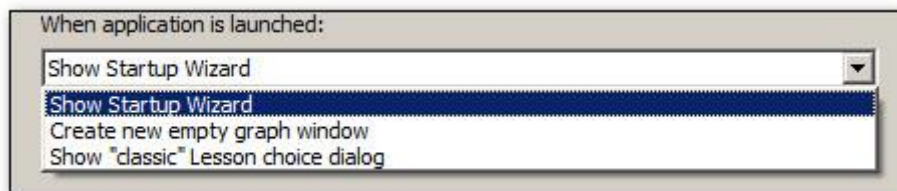
A õwindowö is the term used for the screen area where data is displayed and/or manipulated. The graph window on the screen is designed to provide a powerful yet easy-to-use interface for working with data.

Launching the BSL 4.1 Application

To launch the full BSL application (referred to in this guide as BSL *PRO*), choose the õCreate/Record a new experimentö Startup Wizard option and click OK.

By default, the Data Acquisition Settings window is presented whenever a new graph is launched. This window acts as a õcommand centralö for setting up important initial parameters such as channel setup, sample rate, acquisition length, event marking, triggering and more.
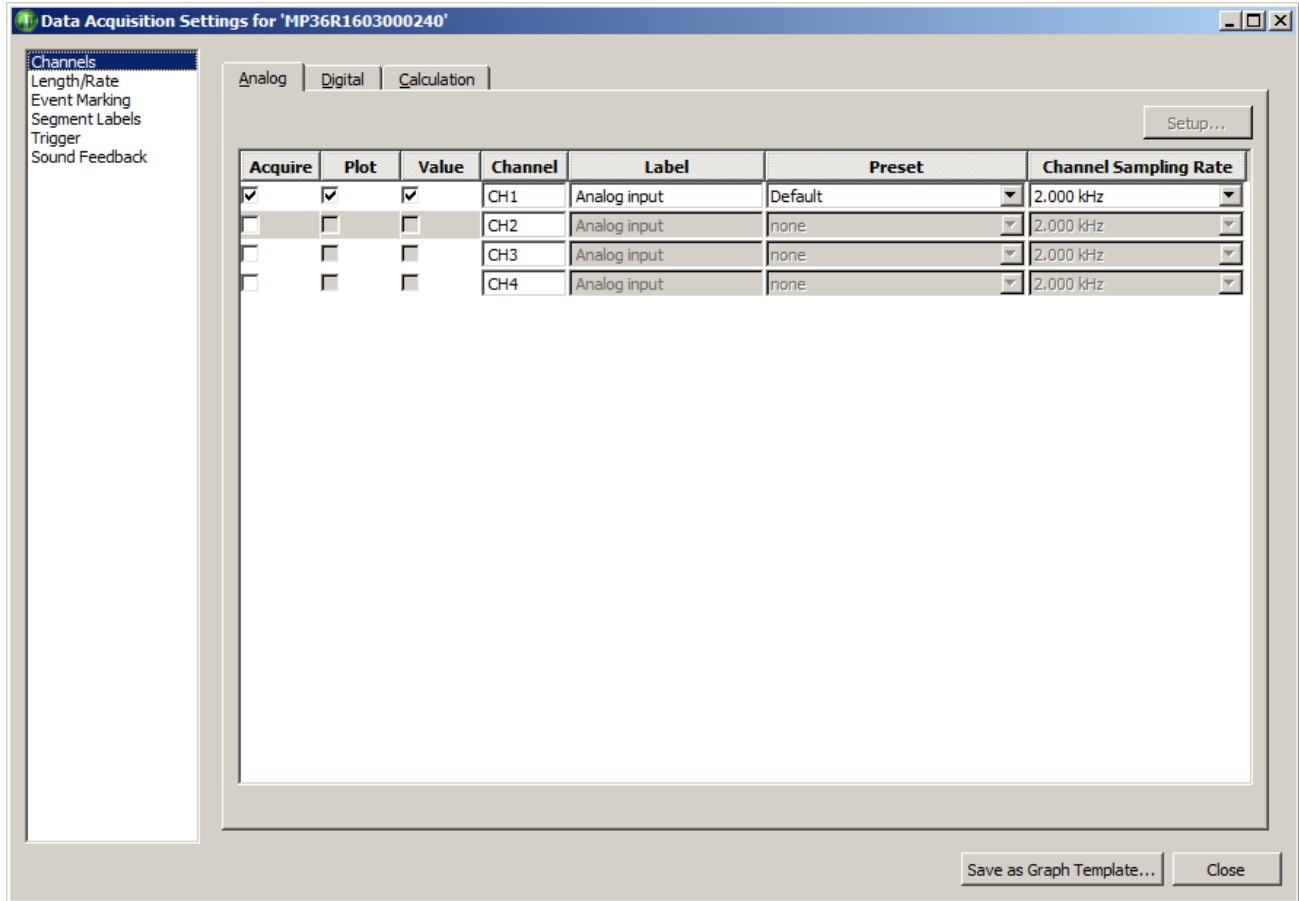
Once these settings are in place, they can be saved for future experiments by choosing the õSave as Graph Templateö option. Since all selected settings are saved in the template, the Data Acquisition Settings window will not be presented when the graph template is re-opened. However, for all new graphs, this window will appear on top of the application for convenient access to necessary parameters. To open the application and set the acquisition parameters later, click õClose.ö (To set up acquisition parameters from within the open application window select the MP menu and choose õSet Up Data Acquisition.ö)

After setting the above parameters, use the current application window, create a new window, or open an existing window. To create a new or additional graph window after the original launch, choose File > New > Graph Window.

Basic Analog Channel Information

The first option under Data Acquisition Settings is õChannels.ö Under this setup dialog, up to four analog channels, 16 calculation channels, or 8 digital channels can be selected. For more information on channel setups, see the analog channel setup sections beginning on page 101.

- The default setting enables the Acquire, Plot and Value options for one channel of data on Analog CH1. Itøs normally recommended that all three of these boxes be checked for each selected channel.

- Four analog channels are available in MP36/MP35 hardware, two analog channels in MP45 hardware.

- Digital channels are not supported in MP45 hardware.

Acquire   Checking the Acquire box for a given channel indicates data will be collected on that channel.

Plot   Determines if data will be plotted in real-time during the acquisition. If the plot box is unchecked, data will still be recorded, but the associated channel will remain hidden. The channel (and data) can be õunhiddenö by positioning the mouse pointer over the channel number box and Alt+clicking.

Value   Enables a separate õShow Input Valuesö bar graph for numerically and/or graphically displaying the values for each channel in real time.

Channel   Available Channel tabs are Analog, Digital, or Calculation. In the sample above, õCH1ö indicates Analog channel one.

                 In contrast to analog data, Digital channels collect binary data that signify when a measuring instrument is õonö or õoff.ö For example, Digital channels record whether an internal switch is open or closed, as in reaction time studies or control applications. Digital channels are acquired, plotted, and display values in the same fashion as analog channels. *Digital channels are not supported in MP45 hardware.*

                 Calculation channels are used for online computations and transformations of other channels. These channels are set up similarly to analog and digital channels but include additional dialogs for specifying types of transformations and computations to be performed. For a detailed summary of Calculation channel options, see the Calculation Channel section beginning on page 116.

Label   To the right of each channel number is an editable field for entering channel information.

Preset   Analog and Calculation channels include onboard Presetsô choose a preset and the software automatically sets the gain, offset, etc. appropriate for the selected application. Choose from the list of available presets or create a custom preset; see page 103 for details.

Channel   The channel sample rate can be varied from the acquisition sample rate. Channel sample rate
Sampling   options are equal to or less than the acquisition sample rate (as established via õMP
Rate   > Set Up Acquisitionö). The options are a specific power of 2 less than the acquisition sample rate. Channel sample rate info is included in the Display > Channel Info dialog. Use the pull-down menu to set the channel sample rate. See page 103 for details.

Basic Digital Channel Information

In contrast to analog data, Digital channels collect binary data that represent when a measuring instrument is õonö or õoff.ö (For example, records whether a switch is open or closed, as in reaction time studies or control applications.) Digital channels are acquired, plotted, and have values listed the same fashion as analog channels. For more details about Digital channels, see page 116.

Basic Calculation Channel Information

Calculation channels are used for online computations and transformations of other channels. These channels are configured similarly to analog and digital channels, but also have additional dialogues to specify the types of transformations and computations to be performed.

Calculation channels include Presets as a quick way to get startedô choose a preset and the software automatically sets the gain, offset, etc. appropriate for the selected application.

When a new Calculation channel is enabled, a simple setup dialog corresponding to the selected preset is presented, which helps facilitate proper setup. Choose from the list of available presets or create a custom preset; see page 121 for details.

For a detailed summary of Calculation channel options, see the Calculation Channel Chapter on page 121.

Setting up Acquisitions
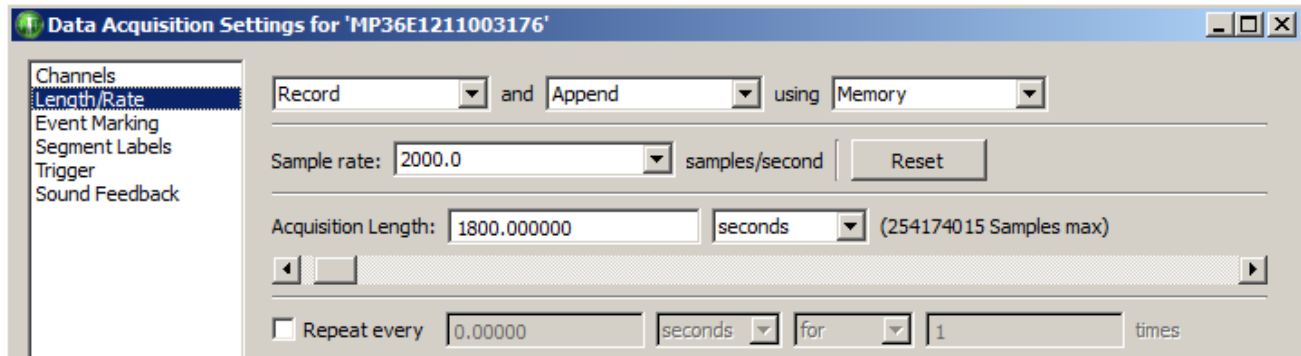
Once the channel parameters have been established, the next step is to specify the acquisition settings. Choose Set Up Acquisition from the MP menu to generate the acquisition parameter dialog. The basic parameters involve specifying:

a) How data should be collected and stored

b) The data collection rate

c) The acquisition duration (total length)

Storage   Record and Append to Memory is the default acquisition option. Under this option, the hardware automatically records data into a single continuous file, and stores the data in computer memory during the acquisition.

The third popup menu at the top of the dialog (which defaults to Memory) specifies how data is stored during the acquisition. The available options are Memory or Disk . Computer memory is usually faster (but less abundant) than disk space. Data cannot be stored directly to the hardware.

Rate   Acquisition Sample Rate is analogous to %mm/sec+on a chart recorder, and refers to how many samples the MP System should take each second. The higher the sample rate, the higher the signal quality. However, as the sampling rate increases, so does the demand for system resources (memory, disk space, etc.). There is a %point of diminishing return+in terms of sampling rate for almost all types of analog signals, where sampling above a given threshold adds relatively little information.

The MP36/MP35 sampling rate has a lower bound of 2 samples per hour, and an upper bound of 400 kHz aggregate. The MP45 sampling rate has a lower bound of 2 samples per hour and an upper bound of 96 kHz aggregate. The MP unit must use a pre-defined rate; it does not accept custom rates. The default Acquisition Rate is 2000 samples per second.

Choose the best acquisition sample rate from the pop-up list.

Note: Channel sample rates are variable based on the acquisition sample rate. All channel sample rate options are equal to or a specific power of 2 less than the acquisition sample rate.

Duration   The final acquisition parameter is Acquisition Length (Total Length), which controls how long an acquisition will last. This can be scaled in seconds, minutes, hours, milliseconds or number of samples. Set this value either by entering a number in the acquisition length box, or by sliding the Acquisition Length scrollbar left or right. The default Acquisition Length is 1800 seconds (30 minutes).

Starting an Acquisition (Recording)
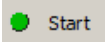
Once the acquisition parameters have been specified and the channel setup defined, the next step is to start the acquisition. If a file window is not already open, choose File > New > Graph window.

Status

To the left of the Start button, a green circular status light should appear. The status light indicates the active communication link between the computer and the MP data acquisition unit.

- If the data acquisition unit is properly connected to the computer and is powered on, the circle will be solid and green.

- If the data acquisition unit is not properly connected or not communicating with the computer, the circle will be solid gray.

Start

To start an acquisition, position the cursor over the [● Start] button and click the mouse button, or select **Ctrl+ Spacebar**. If no input devices (e.g., electrodes or transducers) are connected to the hardware, it will collect a small value of random signal õnoiseö with a mean of about 0.0 Volts.

- For information on how to connect measurement devices to the hardware, see the *BSL Hardware Guide.pdf*.
- To start an acquisition using a variety of õtriggers,ö see page 207.
- Graphs that open without a Start Button
    - o Compressed Graphs
    - o Igor Pro Experiment
    - o PhysioNet
    - o Raw Data Files
    - o Text Files
    - o Analysis menu operations: Histogram; FFT (Magnitude and Phase); IFFT; Rate (put result in new graph option)

Once an acquisition has started, the Start button status will toggle to Stop, and two opposing arrows will blink, indicating that data is being collected. The green õBUSYö indicator light on the front of the MP data acquisition unit will illuminate.

Stopping an Acquisition

To stop an acquisition at any time, click the [⇄ Stop] button in the lower right corner of the screen or select **Ctrl+ Spacebar**.

An acquisition will stop automatically when it has recorded an amount of data equal to that indicated in the Total Length box. To save this data file, choose File > Save.

Display modes

The display modes are Chart, Scope, X/Y, Stacked Plot, and Playback. The onscreen data display can be changed at any time, even during an acquisition. To change the display mode, click the corresponding icon in the toolbar.

[▤] Chart mode

Chart mode is the default display mode.

Chart mode plots data much as it might appear on a chart recorder, with time on the horizontal axis.

Each channel of data is in its own õtrackö across the screen, with borders between channels. The waveforms will not cross boundaries into the tracks of adjacent channels.

If a waveform is plotted off the scale of the channel track, choose autoscale waveforms and BSL *PRO* will select the õbest fitö for waveforms to their tracks.
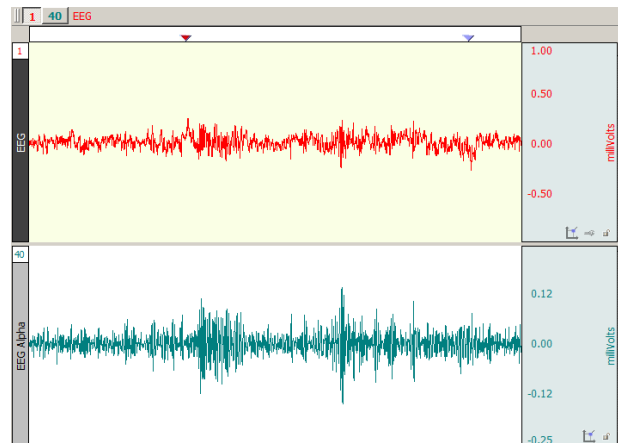
Scope mode

Scope mode plots data much as it might appear on an oscilloscope, with time on the horizontal axis.

Scope mode is similar to Chart mode, except that there are no borders between different channels.

▪ To help emphasize the selected wave in Scope mode, select the õGray non-selected wavesö Preference (via Display > Preferences).

Waveforms can overlap. The autoscale waveforms command will automatically separate the waveforms in the graph window.

Note: When only one waveform is present, the scope and chart modes are identical.
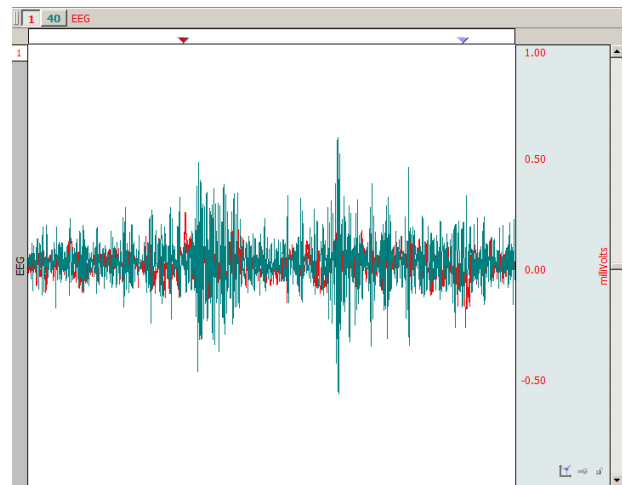
X/Y mode

X/Y mode plots data from two channels against each other, with the values from one channel on the horizontal axis and the values from another channel on the vertical axis. Plotting a channel against itself displays a straight line.

X/Y mode can be useful for chaos investigations and respiration studies.

Note: When viewing data in X/Y mode as it is being acquired, plotting only the most recently acquired data point can be a useful option. To do this, select Display > Show > Dot Plot and then Display > Show > Last Dot only.
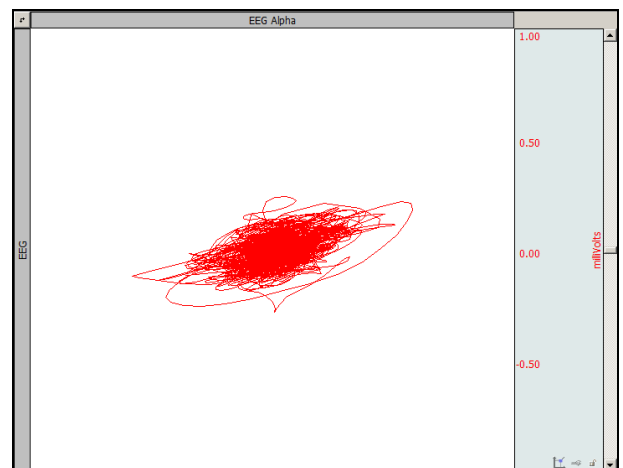
Switching to X/Y mode during acquisition can be slow. For best performance, switch to X/Y mode either before starting the acquisition or after stopping the acquisition.

X/Y mode continued

Plotted channels

• *To change the channel being plotted*: Click the Channel label once and hold.
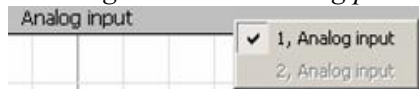
X-axis, click *above* the waveform; Y-axis, click *left* of the waveform.

• *To flip the axes*: Click the upper left button

Click this to exchange the X and Y axis. This flips the plot diagonally.

• .
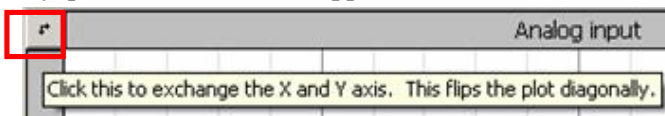
• *To change the channel label for this plot*: Click the Channel label.

Biopac Student Lab MP36

Enter channel 1 label

Analog input

OK   Cancel

Toolbar icons

The center cluster of toolbar items is specific to X/Y mode. The left two buttons in this group are shortcuts for the Autoscale vertical and Autoscale horizontal functions. Adjacent to these buttons are two buttons that perform the center vertical and center horizontal functions.

Tools

Cursor In X/Y mode, the I-beam tool in the lower right hand corner of the graph window changes into a crosshair. When the crosshair is moved into the graph window, the coordinates of the crosshair are displayed in the upper left corner of the graph window. The X value refers to the coordinate of the crosshair in terms of the horizontal axis, and the Y value describes the location of the cursor in terms of the vertical scale. By pressing the mouse, a crosshair is drawn over the closest data point and the measurement toolbar õsnapsö to that position to show the amplitudes of the actual pair of data samples plotted on the screen. In BSL *PRO* and higher, the Channel number and label are also displayed next to the measurement values.
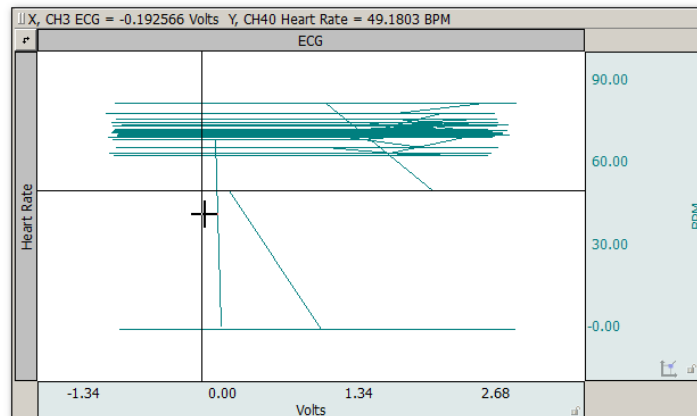
X/Y plot with ECG on X-axis and BPM on Y-axis

Autoscale   In X/Y mode, the Autoscale waveform function changes to read Autoscale vertical, which plots the vertical channel so that it takes up two-thirds of the vertical channel space. This function controls the õheightö of the data being plotted in the graph window.

Similarly, the Autoscale horizontal function plots the waveform so that the waveform is plotted in the center two-thirds of the window. This function controls the õwidthö of the data being plotted in the graph window.

Autoscale commands adjust the center point and the range of data displayed. To manually change the scale, click in either the horizontal or vertical scale area. In this case, the scale at the bottom edge of the graph windows (which usually reflects time) is the scale for the X variable, and the vertical scale controls the scale for the channel plotted on the Y-axis.

Center   In X/Y mode, since only two channels can be displayed at a time, tile waveforms and compare waveform are replaced with Center horizontal and Center vertical. These two Center commands change the midpoint of the horizontal and vertical scales (respectively) so that the midpoint of the scale is equal to the mean value (average) for that channel. These features are useful for centering the display so that it is easier to interpret.

Ch. # Box: In X/Y mode, the channel numbering boxes are disabled.

Meas. Menu: In X/Y mode, the measurement popup menus are disabled.

Plot Recent Data Only

Use this option in X/Y mode to plot a user-defined amount of recent data. Checking the õPlot recent data onlyö and entering a value will hide plotting for all data not included in the entered time value.
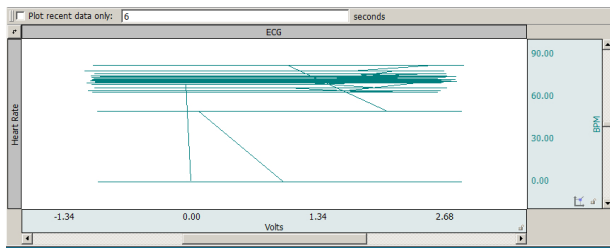
Plot recent data option not applied   *Plot recent data option applied with 6 sec. value*
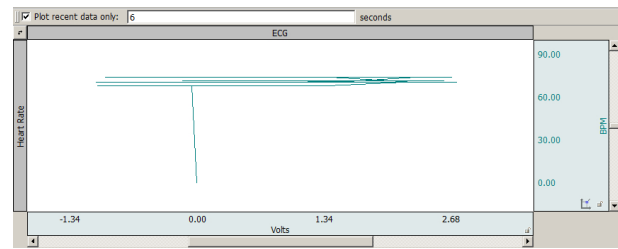
Stacked Plot mode

Stacked Plot displays multiple time ranges on top of each other and is enabled for acquisitions set to Append (except when in X/Y mode). In this mode, all appended segments are stacked in the display, but only one segment õsliceöis active (õselectedö). To view an individual segment, click the Chart mode icon.

▪ Click the Stacked Plot mode icon to display the Stacked Plot controls beneath the toolbar:
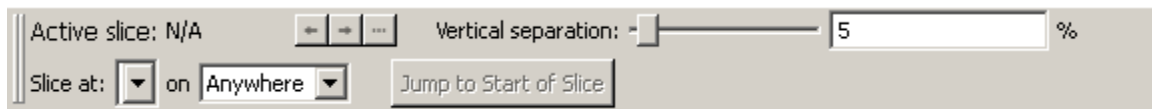
To change the active slice, click the Jump Tool or the í   icon.
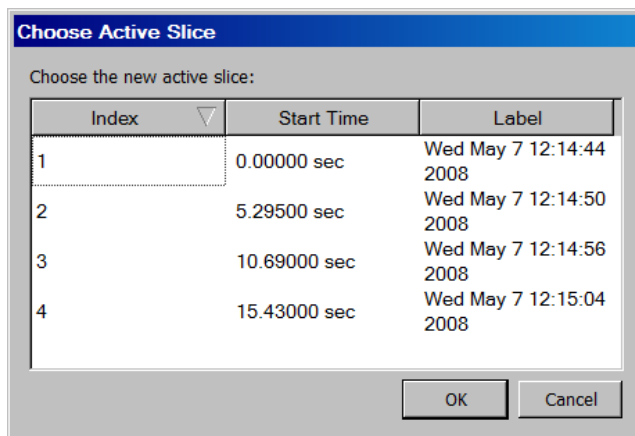
The selected segment is used for all enabled software functions. This means that autoscaling can easily create what looks like a mess if the selected segment is not appropriate for scaling the largest segment.

In compound action potential graphs in Stacked Plot, the last segment slice will most often be the largest, so selecting the last segment before autoscaling will likely yield the expected result. The Transform menu is disabled in Stacked Plot mode.

A commonly used data visualization technique for examining the evolution of waveform morphology is the 2D waterfall plot or õstacked plot.ö A stacked plot draws multiple traces for a single waveform on top of each other, or õslices.ö Each individual slice is a time-shifted plot of the original waveform. The slices toward the bottom of the plot occur earlier in time then the slices toward the top.

Data can be acquired in stacked plot mode, but it is processor intensive. If acquisition setup includes high sampling rates or control channels with low latency, acquire in chart or scope mode and switch to stacked plot mode after acquisition.

The slices can be aligned at any type of events in the graph. This allows for alignment at appended segments but also at locations found through other means. For example, an ECG waveform can be aligned at the start of the T-wave to examine how the T wave evolves in time.

Active slice   In stacked plot mode, there is a single slice that is called the õactive slice.ö By default it is drawn in black; to change the color, select Stacked Plot Options > Drawing Settings. The values on the axes in the graph, grid, displayed events and text annotations, selections, and any transformations all apply to the active slice. The active slice can be changed using the navigation buttons in the graph toolbar.

Vertical Separation   The vertical separation between consecutive slices is expressed as a percentage of the entire visible area. This percentage is kept constant through zooming and scrolling operations.

Stacked Plot Options
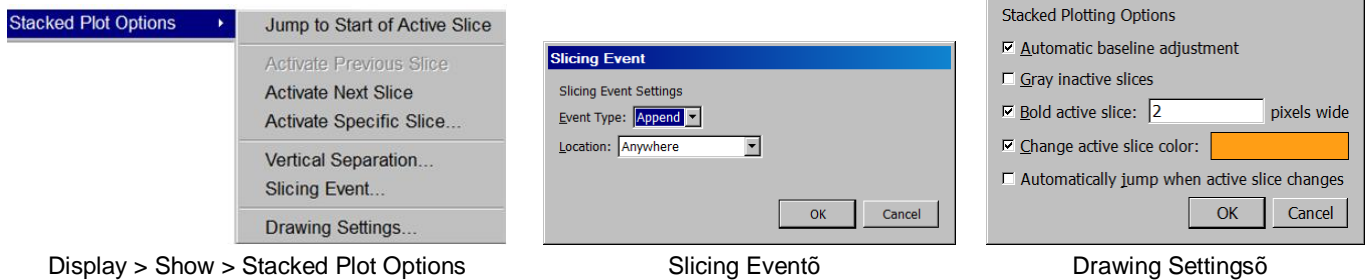
Display > Show > Stacked Plot Options   Slicing Eventõ   Drawing Settingsõ

Use Stacked Plot Options to activate slices or visually distinguish the active slice from other slices being drawn in Stacked Plot mode. (Display > Show >Stacked Plot Options)

Automatic baseline   Adjusts the baseline of each inactive slice to overlap the baseline of the active slice prior to the application of any vertical separation. This helps compensate for baseline drift in a signal. If it is disabled, no baseline compensation will be applied and the stacked plot may exhibit visual vertical segment ordering problems resulting from baseline drift (but in this mode can be used as a tool to examine baseline drift).

Gray inactive slices   Draws the active slice with a solid pen and draws inactive slices with a dashed gray pattern pen. The gray pattern alternates pixels between the chosen waveform color and the white background and has the effect of lightening the inactive slices, so it may be necessary to zoom in to see the effect.

Bold active slice   Draws the active slice with a thicker pen. In step and line plot modes, plotting normally occurs with a one pixel wide pen. Inactive slices will remain one pixel wide while the active slice will have the thicker pen as indicated in the edit field. When the waveform is in dot plot mode, the pixel width will be added to the waveform's default dot size to increase the dot size for the active slice.

Change active sliceí   Draws the active slice in a different color than the chosen waveform color. When enabled, the same color is used for the active slice of each waveform in the graph. The color can be changed by clicking on the colorwell to the right of the checkbox to generate a standard color picker to select color.

Automatically jumpí   Use the Jump tool (green arrow) to change the active slice. Each time the active slice is changed the left edge of the plot area will be changed to match the start of the newly activated slice. When disabled, each time the active slice is changed the display will be adjusted in such a way that the time interval between slice starting positions and the display origin is kept constant.

Functionality in Stacked Plot mode

Autoscaling

When a graph is displayed in stacked plot mode, all autoscaling and related display operations (tile, compare, overlap) will examine the visible data of the active slice only. It will not be possible to perform autoscaling operations using the data of any inactive slice.

Autoscale Horizontal

In stacked plot mode, autoscale horizontal will make the active slice occupy the entire visible area. The slicing event corresponding to the beginning of the slice will be placed at the left edge of the screen and the next slicing event (or last sample point of the waveform if the active slice is the last slice) will be placed at the right edge of the screen. The vertical offset will remain unaffected.

Data Views

Different data views may have independent Stacked Plot settings. All settings are independent including drawing preferences, slicing events, vertical separation, and active slice settings. Stacked plot settings are stored individually for each data view in the graph file and will be restored when the graph file is opened from disk.

Any graph-wide operation that may affect the active slice will update all data views that are configured to use stacked plot mode. This includes operations that affect the data (e.g. transformations) or events (e.g. waveform editing).

Graphs Containing No Slices

It is possible that graphs may not contain any slices whatsoever if no events match the slicing event criteria. If a graph in Stacked Plot mode contains no active slices, it will be drawn as if the graph was in regular chart mode with the following differences:

All data is drawn using any active slice settings given in the stacked plot drawing options.

The õActive sliceö index will read õN/Aö.

The previous/next/choose slice graph toolbar buttons and õDisplay > Show > Stacked Plot Optionsö menu items will be disabled.

It will be possible to view all data from t = 0 to the final data sample of the graph using the horizontal scrollbar.

All autoscaling operations will function as if chart mode was active. Autoscale horizontal will make all of the data of the selected waveform visible on screen.

If the table of available slices was being displayed prior to the removal/editing of the last matching slicing event, the table will be emptied and the õOKö button dimmed. The cancel button will remain active for the table window to be dismissed.

The slicing event, vertical separation, and drawing menu items and toolbar controls will remain active.

Playback Mode (Replay)

Playback mode will replay a graph file stored on disk in real time to simulate acquisition. Analog, digital and calculation channels are replayed as stored in the graph file, but in BSL *PRO* and higher, calculation channels can be reconfigured to reproduce online calculation channels that have no offline equivalents. Calculation channels from the original graph can be modified, extended, or removed without affecting the data stored on disk in the original graph file.

1. Select File > Open for Playback.

2. Locate a graph file and then click Open.

3. A new graph window will be generated.
   - The õConnected toí   : hardware menu will indicate that the graph will be õacquiringö data from the specified file and the Start button will change to a õReplay.ö

4. Press Replay to begin playback.
   - Button alternates with STOP, canøt pause.

5. Select Playback > Quit Playback Mode to return to acquisition status.
   - Playback mode may also be entered and exited in the MP > Manage Hardware Connections õConnected Hardwareö dialog. (see below)

File	Edit	Transform	Analysis	Di
New...			Ctrl+N	
Open...			Ctrl+O	
Open Recent			▸	
Open for Playback...				
Close			Ctrl+W	
Save			Ctrl+S	
Save As...				
Save Selection As...				
Save Journal Text As...				
Send E-Mail Attachment				
Copy to Dropbox				
Open from Dropbox				
Logout from Dropbox				
Page Setup...				
Print...			Ctrl+P	
Go to Startup Wizard				
Quit			Ctrl+Q	
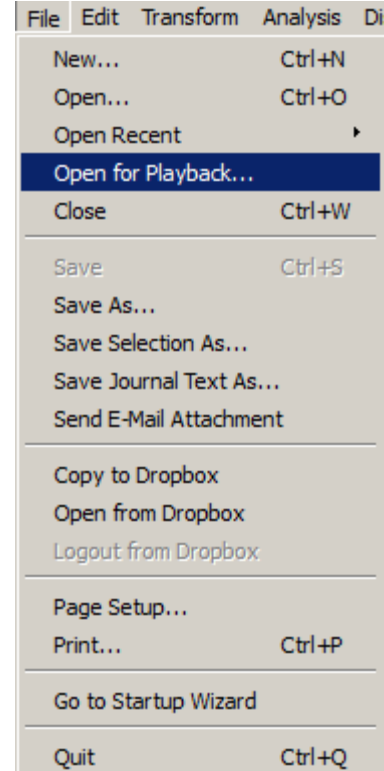
Use *Playback* to experiment with different calculation channels settings on the same data or to recreate an experiment for demonstration purposes.
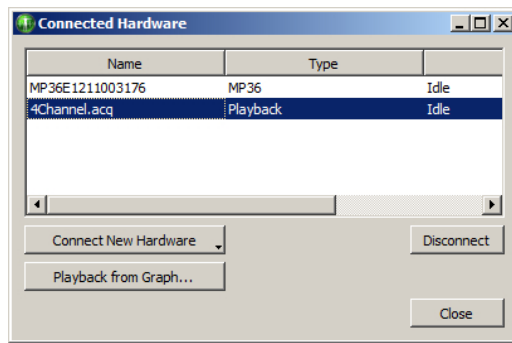
Playback mode has millisecond timing accuracy and allows for reconfiguration of most acquisition parameters. Exceptions include:

- Length is limited to the amount of data in the file
- Acquisition Sample Rate is fixed (use Channel Sample Rate to downsample)
- Number of analog and digital channels is fixed
- Save last and MP modes are disabled
- õAppendö will replay the same data.
- Journals will not be displayed during Open for Playback
- Output Control panel will not be displayed during Open for Playback

Do not record data while playing back a data file. If one data file is open in "Playback" mode and is 'replaying' and a second data file is open in MP mode and is acquiring data, clicking back and forth between graph windows causes the MP menu to flip to the Playback menu (even though 'Connected to' shows communication with an MP unit).

See the BSL *PRO* õ4Channel.acqö file in the PRO Samples folder as a sample of data playback.

(Main drive:\Program Files\BIOPAC Systems, Inc\Biopac Student Lab 4.1\Sample Data\PRO)

Data Views

A õData Viewö window is used to provide an alternate view of the same data. Data can be presented in two or more modes for comparison, such as X/Y plots and chart plots. To compare responses in real time, turn off Autoplot in one Data View (e.g., Dose 1) and continue Autoplotting in another (e.g., Dose 2).

To create a new Data View for the active (selected) graph, choose

- File > New and select type Data View or
- Display > Create Data View

This will generate a new window displaying the active graphøs data, and will name the new window õData View of ―Filenameø .

TIP   Use the Jump-to tool (see page 55) to correlate data views.

Data Views share fundamental data characteristics such as channel labels, events, and sampling rates, but can be customized for the following:

- horizontal scale, precision, and offset
- vertical scale, precision, and offset
- measurements, including number of rows, precision, visibility, and use of interpolation
- grid settings, including spacing, visibility, and locking state
- selected area
- autoplotting
- hidden channels
- autoscrolling
- channel button display state
- wave color
- event display state
- channel order
- plot mode
- channel drawing mode (step, line, or dot, including dot plot size and type)
- hardware õconnected toö display

The Data View window can be used like any other graph window. The menus and controls can be used to change how the data is presented. An acquisition can be started or stopped in any of the Data Views for a graph, and any transformations performed on the data in the Data View will be reflected in the graph and all of the other Data Views. Printing a graph from a Data View will use the display settings of that Data View for outputting the graph.

When a file is saved to disk, the display configurations of any Data Views that are open are saved into the graph file. When the graph file is reopened, all of the Data Views and their display settings will be restored.

- Data Views are saved with the data file only if they are open at the time the original graph is closed and saved.
- Closing a Data View causes this view to be lost; it is not saved with original file.
- Closing a Data View that was previously saved with a data file will not be saved if the data file is saved after closing the Data View.
- Closing a Data View will not invoke a warning that the Data View will not be saved.

In BSL 4.0.1 and higher, a selected area can be shared across multiple Data Views by clicking and holding the left mouse button over the I-beam toolbar cursor and choosing the õLink Selections Between Data Viewsö option. (See example figure right.)
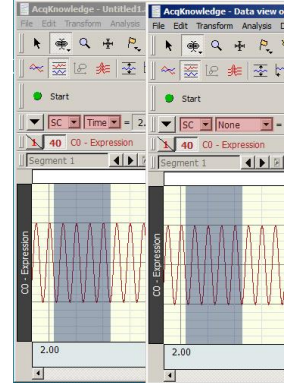
Analysis

Sample files were installed with the software. Select File > Open and choose a file from the list in the dialog.

If opening the sample data file õ4Channel.acq,ö the screen should resemble the following sample file display.
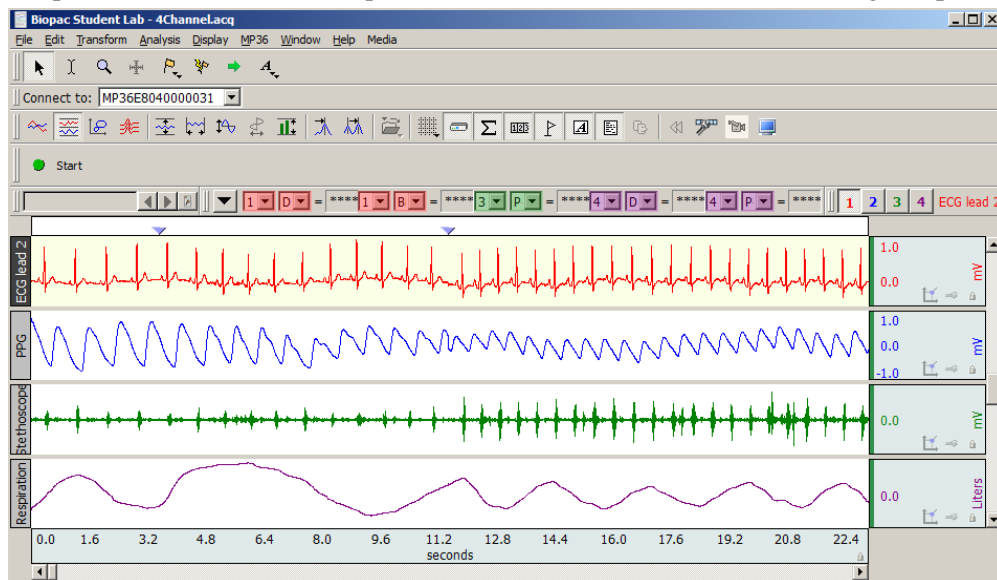
Sample File Display

The sample graph displays four different types of data, and there is a border between the waveforms.

To the left of each waveform is a vertical strip containing a text string that can be used to help identify each waveform.

The time scale along the bottom denotes when the data was recorded relative to the beginning of the acquisition.

The maximum vertical scale range is from +10 to -10 Volts.

- ➢ This reflects the maximum input voltage the MP unit can accept and encompasses a greater range than normally encountered.
- ➢ The display scale can be adjusted to virtually any value range, as demonstrated in the graph window above.

As indicated by the horizontal scale, only a few seconds of data are displayed on the screen. Choosing õChannel Infoí ö from the Display menu will display the total length of the record along with other information.

To view data that was collected earlier in the record, use the horizontal scroll bar to move to the desired point.

Alternatively, position the cursor in the horizontal scale area (where the numerical values are listed) and click the mouse button. This will generate the following dialog (see page 67 for details).
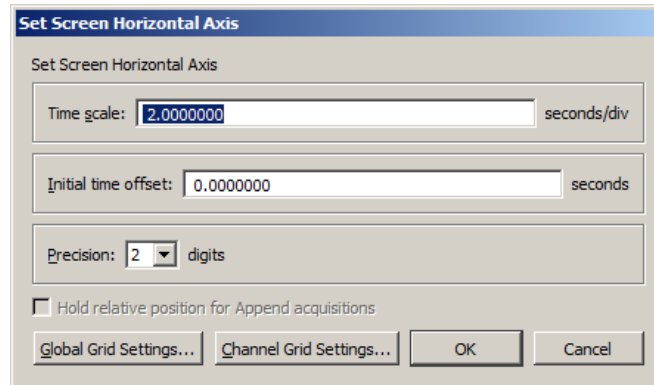
Use the Time scale box to increase or decrease the amount of data that appears on the screen at any given time. In the sample dialog, this is set to 2 seconds per division. The divisions on the screen are indicated by the four vertical lines, thus displaying eight seconds at a time (two seconds per division times four divisions). By entering a larger value in this box, more of the record will be displayed on the screen at any given time. Conversely, entering a smaller value in this box will cause a shorter segment of data to be displayed on the screen. (Above screenshot is from BSL *PRO*)

  ➢ To display the entire waveform (in terms of duration), a shortcut is to choose Autoscale horizontal from the Display menu. The Autoscale horizontal command fits the entire data file into the window, regardless of the total length of the acquisition.

The Initial time offset box can be used to õjumpö to a different point in the time display. Changing the value in this box allows the display data beginning at a certain point in the record. For example, to see the data at the beginning of the record, enter an initial offset of 0 seconds, which would result in the following:
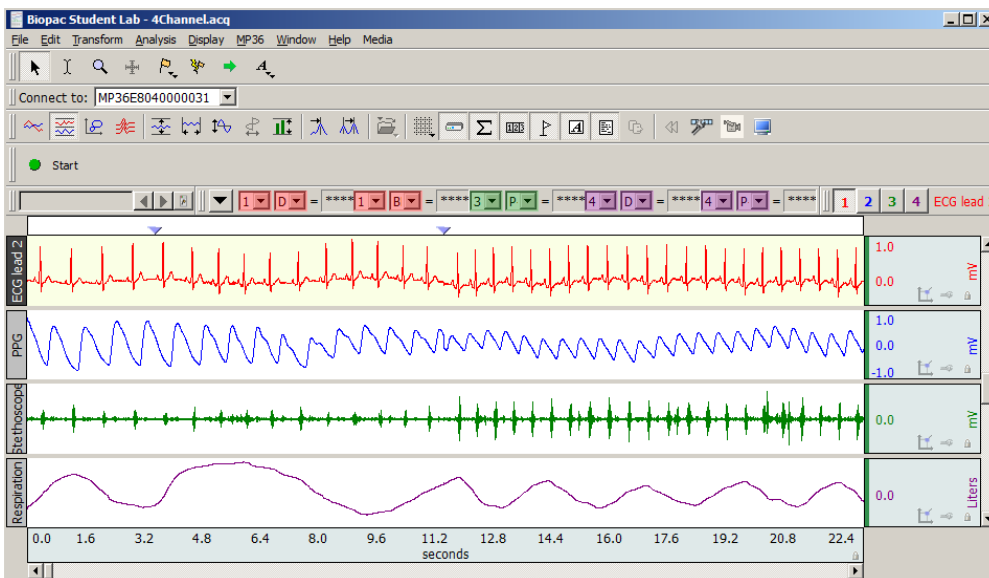
As observed tell from the time scale, the first data displayed (at the left edge of the screen) was collected at the beginning of the acquisition. Also, the scroll box has moved to the left, indicating that the data on the screen represents data collected earlier in the record.

After clicking the horizontal scale area again, the same dialog will appear. This time the value in the start box should have changed to reflect the new section of data being displayed on the screen.

BSL *PRO* also allows customization of the vertical scaling, or amplitude, of each waveform. Clicking the vertical scale area produces a dialog (see page 69 for details).

Use the vertical scale dialog to change the range of amplitude values displayed (scale) and set the value that appears in the center of the vertical scale (midpoint).

The midpoint and apparent magnitude of each waveform can be changed by modifying the values in each box. By changing the value in the scale box, a smaller value has the effect of increasing the apparent amplitude. Entering a number about half the current value will cause the amplitude of the wave to appear to double.

- Scaleô In the sample dialog, the units are set to 25 mV per division. As with the horizontal scale, there are four divisions on the vertical axis, so this setting should show 100 mV range of data.

- Midpointô The box below this controls the midpoint of this range. In this case, the midpoint is set to 0 mV, which means that this channel will display the range from - 50 mV to + 50 mV

As with the time scale, BSL *PRO* can automatically apply the best fit in terms of midpoint and units per division. To do this, select õAutoscale Waveformsö or õAutoscale Single Waveformö from the Display menu, and the amplitude and offset of each wave will be adjusted to fit their sections.
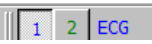
Any modifications to rescaling (either horizontal or vertical) will only affect the way data is displayed, and will not change the basic characteristics of the data file.

Selecting a waveform

Although all four waves are displayed at once, it may be preferable to operate on only one channel at a time. To do this, the desired channel muse be selected by clicking inside its boundaries on the graph. Selecting a channel allows highlighting of all or part of that waveform, and enables transformations to be performed on a given channel.

In the upper left corner of the graph window there is a series of boxes that represent each channel of data. The numbers in the boxes correspond to the channel used to acquire the data (the specifics of setting up channels are discussed on page 101. In the sample waveforms shown previously, ECG channels are represented by channels 1 and 2, with respiration on channel 4 and blood pressure on channel 5.

To select one of these channels

- position the cursor over the channel box 1 2 ECG that corresponds to the desired channel and click the mouse, or

- position the cursor on the waveform of interest and click the mouse.

Show/Hide Channel

To õhideö a waveform, press ALT for Windows or OPTION for Mac and click the channel box.

To view a hidden waveform, repeat the appropriate key-click combination.
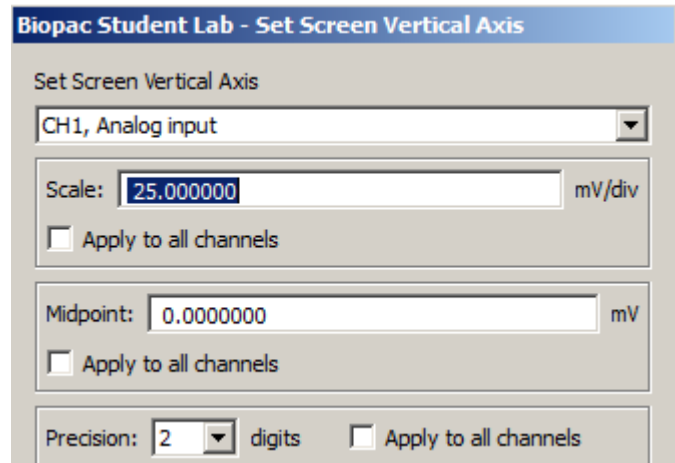
Collapsing Channels

In BSL *PRO* 4.1.1 and higher, individual or multiple channels may be quickly õcollapsedö by simply clicking the
ˇ button appearing in the upper left region of each channel. When a channel is collapsed, all data is retained but
hidden from view, and the button status changes to › while collapsed. Collapsing a channel allocates more
vertical space to remaining channels, enhancing the view of visible data.
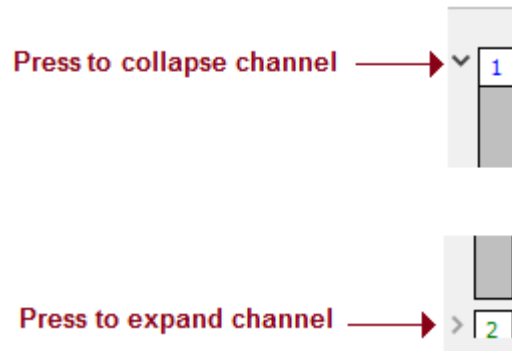
Channel "Collapse" button

NOTE: In certain operating systems, the ˇ or › buttons may instead appear as ⊟ and ⊞ characters. See below
example showing Channel 2 collapsed. Note that when a channel is collapsed, the channel label appears in a gray
horizontal bar indicating the channelsø location.
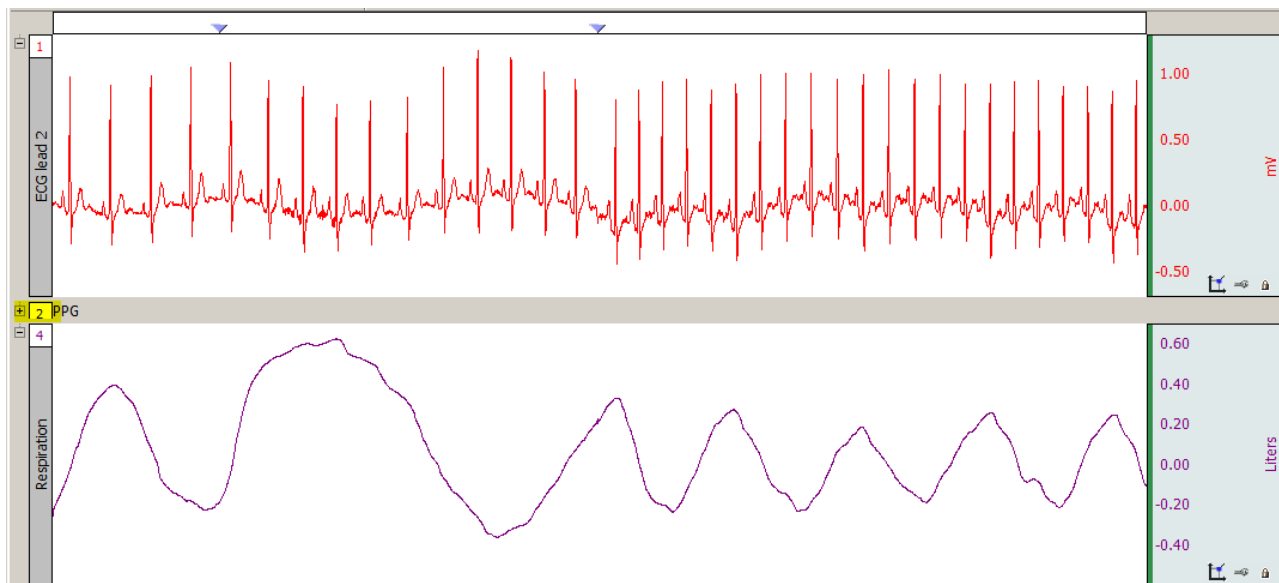
Channel 2 collapsed

To expand (unhide) the collapsed channel simply click the › or ⊞ button, or double click the collapsed channeløs
label.

NOTES:

- Collapsing or expanding channels is supported in Chart or Stacked Plot mode only.

- Pressing the Alt/Option key while clicking any button will collapse or expand all visible channels
  with the exception of one. (A minimum of one channel must remain uncollapsed. It is not possible to
  use the collapse or expand button on graphs with single channels.)

- Collapsed channels are retained when a graph is saved and reopened.

Zoom

Another way to examine data is to use the õzoomö tool. The zoom tool allows any portion of any wave to be selected and magnified. To use the zoom tool, click the $\boxed{\mathbb{Q}}$ icon in the lower right portion of the screen. As the cursor is moved into the graph area, note that it changes from an arrow $\boxed{\text{↖}}$ to a crosshair (+). Start by positioning the cursor in one corner of the box, holding down the left mouse button, and dragging the crosshair horizontally, vertically, or diagonally to form a õboxö which encompasses the zoom area. Upon releasing the mouse button, BSL *PRO* automatically adjusts the horizontal and vertical scales. To õunzoom,ö choose Zoom back (or Ctrl-) from the Display menu.

Select an area

Once a channel has been selected, data in that channel can be edited by selecting a section of the waveform. Avaliable options include cutting, copying, and pasting sections of waveforms. Transformations and Analysis can be applied to entire waveforms or specific sections of waveforms only.

For any of these functions, select (or highlight) an area to be operated on. To select a section of a waveform, position the cursor over the $\boxed{\text{I}}$ icon in the lower right hand corner of the screen and click the mouse. Now move the cursor to the first point in the area to be selected. When moving the cursor into the graph area, note that it changes from an arrow cursor to an I-beam editing tool.

To highlight a section of a waveform, position the $\boxed{\text{I}}$ cursor at the left edge of the desired area and hold down the mouse button. Now move the mouse to the right until the desired area has been selected. The selected area will have a darkened appearance.

To select more than one screen of data, position the $\boxed{\text{I}}$ cursor at the left edge of the section to be highlighted, then click and hold the mouse button. Use the scroll bars to move to a different point in the record, and when reaching the desired endpoint (right edge) of the selected area, hold down the Shift key while positioning the cursor and click the mouse. Selecting an area this way will also allows fine tuning of the selected area to include only a specific range of data.

Once a channel has been selected and a section of that area highlighted, that particular section of the waveform can be edited or modified. The editing commands behave much the same way as the editing functions in a word processor. Copy, delete or paste sections of data as defined by the selected area. If necessary, an edit can be reversed by choosing Undo from the Edit menu, or by using the standard undo shortcuts **CTRL + Z** for Windows or ⌘ +Z for Mac.

Selecting a portion of a waveform also allows transformations to be applied to a particular area, rather than the entire area or all waveforms. Selecting an area also allows snap measurements to be taken for parameters such as Delta T, Mean, Standard Deviation, Frequency, and so forth. The measurement options are discussed in the next section.

In BSL 4.1 and higher, the selection tool has been extended to select appended segments. To select an appended segment, double-click on the segment with the selection tool active. To select multiple appended segments, hold the Shift key down while double-clicking.

The Selection Palette (**Display > Show > Selection Palette**) can also be used to select an area.

Keyboard data selection

Keystroke combinations can similarly used to select or deselect graph data on a sample-by-sample basis. This helps add an enhanced level of precision to the selection operation. See data selection keyboard shortcuts on the following page. (BSL *PRO* and higher)

Keyboard Shortcut	Description
Windows: Shift + Ctrl + Left Arrow **Mac:** Shift + Command + Left Arrow	Subtracts one sample interval from the right edge of the selection. If the selection is empty, no action is performed.
Windows: Shift + Ctrl + Right Arrow **Mac:** Shift + Command + Right Arrow	Subtracts one sample interval from the left edge of the selection. If the selection is empty, no action is performed.
Shift + Left Arrow	Adds one sample interval to the left edge of the selection.
Shift + Right Arrow	Add one sample interval to the right edge of the selection.
Left Arrow	Moves the selection one sample to the left, constructs a zero width selection.
Right Arrow	Moves the selection one sample to the right, constructs a zero width selection.

Transform data

BSL *PRO* includes a library of functions to transform data or perform mathematical calculations on waveform data. All of these options can be found under the Transform and Analysis menus, and are discussed in detail in the Analysis section beginning on page 276.

When performing transformations

- If a section of a waveform is highlighted, the transformation will apply to that section.

- If no area is selected, BSL *PRO* will always select a single data point.

- If the transformation can only be performed on a selected area (digital filtering, for instance) and a single point is selected, the entire waveform will be used (and the transform entire wave option will be disabled; close out of the dialog and select an area if desired).
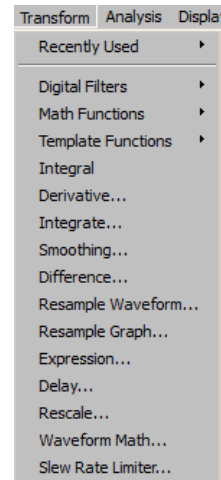
Focus Areas

Focus areas are comprised of selected time ranges within the graph. The purpose of the õFocus onö tool is to easily isolate selected areas within the graph window for discrete analysis. This can be useful for identifying areas of interest within a larger data set by highlighting, naming and storing them permanently in the graph. When a focus area is assigned, that portion of the graph will appear shaded with borders appearing at the edges. The assigned focus area label will be displayed vertically in the shaded area. (See following page for example.) Focus areas may also be defined via the õFocus onö toolbar above the graph, and in the Find Cycle Analysis feature.

- Focus areas are graph level data, similar to events. Defining a focus area in one data view defines it for all data views, etc.

- Focus areas are drawn only for graph windows in chart, stacked plot, or scope mode. They are overlaid on top of data and events but underneath text annotations and selections.

- Focus areas may overlap.

- Each focus area is required to have a unique name.

Creating Focus Areas

To create a focus area:

1. Select an area of interest in the graph data using the I-beam tool or selection palette.

2. Create the focus area using one of the following methods:

- Click on the õaddö $\boxed{+}$ button to the right of the õFocus onö toolbar.

- Choose õDisplay > Create Focus Area.ö

- Right-clicking in the graph and choosing õCreate Focus Areaö from the contextual menu.

3. Name the focus area by typing into the label field.
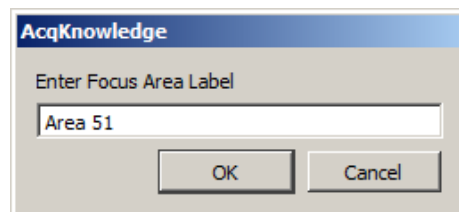
The new focus area label will appear in the õFocus onö toolbar field.

The new focus area and label will appear in the graph.
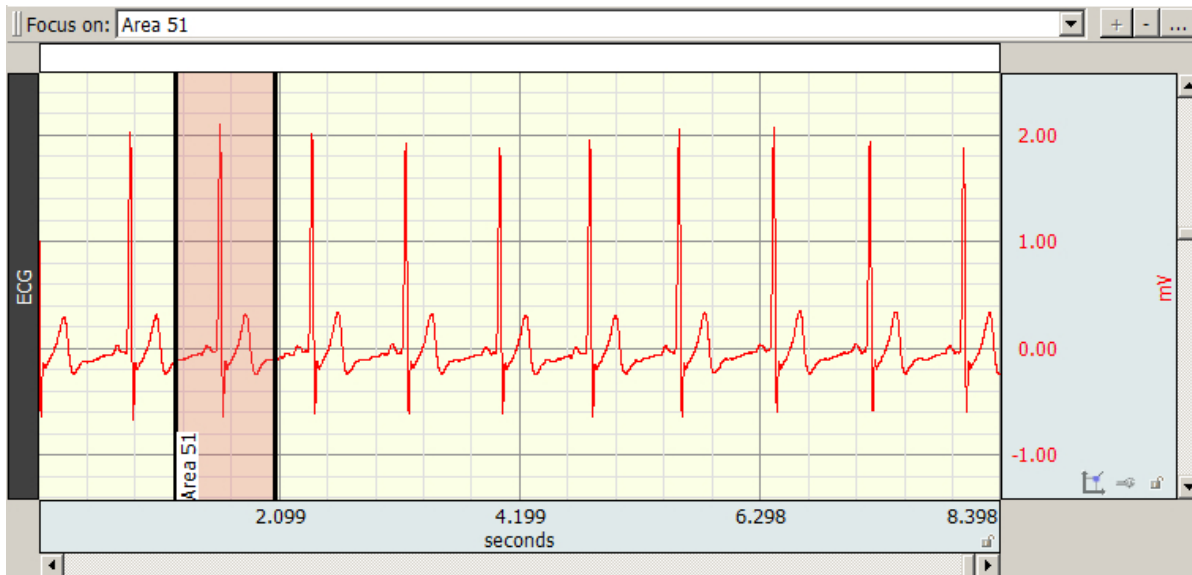
Multiple and overlapping focus areas can be created by selecting additional data and using the õaddö [+] button.

Navigate quickly to a focus area time selection in the horizontal axis by selecting its label from the õFocus onö toolbar field.
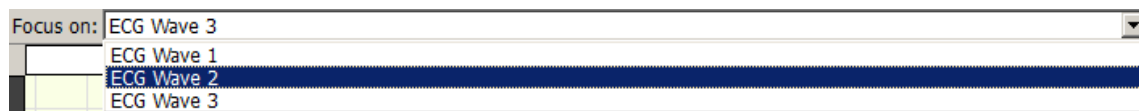
To remove a focus area, use the õminusö õFocus onö toolbar button. [-]

TIP: To remove multiple focus areas at once, hold down the Ctrl key (PC) or Option key (Mac) and click the õminusö focus area toolbar button. [-] (A confirmation dialog will appear before focus areas are removed.)

To rename a focus area, use the õellipsesö toolbar button. [...]

To highlight the current focus area, click the õhighlightö button. [HH]

Focus Areas in Specialized Analysis

Most Specialized Analysis tools can be limited to running analysis on a focus area by choosing the õfocus areas onlyö option in the setup dialog.
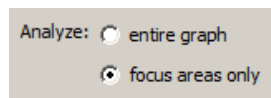
Printing Focus Areas

Focus areas can be included or excluded from a printed graph by selecting or deselecting the õPrint focus areasö option in Print Setup.
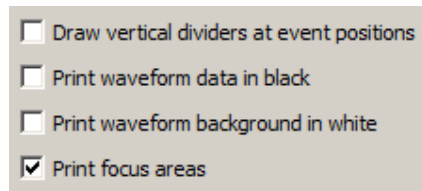
Focus area preferences can be modified by using Display > Preferences > Focus Areas. For further details see page 329.

For Find Cycle focus area options, see the Find Cycle section on page 282.

Measurements

Measurements appear in the row of boxes across the top of the graph window. The number of visible measurement boxes and the display precision can be specified in the õPreferencesö dialog of the Display menu. Each measurement consists of three parts: (a) the channel selection, (b) the measurement function, and (c) the result or actual measurement value.
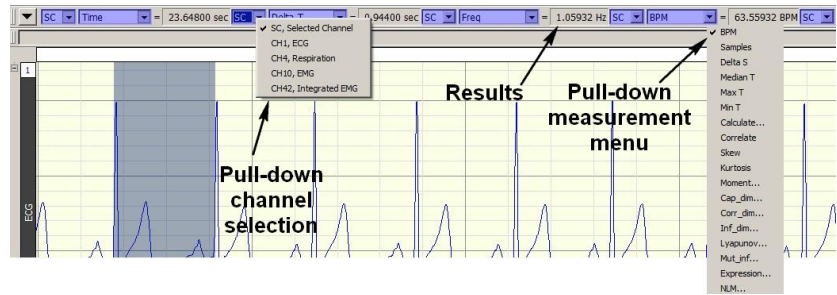
For example, the results for ‰SC, Selected Channel+is:

Time	23.64800 sec
Delta T	9.44000 sec
Freq	1.05932 Hz
BPM	63.55932 BPM

The pop-up channel selection calculates a measurement either for the selected channel (SC) or from a numbered channel in the graph. To switch between the channel options, click in the channel window. The pop-up menu shows the channel numbers and labels for all channels in the file. By default, each measurement will reflect the contents of the selected channel.

The pull-down measurement menu allows selection between different types of measurements. To choose a measurement, click the measurement popup menu and select a measurement from the list.

- Some measurements (such as Time or Value) look at only a single data point whereas other measurements (such as mean and delta T) examine a range of data on the selected channel.
- Some of the measurements that depend on a selected area (such as delta T) look at differences in the horizontal axis measurement whereas other range measurements (such as peak-to-peak) use the vertical scale information in calculating measurements.

For a complete description of each of the measurement functions, turn to page 85.

The final component of a measurement window is the measurement result.

- When an area is selected (or if the selected area is changed) the measurement result automatically updates to reflect the change.

Events (Markers)
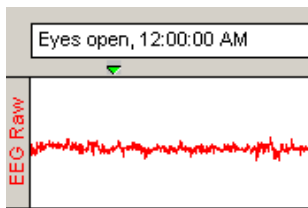
In many instances it is useful to have the software mark an occurrence or event during an acquisition so it can be referenced later. For example, itøs often helpful to note when a treatment began or when an external event occurred in order to examine any possible reaction. Events, or Event markers, are used to note these areas of interest.

Event markers can be pre-established and automated. Event icons and labels appear at the top of the graph window, and can be edited, displayed, or hidden from view.

Event markers can be added during an acquisition by pressing the Esc key. This will insert an event at the exact time the key is pressed and will activate the text line entry so a comment can be associated with the event.

For a detailed description of event markers and event marker functions, including options to pre-establish event labels and set function keys for different labels, see Set Up Event Hotkeys (page 191).

See also: Text Annotation, page 56.

Grids
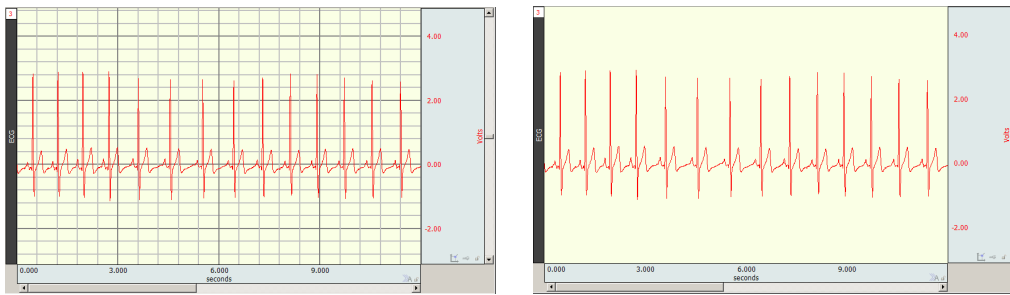
Grid superimposes a set of horizontal and vertical lines on the graph window. The grid is designed to allow for easy measurements, since the grid lines correspond to horizontal and vertical scale divisions. The grid can be locked (analysis, printing) or unlocked (visual aid).

To activate the grid display, choose Display > Show > Grid or click the ▦ toolbar icon.

- To display minor grid lines, use Ctrl-▦.
- To customize grid line and color and optimize the display and print features, choose Display > Show > Grid Options.

For more information about using and printing grids, see page 73.

Note: The Scale dialogs change when grid lines are locked. See page 67 for details on Horizontal Scale and page 69 for details on Vertical Scale.

Horizontal Split View

Horizontal Split View is a tool for õsplittingö the data in a single graph into two simultaneously viewable areas and displaying them side-by-side for convenient viewing. Split View is available for data plotted in scope, chart or stacked plot modes. Both views can contain independent time scales, initial offset and autoscroll settings. This can be useful for making side-by-side comparisons of data at different time ranges, or for reviewing the same section of data in two separate time scales for more detailed examination. Split View configurations and scalings can be saved and restored in the graph.

Split View can be activated via the following methods:

- Choosing Display > Split View.
- Clicking the Split View toolbar button. ◄▌►

Either method divides the graph into two equal regions with independent time scales, and the bar in the center can be dragged to the desired location.
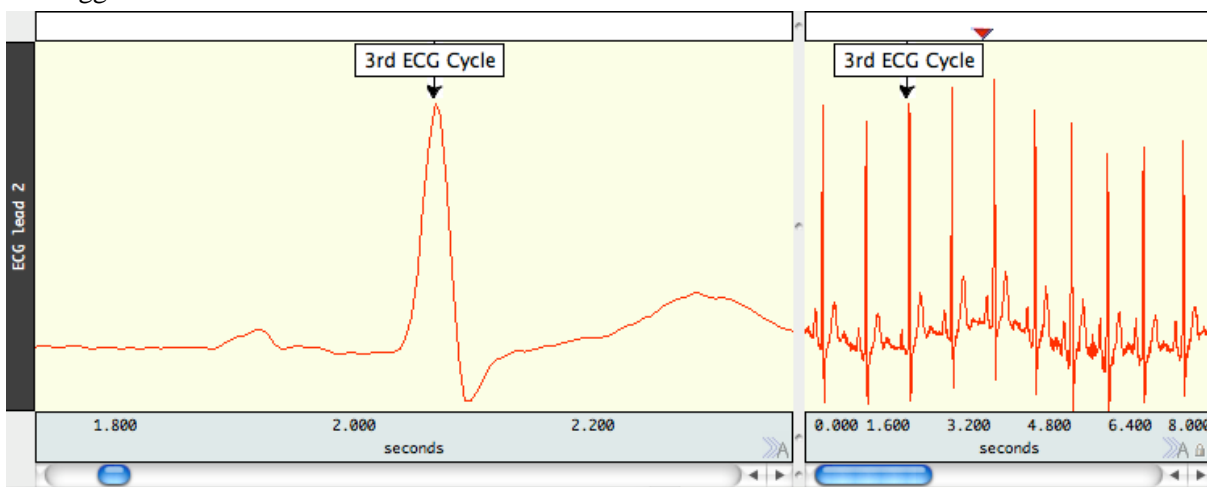
In the above example, the view in the left pane was rescaled independently of the view of the same data on the right pane. This enables a closer view of an area of interest while maintaining the original data display. If a Split View encompasses any events, annotations or focus areas, these will be visible in both panes.

- Note that events, annotations, selected areas and focus areas appearing in the Split View are duplicate displays of the same items. If any of these items are added, modified or deleted in one view, this change will also be applied to the other view.

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- Split View is not supported in XY mode.
- Printing of Split Views is not currently supported within the BSL application. If printing is desired, save the graph in *.jpg format or use standard operating system screen capture utilities.

To exit Split View, uncheck the Display > Split View option or drag the Split View bar back to its home position at the left of the horizontal scale.

Autoscroll Horizontal Axis Controls

During data acquisition, three plotting modes are offered. These are normally accessed via the MP menu, but can be more easily dialed in by using the »M button in the lower right of the horizontal axis region. This button toggles between the following modes, and the button display changes to reflect the plotting type selected.

Status	Icon	Description
Manual	»M	Horizontal axis is not modified by application during data acquisition. Only manual adjustments affect the data plot. Equivalent to unchecking both MP > Autoplotting and MP > Scrolling.
Sweep	»S	Data is plotted until it reaches the right edge of the graph. At this point the data is scrolled, clearing data display and showing the newly acquired data starting at the left edge. This mimics the "sweep" of an oscilloscope. Equivalent to checking MP > Autoplotting and unchecking MP > Scrolling.
Autoscroll	»A	New data is plotted at the right edge of the graph. When new data is acquired, existing data is scrolled to the left, creating space to plot new data. Equivalent to checking both MP > Autoplotting and MP > Scrolling.

Journals

The Journal is a general-purpose text editor built into BSL *PRO* that works like an "electronic notepad" for recording notes and data and saving text and/or numeric values for later review. The Journal can be used at the same time data is being acquired. Every graph file has a graph-specific Journal file permanently linked to it. There is also an option to generate independent Journals for data view, use with multiple graphs or protocols.
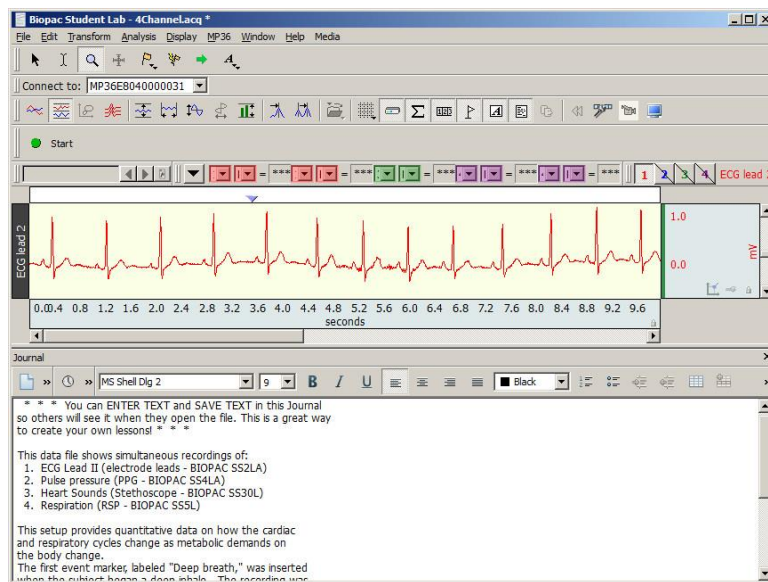
Graph-specific journal— Journal is saved with graph; preferable for retaining notes and analysis within a graph file. Display settings are independent. To save a graph-specific Journal independent of its graph, use File > Save Journal Text As option.

Independent Journal— Journal is saved into its own file, separately from graphs; preferable when performing analysis on multiple graphs at the same time. Independent journals allow multiple journal windows to be open at the same time (each graph view can have its own journal associated with it), but only one Independent Journal can be used at a time.

For more information on using Journals, see

Saving data

Once data has been collected, it can be saved as a file and opened later. The data file can be moved, copied, duplicated and deleted just like any other computer file. By default, files are saved as BSL *PRO* (.ACQ) files, which are a proprietary format designed to store information in a format as compact as possible. Although these files can only be opened from within BSL *PRO*, the data in these files can be exported either as a text file or as a graphic image.

Exporting data to a text file allows data to be examined using other programs, such as a spreadsheet or statistical analysis package. Saving data as a graphic (.JPG) enables working with the data in graphic format.

One of the most useful applications of this is the ability to edit and place BSL *PRO* data as it appears on the screen. This feature can be used to paste graphs into word processors, drawing programs, and page layout programs. To learn more about these options, turn to the Save As section beginning on page 230.

Format change warnings

When a file save function requires a format change for compatibility or alters file content, a prompt will be generated to require the user to confirm the option to update format or convert and save.
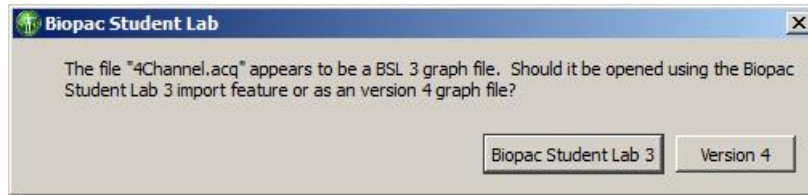
Created with a previous version of BSL *PRO*
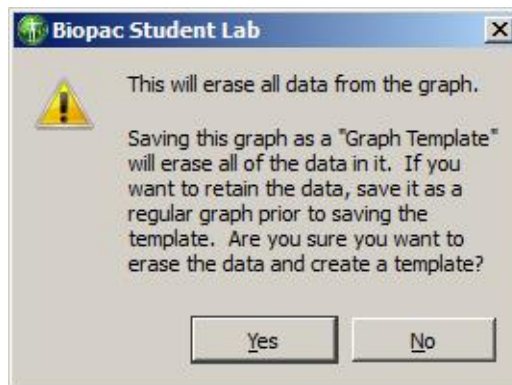
Saving as a "Graph Template" will erase all data

Print
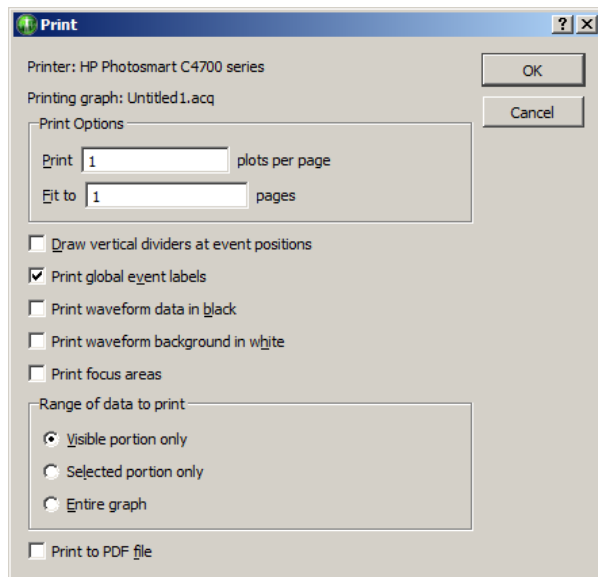
BSL *PRO* supports high-resolution hard copy plots of graphs much as they appear on-screen.

- To print a file, choose Print from the File menu. This will print the contents of the screen on the selected printer.

- To print the entire file, choose Autoscale Horizontal from the Display menu first.

- Printing a Journal uses a separate command from printing a graph file.

The contents of a file can be printed across several pages by entering a value in the õFit toö box. For example, entering õ4ö in this box will place the length of the page evenly across four pages when printing.

Print options are available clicking OK in the initial File > Print dialog; see page 239.

Chapter 3   User Interface & Context Menu Features
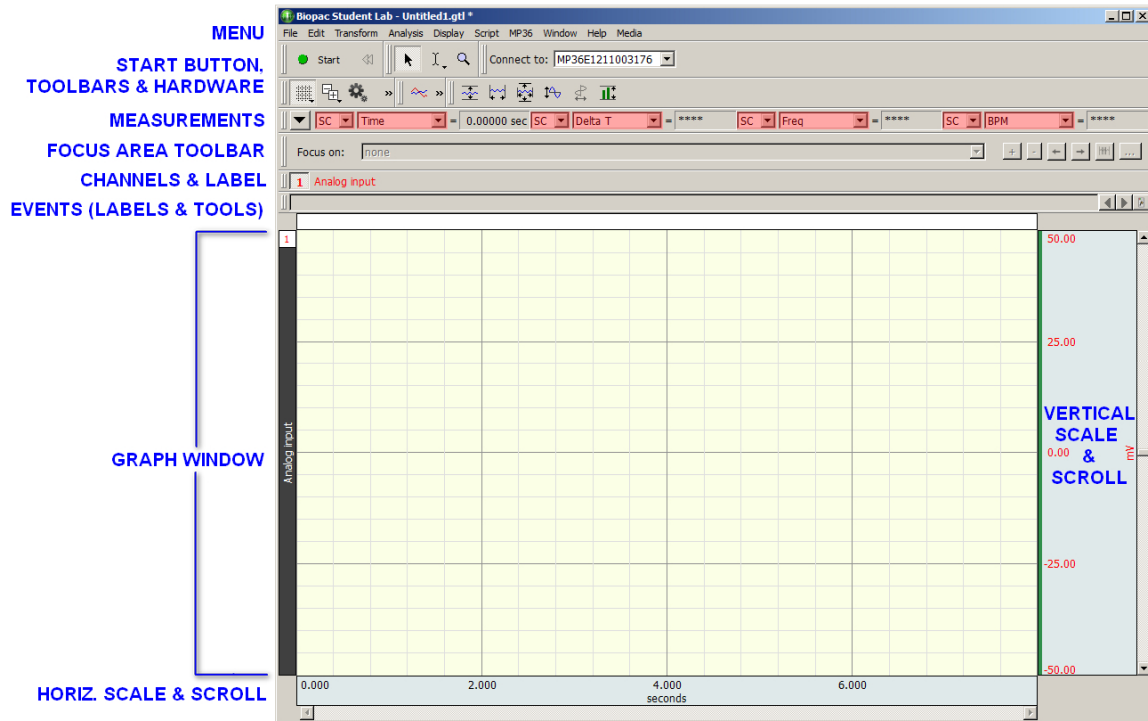
- Toolbars
- Keyboard Shortcuts
- Mouse Controls
- Custom toolbars for transformations and analysis
- Toolbar position retention and changes
- Event tool enhancements
- Typed event label drawing improvements
- Button Transparency
- Transformation History

- Customizable Chart Track Dividers
- Plotting Background Colors
- Vertical axis scaling buttons
- Long channel labels and units
- Graph window tooltip improvements
- Menu item tooltips
- Channel Info

Toolbars

Many of the most commonly used features in BSL *PRO* can easily be executed with a mouse click. The toolbars contain shortcuts for some of the most frequently used BSL *PRO* commands. Click an icon to activate it; icons are grayed out when they are not applicable.

Toolbar positionô Toolbars for Measurements, Channel number, and Hardware revert to the default location when a file is opened (position is not retained).

By default, a minimal toolbar configuration is presented when Acq*Knowledge* is first launched. The default toobars will appear as follows:
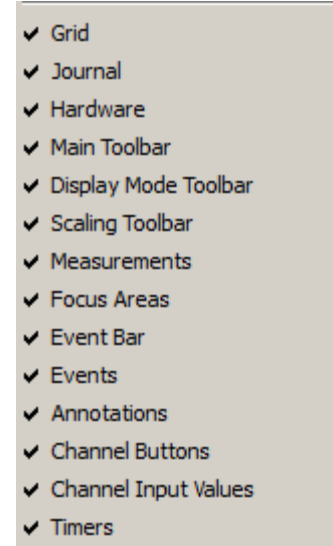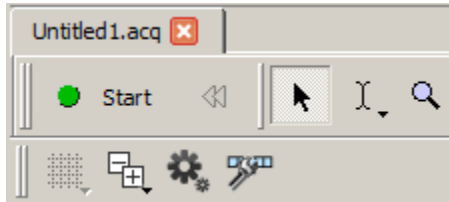
The default toolbars consist of:

- Start/Stop button
- Cursor Toolbar (Arrow, I-beam and Zoom tools)
- Main Toolbar (Grid, Toolbar Display, Preferences and Customize Toolbar buttons)

The full range of available toolbars can be displayed by enabling the checkbox options in the Toolbar

Display shortcut button , or via Display > Show and enabling the desired options. Once the toolbar options have been selected, this will be the default toolbar display for all new graphs. All toolbars can be deselected and hidden with the exception of the Start/Stop button and the Cursor Toolbar (Arrow, I-beam and Zoom tools).

Saved graphs created with different toolbar configurations will open with those toolbar options displayed.

Toolbar positionô Toolbars can be dragged and repositioned to any border of the graph window, or floated on top of a graph. Toolbars retain the last position they were left in after the application is closed and a new graph reopened.

Restoring the default toolbar position – The default toolbar positions can be restored by going to Display > Preferences > Other and selecting õReset toolbar positions.ö The application must then be closed and relaunched for the reset to take effect.
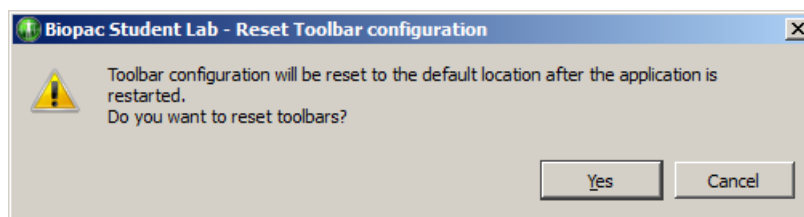
NOTE: The õReset toolbar positionsö option restores the default toolbar locations only; it does not hide toolbars or restore the default minimal toolbar configuration displayed upon first launch. To return toolbars to the default minimal configuration, it is best to deselect unwanted toolbars in the toolbar display menu. (Use the Toolbar Display shortcut button or Display > Show.)

The toolbars can be reset to the default minimal configuration by holding down the Shift key while launching BSL *PRO* but this is a õnuclearö option.ö Choosing this option will reset ALL program defaults to the factory configuration. Do not choose this option if the configuration contains custom settings that need to be saved.

Main, Display and Scaling Toolbars

Main Toolbar	Display Mode Toolbar	Scaling Toolbar

TOOLBAR ICONS	FUNCTION
	Show/Hide gridlines in the graph window. Click and hold the mouse to display various grid preset options.
	Opens popup menu for showing/hiding individual toolbar options.
	Opens the Preferences dialog.
	Opens the customize toolbar menu.
	Change display to scope mode.
	Change display to chart mode (default).
	Change display to X/Y mode.
	Toggle Stacked Plot (overlap segment) mode; see page 35.
	Horizontal Split View; see page 47.
	Create Data View; see page 38.
	Autoscale selected waveform only.
	Autoscale waveforms along the horizontal axis.
	Show all data in graph by autoscaling both horizontally and vertically. See page 318 for details.
	Center waveforms vertically in the active window.
	Center waveforms horizontally in the active window (X/Y mode only).
	Adjusts vertical scale of selected channel to display full range of data. See pages 70 and 317 for more details.

'Connect to' Hardware toolbar

Connect to: MP36E1211003176 ▼
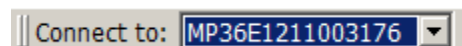
The 'Connect to' hardware toolbar displays connection information and allows quick access to adding or switching hardware. The Hardware toolbar reverts to the default location when a file is opened (position is not retained).

To switch the hardware unit associated with a graph window, click the õConnect toö box and select an available unit or choose ÷Add New Device.øDifferent hardware types may be added and consolidated in the list by selecting ÷Add New Deviceø

Choose ÷No Hardwareøto run BSL *PRO* in analysis mode only.

Using 'Connect to' to run Multiple Hardware

BSL *PRO* can be used with multiple data acquisition units to:

▪ Control multiple, independent experiments on one computer

▪ Increase the total number of channels used for a single experiment (e.g., 32-channel EEG)

To synchronize the Start of multiple units, use the Trigger function.

To show/hide the õConnect to:ö information, toggle the Show/Hide Hardware icon in the Toolbar.

To switch the hardware unit associated with a graph window, click the õConnect toö box and select an available unit. To add new hardware, choose ÷Add New Device.ø

Once added, the new hardware type will appear in the ÷Connect toø list.

Choose ÷No Hardwareø to run BSL *PRO* in analysis mode only.

Each graph window can support a different MP unit. To add an MP unit for acquisition, open a New Graph (not a Data View).
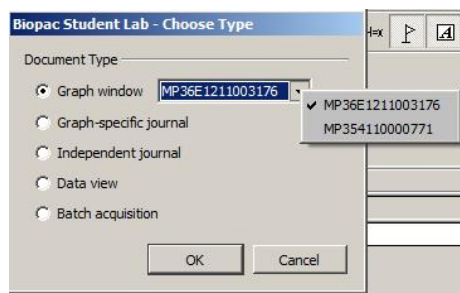
If more than one hardware type has been connected via ÷Connect toø, subsequent new graph windows will contain a hardware selection menu.

For additional control of hardware types and connections, see **MP > Manage Hardware Connections** on page 215.
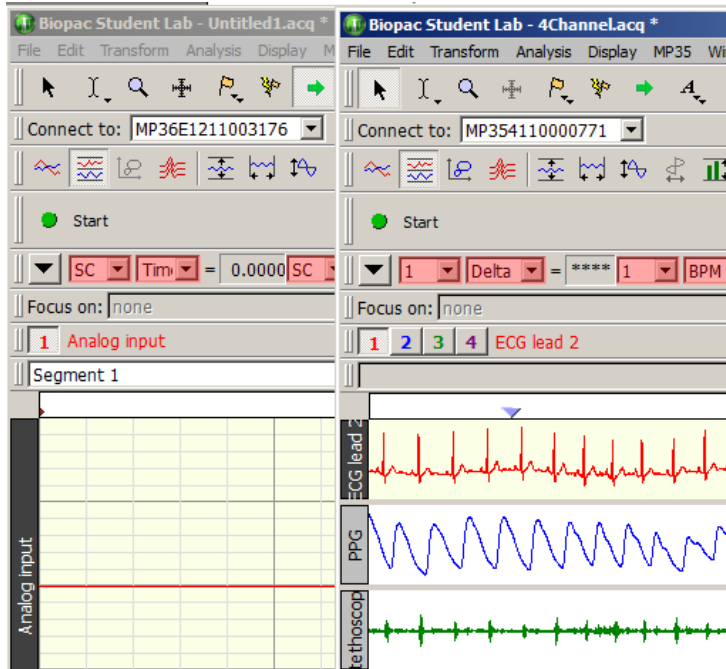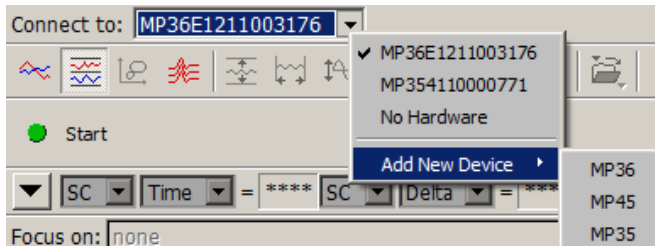
Cursor toolbar
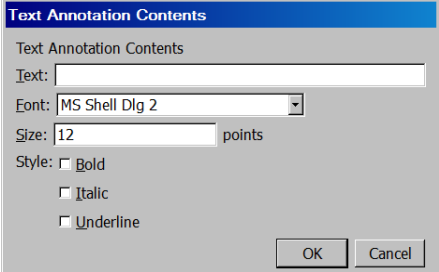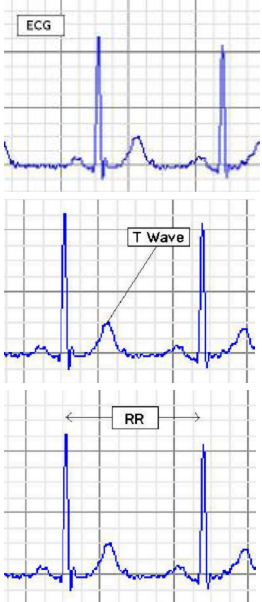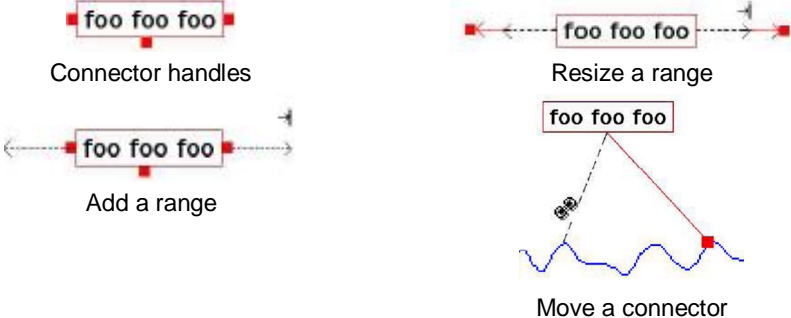
Cursor tools are used in many of the on-screen functions described below, including editing, measurements, and the amount of data displayed.

NOTE: The four rightmost icons on the Cursor toolbar (Event tool, Zap tool, Jump tool, and Annotation tool) do not become visible until data has been acquired, or a graph containing data has been opened. See below for full description of all toolbar button functionality:

CURSOR TOOLBAR	
▶	This is a general-purpose öarrowö cursor tool, used for selecting waveforms, scrolling through data, and resizing the chart boundaries between waveforms when in chart mode. All other cursors default to this mode when the cursors are moved outside the graph area. Use Alt-click to step through the channels; each click makes a new channel õactive.ö The arrow cursor can also be activated by the Ctrl+B keystroke. In BSL *PRO* and higher, holding down the left mouse button with the arrow tool positioned over a graph channel will activate a single data point, which displays as a solid black vertical line. This is known as õspot measurementö mode. Dragging the mouse will then update selected measurement values to the new horizontal locations of the arrowøs position in the graph. The mouse button should be depressed for approximately 0.5 seconds in order for spot measurement mode to become active. Releasing the button restores the arrow cursor to its normal status.
I	This is a standard õI-beamö editing tool. This tool is used to select an area of a waveform (or waveforms) to be edited or transformed. To select it, click the middle button in the lower right hand corner of the screen. Now move the cursor toward the waveform. Note that the cursor changes from an arrow to an I-beam when placed over the graph area. Using this tool to edit data is analogous to editing text with a word processor. When this cursor appears, an area of data can be selected by holding down the mouse button and dragging the mouse to either the left or right. Extend the selected area to include data not visible on the screen by positioning the cursor at the left edge of the area to be selected and clicking the mouse button. Next, use the scroll bars to scroll through the data until the desired data appears on the screen. Hold down the shift key while positioning the cursor to select the right edge of the area to be selected. Click the mouse button to select the area. To extend the selection, hold the Shift key and move the cursor or the arrow keys. The I-beam cursor can also be activated by the Ctrl+I keystroke. Clicking and holding on the I-beam tool will generate a pop-up menu for displaying the Selection Palette or linking selections between Data Views. Show Selection Palette Link Selections Between Data Views
⊕	When õLink Selections Between Data Viewsö is selected, the standard I-beam cursor icon will change to one with a link appearing across it. When enabled, any area selected in a Data View or source graph will also be applied to any other associated data view. For more details, see Data Views on page 38.

🔍	This is a standard õzoomö tool. The zoom tool is used for selecting and magnifying any portion of any waveform. Click the 🔍 icon (in the lower right portion of the screen) to use the zoom tool. As the cursor is moved into the graph area, note that it changes from an arrow ▷ to a crosshair (+). Start by positioning the cursor in one corner of the box, then hold down the (left) mouse button and drag the crosshair horizontally, vertically, or diagonally to form a õboxö that encompasses the area of interest. When the mouse button is released, the horizontal and vertical scales will be re-adjusted. To õunzoom,ö choose õZoom Backö from the Display menu or use the Ctrl ó keystroke.
	Hold the õAltö key to change the zoom mode to zoom out (õó õin the magnifier). The zoom tool can also be activated by the Ctrl+G keystroke.
Grid Control ⊞	Adjust the grid lines horizontal and vertical. Hold the option key for locked grids to drag to the end.

Event Definition 🚩	Inserts an event at the mouse click location. See page 197 for Event details.
	▪ On a plot, the horizontal location matches the ÷xø coordinate of the click
	    ▪ In Chart mode, the event will be placed on the channel track where the click took place.
	    ▪ In Scope mode, the event will be defined on the active channel.
	▪ Within the event bar, clicks define global events.
	When Event Definition is active, the cursor changes to a flag and the cursor includes a downward pointing arrow to indicate where the event will be defined.
	The Event Definition tool is disabled in X/Y mode and if events are not visible.

Event Removal ‰Zap+ 🌸	Deletes event(s) from a graph with the mouse. It allows for quick editing to eliminate misclassified events found through visual inspection. ▪ If the user clicks on a single event, that event will be removed from the graph. ▪ If the user clicks and drags to define a rectangular area (similar to the zoom tool), all events between the left and right edges of the area will be removed; the event icon does not need to lie vertically within the bounded area in order to be removed. When Event Removal is active, the cursor changes to a lightning bolt.
Jump-to ➡	Data views and advanced analysis output display multiple representations of the same data at the same time. Sometimes this association may be abstract or difficult to visualize. The Jump-to tool is a green arrow, and is available in all display modes and during acquisitions. Use the õJump-toö tool to correlate data. • Click the Jump tool on a data point to õjumpöall of the open data views for that graph to the same time. • Click the Jump tool on a point in an X/Y plot to jump data views in chart or scope mode to the point in time corresponding to the point in the X/Y plot. This can be useful for correlating PV loops back to other acquired signals. • Rate analysis output graphs will jump back to the corresponding point of source data at the start of that cycle. • Clustering scatterplots will select the appropriate segment of the source graph corresponding to the chosen data point.

	• Change the active segment in Stacked Plot mode; once a trace is selected the display will adjust to show the new active segment.

Text Annotation
 A
	Use Text Annotation to add floating text notes on top of data in a graph; the text notes move and scale with the data. During report or figure preparation, it is nice to be able to add additional textual information on top of signals to help clarify signals for readers or draw their attention to particular areas of visual interest. BSL *PRO* provides a text annotation facility to assist in figure preparation.
	
	 Click the *A* icon and then click in the graph window to generate the Text Annotation Contents dialog. Drag the red õhandlesö from the annotated text to add connector lines to connect the text to the data.
	
	 Text Annotation Contents
	 Text Annotation Contents
	 Text: [ ]
	 Font: MS Shell Dlg 2 ▼
	 Size: 12 points
	 Style: ☐ Bold
	        ☐ Italic
	        ☐ Underline
	            OK Cancel

Text Annotation A *continued*	ECG T Wave RR ■ foo foo foo ■ Connector handles ■ foo foo foo ■ Add a range ■←----- foo foo foo -----→ ■ Resize a range foo foo foo Move a connector
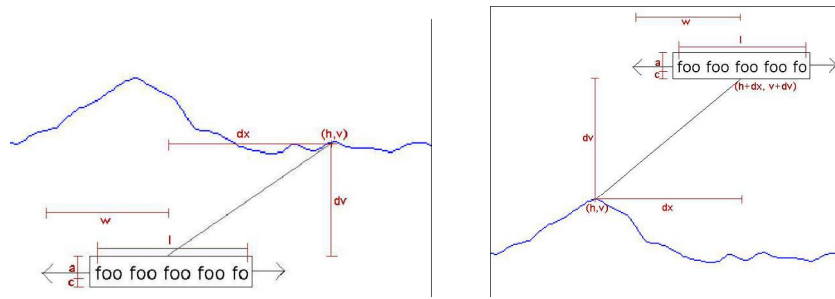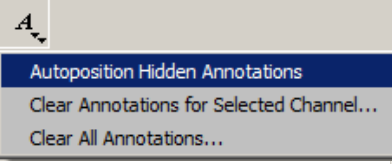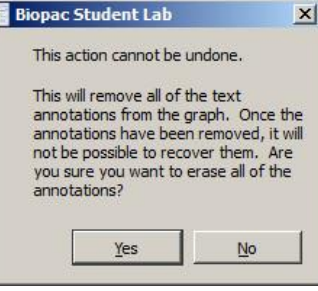
Text annotations are short pieces of text that float above channel data and can be used to draw visual attention to particular areas of interest in a graph. These text annotations can be simple outlined text, can have a connector from the outline boundary to a specific sample point on the waveform, or have a range indicator of a specific width. Each text annotation is tied to a sample of data in a channel; when the data is moved by coping, pasting, or other waveform editing operations, text annotations remain fixed to their corresponding sample positions, similar to channel events.

Although text annotations are tied to horizontal locations like events/markers, they are displayed in a relative fashion. The relative pixel distance between the text annotation outline boundary and the sample of data remains the same under zoom and autoscaling operations.

- For example, an annotation that is 20 pixels above a T-Wave peak position will continue to be drawn 20 pixels above regardless of zoom. This allows for flexible data viewing while maintaining text annotation visibility.

Text annotation controls

Create	Insert using the text annotation cursor tool. With the tool active, click in the graph to define a new annotation.
Select	Click an annotation once to select it.
Reposition	Drag a selected annotation to reposition it.
Add Connector	Connectors or range indicators can be added to selected annotations by using the editing handles on the edges of the selected annotation.
Edit Connector	If the selected annotation has a connector to a data point of the graph, an editing handle will appear on the end of the connector. The connector can be moved to a different data sample of the graph by dragging the editing handle on the end of the connector to the new position in the channel. To remove the connector, grab the editing handle on the end of the connector and drag the mouse inside the text annotation.
Range Indicator	If the selected annotation has a range indicator, editing handles will appear at both ends of the range indicator. To resize the range indicator, grab an editing handle and move the mouse. To remove the range indicator, grab an editing handle and move the mouse back inside the text annotation.
Autoposition	Resizing windows or adding channels may reposition text annotations outside of the visible area. Click and hold down the text annotation tool to activate the text annotation popup menu. The õAutoposition Hidden Annotationsö option automatically repositions all annotations so they are visible.

	Clear all	Click and hold down the text annotation tool to activate the text annotation popup menu. The õClear all annotationsö option will clear all annotations. Since this action cannot be undoe, a prompt will appear confirming the selection.

Selection palette
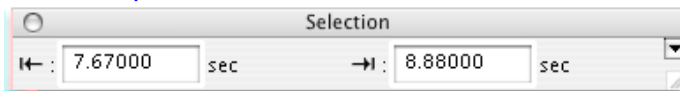
Many of the tools within the BSL *PRO* environment are based around the selection. The selected range of data in the graph is used as the source for measurements, waveform editing, transformations, and other operations. The Selection Palette is a floating dialog that can be used to precisely enter the selection. See page 323 for Selection Palette guidelines.

Start/Stop toolbar
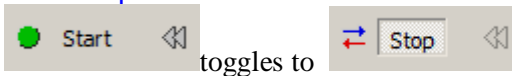
toggles to

Channel Number toolbar

Toggles the display of channel number and label region. The Channel Number toolbar reverts to the default location when a file is opened (position is not retained).
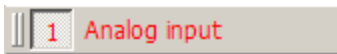
Events toolbar

Select a event to enable the toolbar. Use the arrows to move forward or backward through all event marker types. Click the event palette icon to generate the event palette.

Focus Area toolbar

Use the Focus Area feature to isolate portions of data that are of particular interest within a graph. Focus Areas can be defined, added, labeled and deleted within any portion of the graph. For more details on creating and using Focus Areas, see page 44.

Measurements toolbar
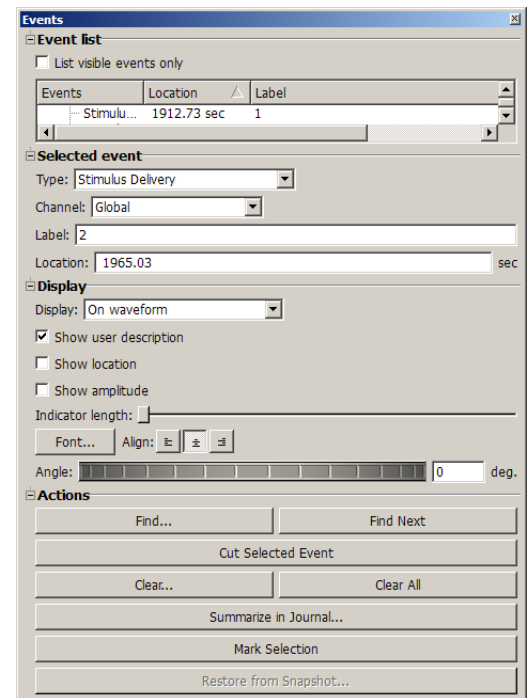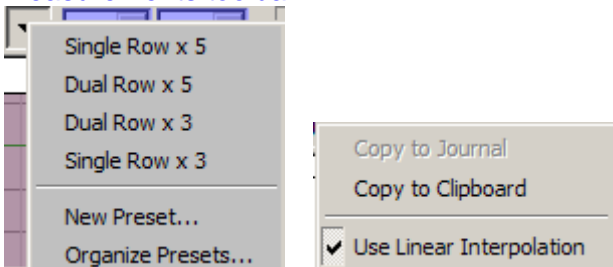
Click the down arrow for quick access to measurement preset functions, including pre-loaded options for organizing measurement rows and columns. Or create and save custom measurement display presets by choosing New Preset, entering a name for the preset, and clicking OK.

Right-click in the measurement bar for quick access to options for copying measurement and using linear interpolation. The Measurements toolbar reverts to the default location when a file is opened (position is not retained).

Custom toolbars for transformations and analysis

BSL *PRO* and above allows users to construct new toolbars for triggering transformations and analysis. An arbitrary number of toolbars may be created and populated with buttons that can trigger any menu item in the Transform and Analysis menus. The contents of the text-only buttons match the menu item title. These toolbars will persist for each user and their positions and visibility within the graph window will be retained.

Transformation toolbars may be accessed via the "Customize Toolbars" button next to the rewind button.
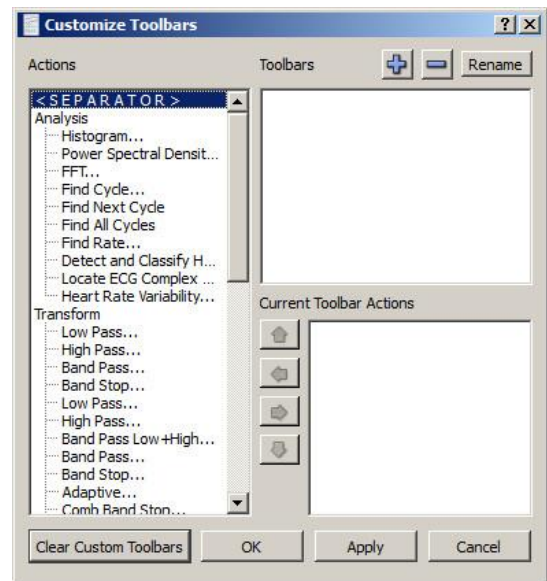
Toolbar position retention and changes

Toolbars can be rearranged within the graph window or detached and turned into floating tool windows. Any modifications made by the user to the position of most toolbars within the graph window will be stored as an application preference and used for new graph windows as they are created and graph files that are opened from disk; however, toolbars for Measurements, Channel number, and Hardware will revert to the default location when a file is opened (position is not retained). Default toolbar positions have changed to move the Start button and cursor tools to the top of the graph window; users preferring the ordering in previous versions may manually reposition the toolbars. **Toolbar Tooltips** may be deactivated when toolbars are detached from a graph.
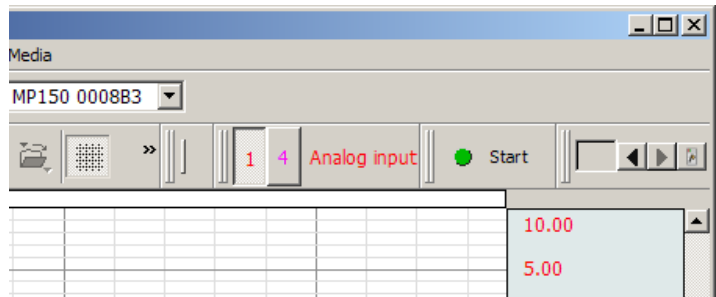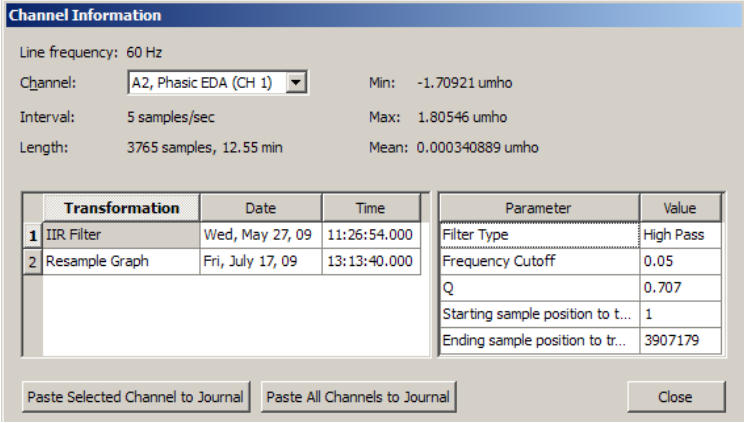
Axis Controls
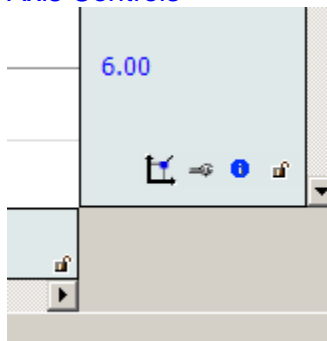
If axis controls interfere with scale values,

adjust the opacity slider in Preferences > Graph

to hide the icons until the cursor passes over them
.

A õscalingö button acts as a shortcut for opening the grid and visible range dialog, similar to double-clicking the axis. If a channel corresponds to an analog channel that has calibration steps, a calibration wrench button be displayed and will open the hardware calibration dialogs. This allows visual access to commonly used operations for channels.

	Module dependent: Generate the scaling or calibration dialogs for the channel input or calculation. Analog inputs will open to the scaling dialog and channels that require calibration will initiate a repeat calibration routine.
	Channel Information Line frequency: 60 Hz Channel: A2, Phasic EDA (CH 1) Min: -1.70921 umho Interval: 5 samples/sec Max: 1.80546 umho Length: 3765 samples, 12.55 min Mean: 0.000340889 umho <table><tr><th></th><th>Transformation</th><th>Date</th><th>Time</th><th>Parameter</th><th>Value</th></tr><tr><td>1</td><td>IIR Filter</td><td>Wed, May 27, 09</td><td>11:26:54.000</td><td>Filter Type</td><td>High Pass</td></tr><tr><td>2</td><td>Resample Graph</td><td>Fri, July 17, 09</td><td>13:13:40.000</td><td>Frequency Cutoff</td><td>0.05</td></tr><tr><td></td><td></td><td></td><td></td><td>Q</td><td>0.707</td></tr><tr><td></td><td></td><td></td><td></td><td>Starting sample position to t...</td><td>1</td></tr><tr><td></td><td></td><td></td><td></td><td>Ending sample position to tr...</td><td>3907179</td></tr></table> Paste Selected Channel to Journal Paste All Channels to Journal Close Use Display > Channel Info or use the channel's contextual menu to display the Channel Information.
	Toggle the lock icon at the right edge of the window to change the lock state of the grid for horizontal axis or the channel. Unlocked is open (latch to right); locked is closed.

Enable cursor tools during acquisitions

Enables access to cursor tools while recordings are in progress. (Display > Preferences > Graph)

Button Transparency

Scaling, calibration, transformation history, and grid lock buttons may be made semi-transparent to allow units, axis values, and other information underneath the buttons to remain visible. The Preferences > Graph panel includes an õAxis controlsö slider to change drawing from fully transparent to fully opaque.

When the mouse is within the buttons, they will be drawn fully opaque regardless of transparency setting. The transparency is shared by the scaling, calibration, transformation history, and grid lock buttons and is the same for all open graphs as this is an application-level preference.

Customizable Chart Track Dividers

Users may change the color used to draw the dividers between channels tracks The Preferences > Graph panel contains "Chart Track Divider Appearance" options.

Plotting Background Colors

Customizable background colors for individual graph channels are available in Preferences > Graph > Plotting Background Colors.

Spectrum Analyzer Palette
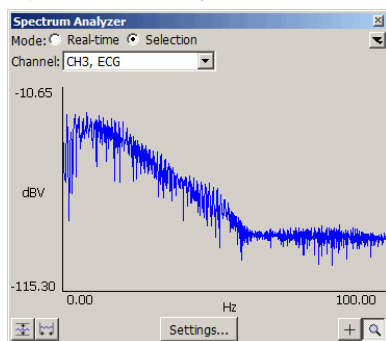
The Spectrum Analyzer Palette provides a dynamic display of the frequency decomposition of data, in real time or post-acquisition.

See page 326 for details.

Keyboard shortcuts

Menu Option	Windows OS	Mac OS
Program info	Help > About Biopac Student Lab	Help > About Biopac Student Lab
Start/Stop Acquisition	Ctrl + Spacebar	⌘ + Spacebar
File menu		
New	Ctrl + N	⌘ + N
Open	Ctrl + O	⌘ + O
Open Recent	Ctrl + 1, Ctrl + 2, etc.	⌘ + 1, ⌘ + 2, etc.
Close	Ctrl + W	⌘ + W
Save	Ctrl + S	⌘ + S
Print	Ctrl + P	⌘ + P
Quit	Ctrl + Q	⌘ + Q
Edit menu		
Undo (when applicable)	Ctrl + Z	⌘ + Z
Cut	Ctrl + X	⌘ + X
Copy	Ctrl + C	⌘ + C
Paste	Ctrl + V	⌘ + V
Clear Last Segment	Use Rewind toolbar button	Use Rewind toolbar button
Clear All Segments	Ctrl + Rewind toolbar button	⌘ + Rewind toolbar button
Duplicate Waveform	Ctrl + D	⌘ + D
Select All	Ctrl + A	⌘ + A

Clipboard
  > Copy Measurements
  > Copy Wave Data
 > Copy Acquisition Settings
	Ctrl + K
	Ctrl + L
	Ctrl + U
		⌘ + K
		⌘ + L
		⌘ + U

Journal
  > Paste Measurements
  > Paste Wave Data
   > Paste Acquisition Settings
	Ctrl + M
	Ctrl + /
	Ctrl + J
		⌘ + M
		⌘ + /
		⌘ + J

Transform Menu		
Recently Used	Ctrl + Shift + 1, Ctrl + Shift + 2, etc.	⌘ + Shift + 1, ⌘ + Shift + 2, etc.
Analysis menu		
Recently Used	Ctrl + Alt + 1, Ctrl + Alt + 2, etc.	⌘ + Alt + 1, ⌘ + Alt + 2, etc.
Find Cycle	Ctrl + F	⌘ + F
Find Next Cycle	Ctrl + E	⌘ + E
Find All Cycles	Ctrl + R	⌘ + R
Display menu		
Autoscale Single Waveform Autoscale Waveforms	Ctrl + Shift + Y Ctrl + Y	⌘ Shift + Y ⌘ + Y

Menu Option	Windows OS	Mac OS
Autoscale Horizontal	Ctrl + H	⌘ + H
Zoom Back Zoom Forward Show > Selection Palette	Ctrl + - (minus key) Ctrl + = (equal key) Ctrl + Shift + = (equal key)	⌘ + - (minus key) ⌘ + + (plus key) ⌘ + Shift + = (equal key)
Cursor Style > Arrow > Selection > Zoom	Ctrl + B Ctrl + I Ctrl + G	⌘ + B ⌘ + I ⌘ + G
MP36/MP35/MP45 menu		
Autoplotting	Ctrl + T	⌘ + T
Exit Playback Mode for all graphs	Ctrl + Exit Playback Mode	⌘ + Exit Playback Mode
Window menu Select Next Tab Select Previous Tab	Ctrl + Tab Ctrl + Shift + Tab	⌘ + Tab ⌘ + Shift + Tab
Horizontal Scroll Location	In chart, scope, or stacked plot mode (i.e., all but X/Y) these keyboard shortcuts can be used to scroll to various parts of the graph.	--
Home	Jumps to t = 0 (i.e., places first sample of data flush with left of graph window)	--
End	Jumps to the end of the currently selected waveform (i.e., places last sample of data of the selected waveform flush with right of graph window)	--
Page Up	Scrolls backward in time one full screen (i.e., places leftmost sample of previous visible area at the right of the new visible area).	
Page Down	Scrolls forward in time one full screen (i.e., places rightmost sample of previous visible area at the left of the new visible area).	
Analog Channel Shortcuts Force Recalibrations	Shift + Rewind button	Shift + Rewind button

Mouse Controls

Contextual menu items correspond to the BSL *PRO* main menu state.

Application menu customization has a corresponding effect on contextual menu display. If a contextual menu item does not have a corresponding application menu item, the menu customization file identifier will begin with õIDM_CM.ö

The following options can be accessed with a right-click for Windows or Control-click for Mac.

- *Mac OS only*: If the mouse is over a portion of the graph that has a context menu available, the cursor will change to an arrow with a menu.

Graph window

Transform	▶
Analysis	▶
Duplicate Waveform	
Select All	
Zoom Back	
Zoom Forward	
Split View	
Autoscale Single Waveform	
Autoscale Waveforms	
Show All Data	
Optimize Ranges	
Channels	▶
Wave Color	▶
✔ Line Plot	
Step Plot	
Dot Plot	
Line Thickness	▶
Last Dot Only	
✔ Grid	
Adjust Grid Spacing…	
Grid Options…	
Grid Preset	▶
Create Focus Area…	
Assign Current Event Type	▶
Event Palette	
Channel Info…	

Journal window

Undo	Ctrl+Z
Redo	Ctrl+Y
Cut	Ctrl+X
Copy	Ctrl+C
Paste	Ctrl+V
Clear	
Select All	Ctrl+A
✔ Word Wrap	
Manage PDFs…	

Horizontal Scroll

| Scroll here |
| Left edge |
| Right edge |
| Page left |
| Page right |
| Scroll left |
| Scroll right |

Vertical Scroll

| Scroll here |
| Top |
| Bottom |
| Page up |
| Page down |
| Scroll up |
| Scroll down |

Measurements

| Copy to Journal |
| Copy to Clipboard |
| ✔ Use Linear Interpolation |

Events

| Insert New Event |
| Paste Event Summary to Journal |

Mouse Scrollwheel Support

The scrollwheel operates on whatever window is underneath the mouse; this window does not need to be the topmost window. Many third-party mice include scrollwheels, scrolling balls, or trackpads to allow for quick access to navigating through a document. Mice may provide two separate controls, one for scrolling vertically and one for scrolling horizontally.

BSL *PRO* supports horizontal and vertical scrolling using the scrollwheels on the mouse. Scrolling is supported in graph windows, journal windows, the event list in the event palette, and a number of other dialogs and windows that contain scrollable lists. A dynamic zoom operation can easily be performed in an BSL *PRO* graph channel by holding down the Ctrl key (PC) or the Option key (Mac). Scroll ÷upø to zoom in and ÷downø to zoom out. (Zoom operation supported in BSL *PRO* and higher)

Mac OS: To increase the scroll speed, hold down the õOptionö key while using the scrollwheel.

Transformation history

Transformation history functionality provides the ability to track transformations that are performed on channel data. This gives a visual indicator of whether transformations have been applied to a channel and a record of the sequence of transformations and the parameters for the transformation. The history for the channel is viewed in the "Channel Info..." dialog. This dialog is accessible via the Channel Info option of the context menu or the Display > Channel Info menu item. This dialog replaces the "Statistics" dialog used in earlier versions.

Cancelling Transformations & Transformation Progress Bar

In BSL 4 and higher, transformation cancel support was restored to the software to offer Cancel buttons in progress dialogs that indicate the completion status of threaded transformations. Progress dialogs have also been enhanced so the textual message includes a graphical progress bar with the percentage that is completed. If the progress message does not contain a percentage, an indeterminate progress bar will be displayed.

BSL 4 and higher extends the analysis package to display dialogs while analysis routines are in progress. This progress dialog contains a cancel button which may be used to terminate the analysis before it is complete.

The event tool allows events to be inserted on a graph with the mouse. When performing event editing, three new context menu shortcuts have been added to help make the process quicker:
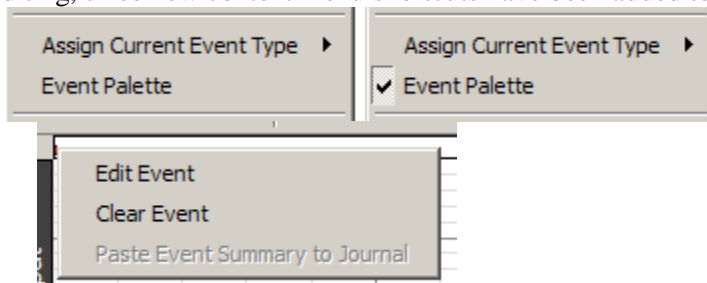
- Assign Current Event Type: Right-click an area with no data to set the type of event that will be inserted on the next left-click of the mouse.

- Event Palette: Toggles event palette displays.

- Edit event: Right-click a specific event to open the event palette to Selected Event controls for the event that was right-clicked.

Typed event label drawing improvements

The Event system has been enhanced to allow different drawing options for channel-specific events when they are drawn in the data plotting area. These drawing options are applied to event labels, event amplitude markings, and event time location text. The following drawing options may be customized:

- Font (including family, size, italic/bold, and other options)

- Rotation angle of text baseline

- Text alignment (left, center, right)
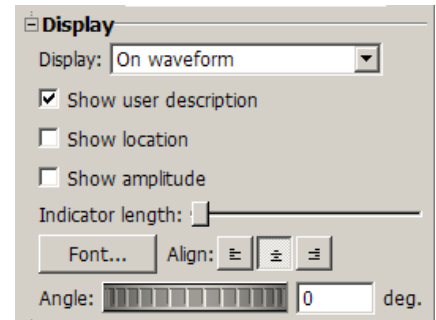
Channel label and units length and tooltips

Character length limitations for channel label and units have been expanded: labels may now be up to 1032 characters and units may be up to 511 characters. Tooltips have been added to display the full channel units when the vertical axis is moused over. Tool tips do not wrap, so long labels may extend beyond the visible viewing area of the computer monitor.
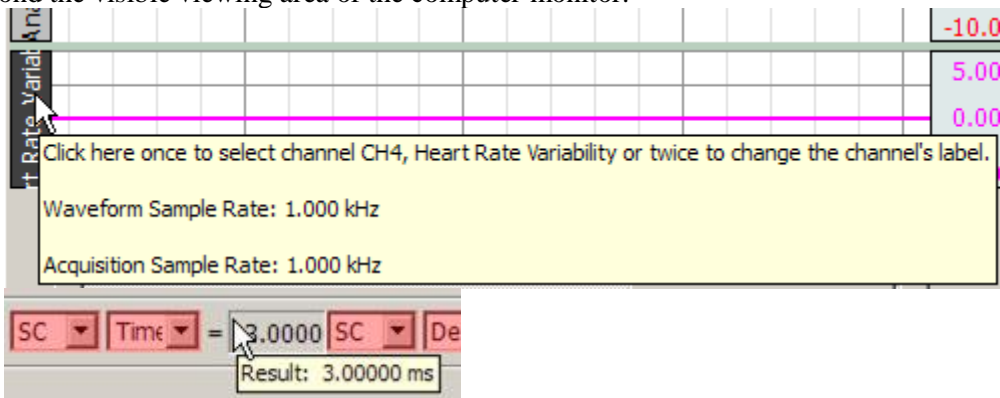
Graph window tooltip improvements

Several of the toolbar buttons and the Start/Stop button in the graph window are associated with keyboard shortcuts that may be used instead of the buttons. Tooltips for these toolbar buttons display the corresponding keyboard shortcuts. **Toolbar Tooltips** may be deactivated when toolbars are detached from a graph.
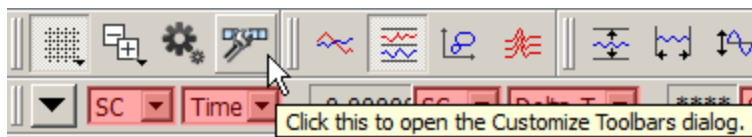
Menu item tooltips

Starting with BSL *PRO*, menu item tooltips will display informational text about how menu items may be used. (Similar text was displayed in earlier versions of BSL *PRO* for Windows in the status area and in earlier versions of BSL *PRO* for Mac as Balloon Help). Analysis menu tooltips have been expanded to provide more detail regarding the types of analysis that are performed by the selected item.

Chapter 4   Editing and Analysis Features

Overview

This section provides a brief overview of some of the most frequently used BSL *PRO* features and functions. For more detailed information about specific features, turn to Chapters 9 through 13.

In the Startup Wizard, select õOpen a graph fileö and õSample data file.ö Then from the *PRO* option, select the õ4Channel.acqö file. The screen should look like this: (**NOTE:** Position of toolbars may vary, as these are user-configurable.)
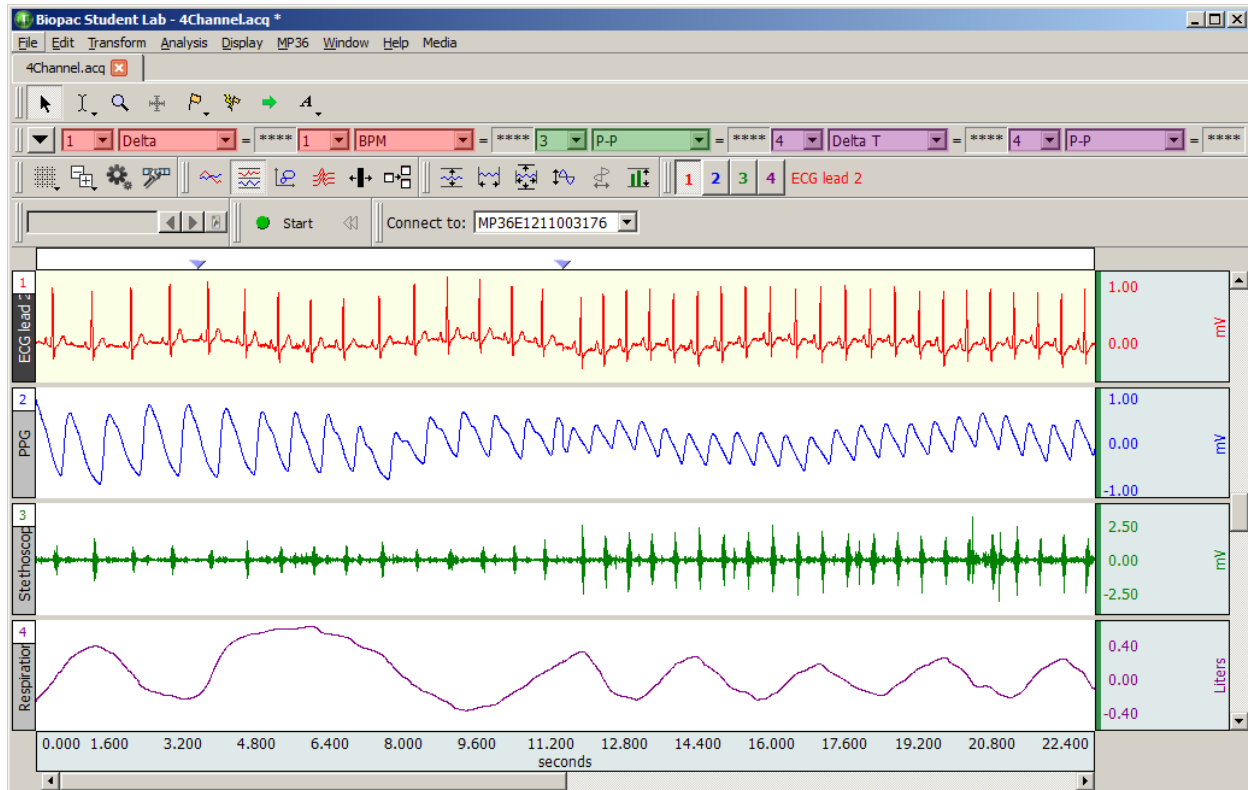
Edit menu functionality during acquisition

The following Edit menu functions may move or alter memory and cannot be performed during acquisition: Undo, Cut, Clear, Clear All, Paste, Insert Waveform, Duplicate waveform, and Remove Waveform.

Scroll bars

Note that here are four channels of data in this file (ECG, PPG, Stethoscope, Resp). Although this record is 23 seconds long, only a few seconds are displayed on the screen at one time. Browse to different locations in the record by dragging the scroll box at the bottom of the screen. Dragging the box left moves to earlier points in time, and moving right displays events closer to the end of the record. Clicking the arrows at either end of the horizontal scroll bar allows movement to different points in time at smaller increments.

A vertical scroll bar is on the right side of the screen, and. Clicking the scroll arrow at the top of the box, note that one waveform appears to move down within its õtrackö on the screen. Moving this scroll box changes the amplitude offset of a selected channel. As with the horizontal scroll bar, either move the box or click the arrows.

Scaling

Horizontal axis

Click the horizontal scale (above the scroll bar) to generate a dialog where values can be entered for units per division and horizontal scale offset.

Set Screen Horizontal Axis

Set Screen Horizontal Axis

Time scale: 2.0000000   seconds/div

Initial time offset: 0.0000000   seconds

Precision: 2 ▼ digits

☑ Hold relative position for Append acquisitions

Global Grid Settings...   Channel Grid Settings...   OK   Cancel
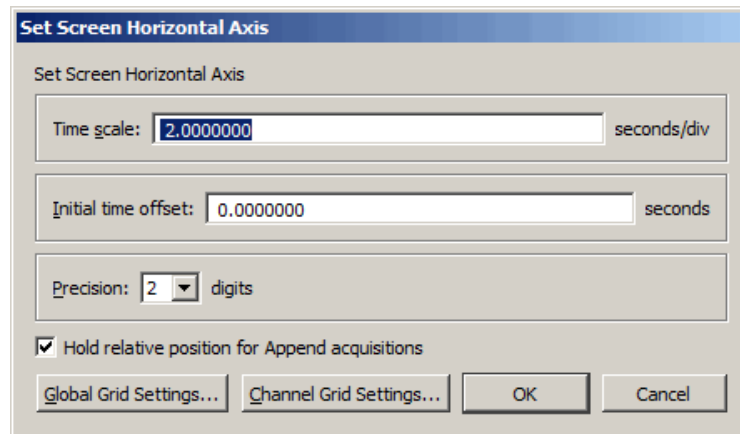
Time Scale

The time interval (units per division) between the on-screen grid marks. There are four vertical divisions per screen, and the default is 2.00 seconds per division, so eight seconds of data will be displayed on the screen display. Entering a larger value will display more of the record, and entering a smaller value will display less.

Initial offset

The time corresponding with the first data point displayed. For example, to display the middle 1/3 of the data file (assuming the record is 30 seconds long), set the offset to 10 seconds and the seconds per division to 2.5 seconds.

Precision

Controls number of decimal places following whole units appearing in the horizontal axis.

Hold Relative Position for Append acquisitions

This option is active in **Append** acquisition mode only. When checked, the display for appended acquisitions will show the same relative position with respect to the start of acquisition. This is convenient when performing short-duration; high-speed acquisitions where a user needs to zoom in on a signal of interest and have the relative position (from the start of acquisition) stay the same.

When zooming in on a section of data within a recording segment, the next appended segment will õholdö its relative horizontal position (start and end times with respect to the start of each segment).

When using the I-beam tool to select a sub-section of the data, this sub-section will hold its relative position and update the measurement values on each subsequent appended segment.

If the selected data area falls within two or more appended segments, this feature is not implemented.

Example of Hold Relative Position feature:

Action Potential setup: 100,000 samples/sec, 50 millisecond recording length, Append mode and stimulator set to output 19 milliseconds after the start of the recording.

After the first recording segment, the zoom tool is used to expand the area of interest (top figure below). The I-beam cursor is used to select a measurement area around the nerve response. The õP-Pö measurement shows the nerve response amplitude. After clicking **Start** and recording the next segment, the relative position of both the horizontal time scale and the measurement selected area, with respect to the start of recording is maintained (bottom figure below). This makes it very easy to measure the changes in the amplitude of the nerve response with changes in stimulus level.

Global Grid Settings

Opens dialog for applying master grid settings for all channels. For more details, see Grids on page 73.

Channel Grid Settings

Opens dialog for selectively applying grid settings to one or more channels. For more details, see Grids on page 73.

Vertical (Amplitude) axis

Clicking the mouse in the vertical scale area (where the amplitude of each channel is displayed) generates the Set Screen Vertical Axis dialog, where values can be entered for units per division and vertical scale offset.

Scale

Determines the limits of the viewable vertical axis scale (usually Volts). BSL *PRO* divides each channel into four vertical divisions. When data is displayed in chart mode, each õtrackö is divided into four divisions. When data is displayed in scope mode (or if there is only one channel of data) the entire screen is divided into four intervals. To increase the apparent amplitude for a given channel, set this value to a smaller number; entering a larger number will cause the waveform to appear to have less variability.

Midpoint

Refers to median displayed value for a particular channel. A checkbox to the left of each of these options allows these scaling options to be applied to all channels. By default, the selected scaling options will apply only to the channel indicated in the dialog. To apply to all channels, click all of the checkboxes.

Precision

Controls number of decimal places following whole units appearing in the vertical axis. Can be applied to selected or all channels.

Apply to all channels

Applies settings selected in the various dialog options to all channels.

Range Guide

The Range Guide is a green bar that runs along the vertical scale in the graph window for analog channels (see right).

It displays the maximum signal range for the Gain established for that channel. The Range Guide can be used as a visual aid to establish the proper Gain.

The MP hardware measures the actual input voltage and compensates for the Gain. As Gain increases, the peak-to-peakof a waveform stays constant but the resolution increases.

Proper Gain will have a smoothing effect on the signal.For the best resolution, establish Gain such that, allowing for baseline drift (if applicable) and the maximum peak-to-peak of the signal, the maximum signal display is close to the maximum range. If the signal is clipped (Fig. 1), lower the Gain. If the signal is too small compared to the range (Fig. 2), increase the Gain to improve signal resolution. Gain settings create a trade-off between range and resolution.
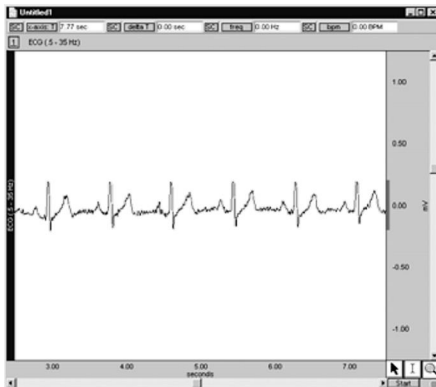
Fig.1: "Clipped" signal   *Fig 2: Signal too small compared to range*
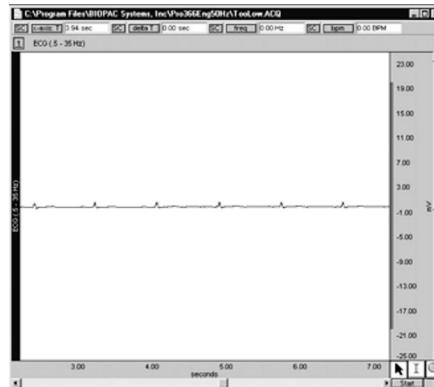
Different gain settings applied to the same signal source show that

Higher Gain **=** better resolution + lower range (Figure 3, top)

Lower Gain **=** worse resolution + higher range (Figure 3, bottom)

To display the full range (Fig. 2 vs. Fig. 3, for example), adjust the Vertical Scale.

The Range Guide will always reflect changes made to the channel Scaling.

To quickly see the total range of each input channel, select **Optimize Ranges** from the Display menu. This will automatically adjust the upper and lower viewable limits of the Vertical Scales for all channels.
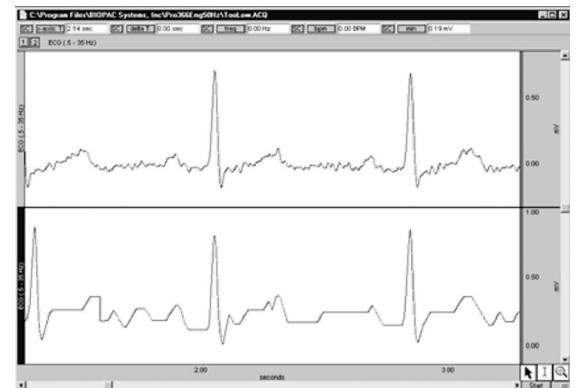
Fig. 3

Adaptive Scaling

Adaptive scaling uses the data to automatically determine the appropriate visible range for the data. As the data changes or the baseline shifts, the visible area shifts along with the data to ensure that data will always be plotted on the screen. Rather than limiting data visibility to a fixed voltage range, the range adjusts for factors such as background noise, electrode movement, EMG interference, disconnection, etc.

Adaptive scaling can be applied to channels individually and can be unique for each Data View. A õsettingsö button is activated when to õUse adaptive scalingö is enabled.
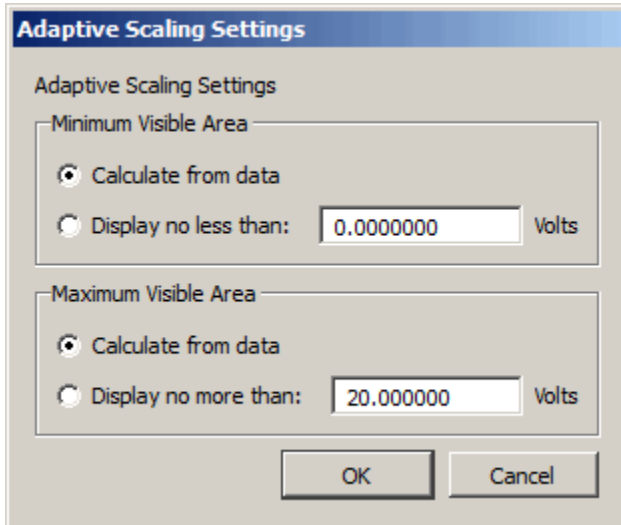
Scaling changes will be applied whenever the domain of the plot area is changed. This includes manual changes to the horizontal scale, horizontal scrollbar use, horizontal auto-scrolling when dragging out a selected area, auto-scrolling or auto-plotting during acquisition, initial enabling of adaptive scaling and auto-scrolling when executing Find Cycle/Peak functions.

Show Textual Value Display

This option enables a real-time display of the most recently acquired values on a channel-by-channel basis, providing amplitude information akin to clinical monitoring displays. This can be useful for obtaining a quick visual numerical summary of incoming data while a recording in progress.
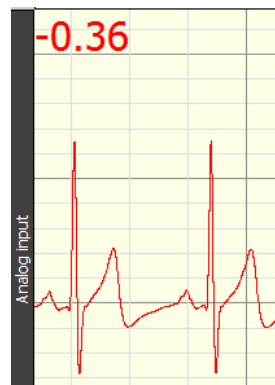
In post-processing, the value display can be seen by performing a õspot measurementö (clicking the arrow cursor on a single data point).
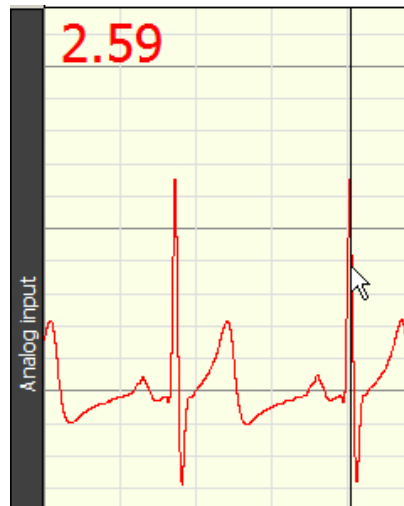
Textual value display in spot measurement mode

Textual value display can be customized for font, color and style, and positioned at the top left, bottom left, top right, or bottom right of any selected channel. These options can be configured independently per channel or applied to all channels.

- In chart and stacked chart modes, the value display will appear for all enabled channels.
- In scope mode, the value display will appear only if the selected channel has the value display option enabled.
- Textual value display is not supported in XY mode.

To enable textual value display:

Click on the vertical axis area to open the setup dialog and enable the õShow textual values displayö checkbox. Use the Settings button to set the font style, size and color.
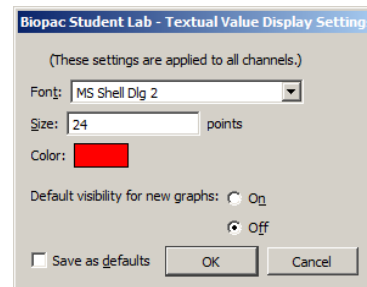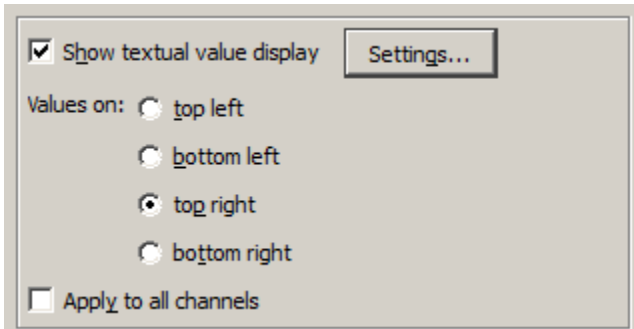
Channel Grid Settings

Opens dialog for selectively applying grid settings to one or more channels. For more information, see Grid Details on page 73.

Grid Details

Grid display can be customized in a number of ways.
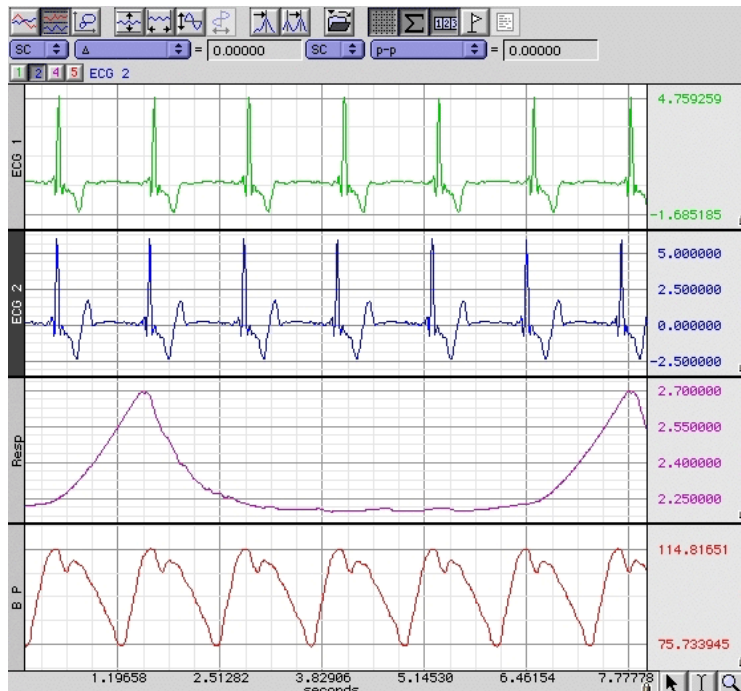
Grid Lock/Unlock

Each scale has a small padlock in the lower right hand corner that displays the current state of the grid lock for that axis and channel. Click the padlock to change the lock state.

- 🔓 Unlocked gridô the number of grid lines and their pixel spacing on screen is kept constant through zoom and scaling operations

- 🔒 Locked gridô the grid lines themselves are maintained at constant values through zoom operations, e.g. a grid line which is located at .753 volts when the grid is locked will continue to be located at .753 volts regardless of changes in scale.
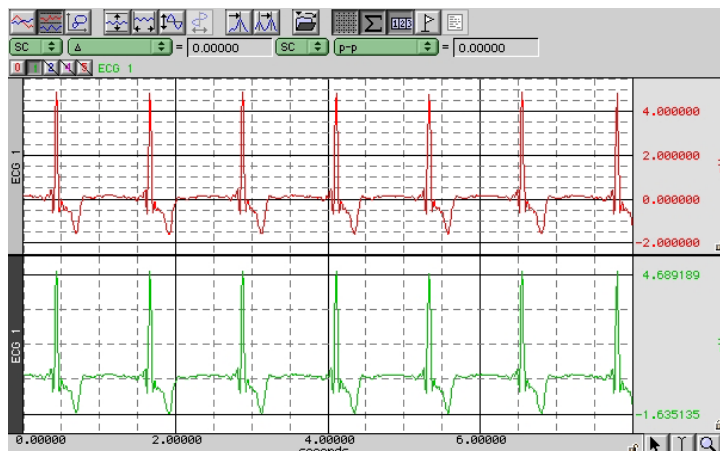
Grids can be locked and unlocked on individual channels.

- The lock for the horizontal axis is shared by all channels.
- The vertical scale can be locked and unlocked independently.

The lock state of the grid can also be changed through the axis dialogs displayed when the mouse is clicked on the axis scale values in the graph window.

- Click the õLock units/divö checkboxes.

  ☑ Lock units/div

NOTE: All grid screenshots are from BSL *PRO*.

Grid Scaling

When the grid is locked, the scaling factors controlling how much data is visible on the screen (the distance between consecutive major lines of the grid and a fixed location for one of the lines of the grid) are specified differently. When the grid is unlocked, these scaling factors do not affect the grid.

 The Grid Spacing option specifies the scaling factors and whether or not to õShow minor divisionsö on the grid display. Changing these values only affects the grid display, not how the waveform is scaled.
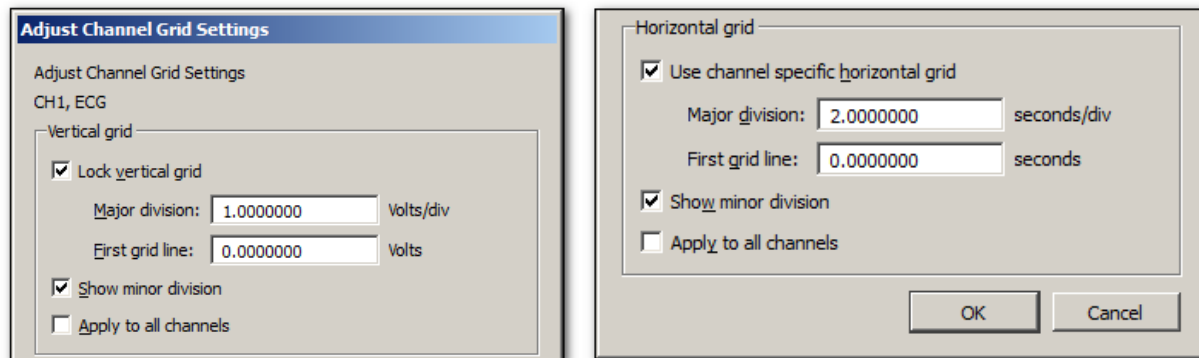
- Vertical grid: the total range of vertical units displayed per track is specified (Major division) along with the first value that should be displayed (First grid line).

- Horizontal grid: the scaling factors are specified in how many seconds of data should be visible on the screen (Major division) and the time offset of the left hand side of the display (First grid line).

- Settings can be applied to a selected channel or all channels. (Controlled by checking or unchecking ÷Apply to all channelsö).

Adjust Grid Spacing

To modify the horizontal and/or vertical grid spacing, choose õDisplay > Adjust grid spacing.ö This will generate the aforementioned dialog for modifying the locked axes of the selected waveform. (õLock vertical gridö and õUse channel specific horizontal gridö must be enabled in order for the gridline fields to become active). Enter the desired values and click OK.

- Settings can be applied to a selected channel or all channels. (Controlled by checking or unchecking ÷Apply to all channelsö).

The following Grid items can also be selected by right clicking with a graph channel and using the contextual menu.

Grid: Toggles Grid display on and off.

Adjust grid spacing: Use to change Grid spacing for one or all channels (divisions between gridlines and position).

Grid Options: Use to change Grid display for one or all channels (Color, width, style, dash length, dash spacing, and scale adjustment position).

Grid Preset: Use to create /save custom Grid presets and organize them in a list. (left)

Example of channel specific horizontal grid
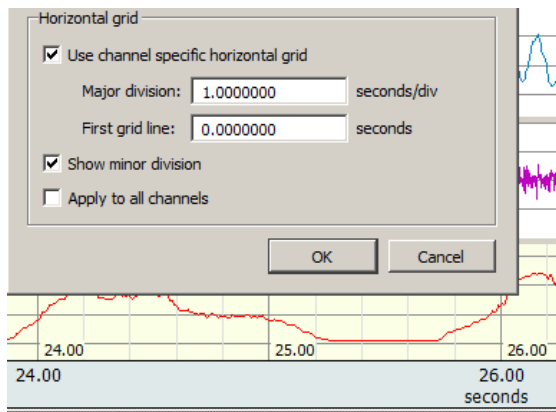
Note in figure on left, the horizontal time scale division is one second per division in the graph channel, but two seconds per division in the horizontal axis. (Green bar area)

Horizontal Axis Grid Controls
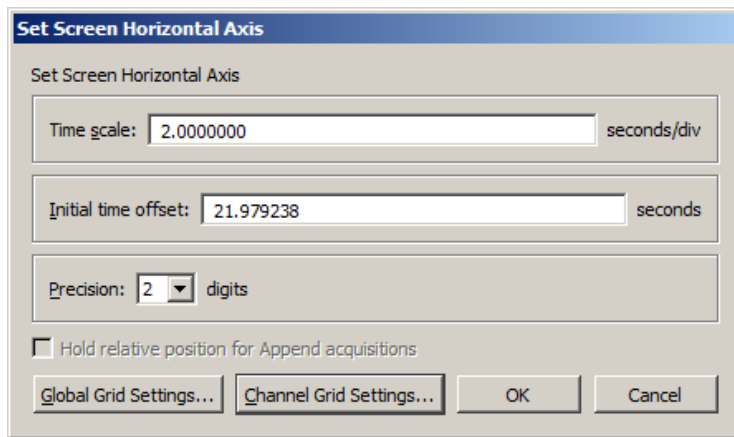
- **Global Grid Settings**: Brings up dialog specifying grid settings used in the shared Horizontal Axis of the graph.
- **Channel Grid Settings**: Brings up the ÷Adjust grid spacing dialogøreferred to on previous page.

Individual channel-specific grid settings take priority over the Global Grid Settings. If no channel-specific grid setting exists, the Global settings are applied.

Grid Tool
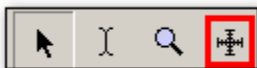
The Grid Tool allows divisions of the grid to be specified with the mouse. This tool has four states:

Ø	Inactive	The cursor changes to a circle with a line running through it. The grid cannot be adjusted since both the horizontal and vertical axes are unlocked.
	Horizontal axis locked	The cursor changes to a horizontal line. A mouse click and drag will change the location of the horizontal lines of the grid.
	Vertical axis locked	The cursor changes to a vertical line. The tool can be used to adjust the vertical spacing of the grid.
	Both axes locked	The cursor changes to a crosshair. The rectangle of a full grid division can be drawn over the data. Adjust the spacing of locked grid lines underneath the waveform.

If the õAltö (PC) or õOptionö key (Mac) is held down for the Grid Tool in any of the active modes, an ellipsis will appear under the cursor. After a mouse click or drag, a Grid Settings dialog will be generated. This dialog is functionally similar to the grid dialogs accessible via the axis settings dialogs.

- Based on lock status, the dialog will allow adjustment of Horizontal, Vertical or combined settings.
- The values displayed in the dialog correspond to the grid ranges that were just drawn out on the screen with the grid tool if a mouse drag occurred.
- If the mouse was simply clicked, the current grid settings are displayed.
- This dialog allows the grid drawn out with the grid tool to be made more precise.

Grid Reset

To return to the original grid, choose õDisplay > Reset grid.ö

This will reconstruct the default, unlocked grid of four divisions per screen with solid light gray grid lines.

Grid Options

The major and minor grid lines can be further customized with spacing, number of divisions, and different colors and dashing styles. These are modified under the dialog generated via Display > Show > Grid options.
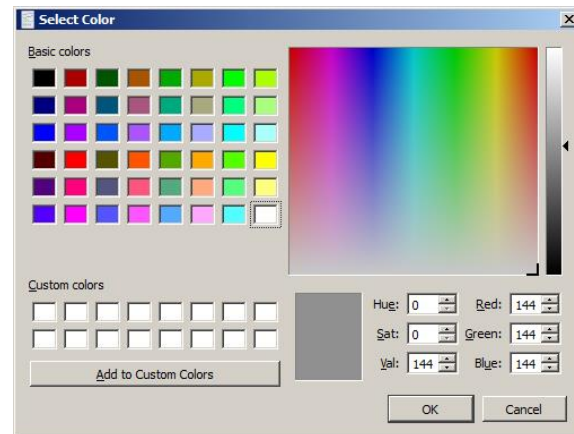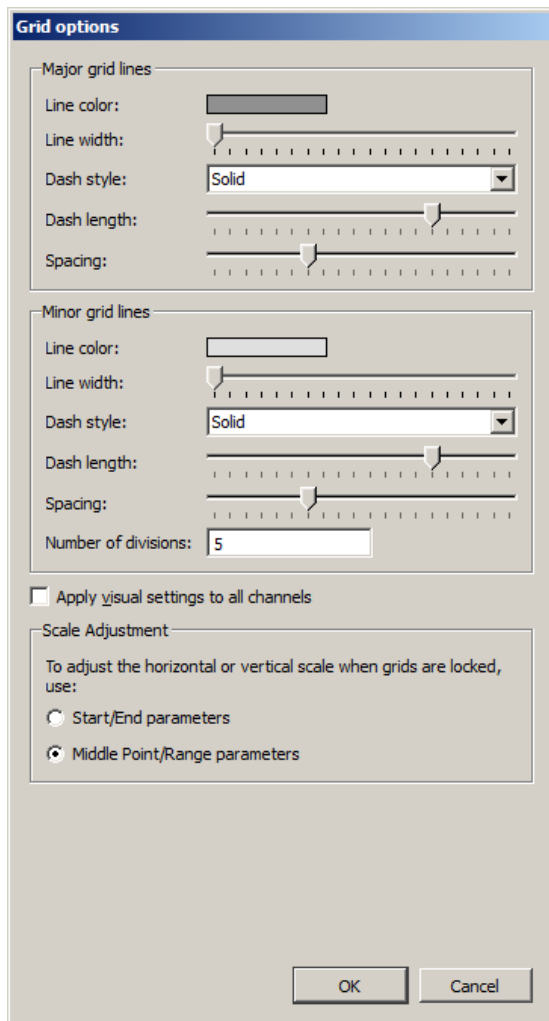
Line color	Click the color well to generate a color chooser.
Line width	Adjust the corresponding slider.
Dash style	Select a style (solid or broken) from the pop-up menu.
Dash length	Adjust the corresponding slider (for any dash mode that is not a solid line).
Spacing	Adjust the corresponding slider (for any dash mode that is not a solid line).
# of Divisions	Enter a value in the text field to set the maximum number of minor grid lines to be displayed in a single major grid division.

Apply visual settings to all channels

When checked, the visual settings for major and minor grid lines are applied to all channels. When unchecked, the settings will be applied to the selected channel only.

Scale Adjustment

Select whether to use Start/End or Range/Midpoint parameters to determine horizontal and vertical scale adjustments. Applied only when grids are locked.

10 sec. Horizontal Scale adjustment set to "Start/End" parameters

10 sec. Horizontal Scale set to "Middle Point/Range" parameters

To undo any selections and return to the original grid, choose "Display > Reset grid." This will reconstruct the default, unlocked grid of four divisions per screen with solid light gray grid lines.

Friendly Grid Scaling

Too much precision can create numbers that are difficult to quickly interpret, so "friendly" grid scaling adjusts the range to the nearest possible whole numbers. For example, it's easier to comprehend 4.1000000 than 4.1427385. Unlocked grids always restrict precision to the minimum needed for a given magnitude. This produces a "friendly" scale that makes it easier to determine the range between the gridlines when data is formatted for display or printing.

With unlocked horizontal grids, the horizontal scale values printed on a graph may not match the horizontal scale values displayed on the application screen. For example, horizontal scale values

Displayed in the application: 0.00000   7.50000   15.00000   22.50000
Printed: 0.00000   7.50125   15.00250   22.50375

The precision will only match when using the "Visible area" print option. With selected area or entire graph options, the precision will not match when grids are unlocked because friendly grid scaling is applied on screen, but is not used during printing where the range is fixed to fill the entire page.

Note that the Zoom tool and vertical autoscale may produce different results. To accommodate the grid precision, the Zoom result may be slightly more than specified in the zoom box. For precise correlation from selected area to result, lock the grids (horizontal and vertical). Precision is not restricted for locked grids or display ranges manually entered in the axis setting dialogs.

Journal Details

To create a journal, choose **File > New > Graph-Specific Journal** or **Independent Journal**, or choose **Display > Show > Journal**. Or after opening a new journal choose **Edit > Journal > Show Journal.** A

Journal may also be opened by using the [toolbar icon] toolbar button and selecting **Journal** from the pop-up menu.

Once a Journal is open, text and data can be entered. To enter text, just begin typing when the journal is open. BSL *PRO* will automatically õwrapö the text to fit the screen width.

In addition to File and Edit menus, there are Time Stamp, Date Stamp and Auto Time functions available in the journal window.
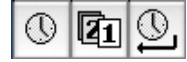
- Time and Date stamps refer to the computerøs clock to record the time and date, respectively, directly into the Journal.
- Auto Time function records the time at the instant the carriage return is pressed, which is useful for tagging commands as data is collected.

Measurements and data may also be pasted into an open Journal. To paste measurements into an open Journal, select an area and choose õ**Paste measurements**ö from the **Edit > Journal** menu. Paste to Journal functions only work if a Journal is open and vary for each journal type:

- Graph-specific journals can only receive measurements and wave data from their associated graph view
- Independent Journals can receive measurements and wave data from any open graph. Results will be put into both the graph-specific journal and the independent journal. Use Journal Preferences to auto-paste to an independent journal if desired.

Set the Journal Preferences (page 335) to simultaneously record measurement name and units or control Event (marker) paste functionality and detail.

To paste waveform data into a Journal, select an area and choose õ**Paste Wave Data**ö from the **Edit > Journal** menu. Allow several seconds for the text file to be written. The result is a text file of wave data pasted into the active journal.

> TIP: When pasting a graph into a Journal: Pressing the Ctrl key (PC) or the Alt key (Mac) will launch a dialog allowing the image to be resized prior to pasting.

A useful feature of the Journal is that it works in connection with the Cycle/Peak Detector and other measurement functions to paste in values from waveform data for further analysis.

In the example above, the *peak-to-peak* and *delta t* measurements were pasted from the open graph window to the Journal. See the Journal paste section on page 247 for more information on how to paste information to Journal files.

Use **Save as/Open Journal Template** to retain SOP text, or standardize lab/computer details for record keeping.

Rich Journals

The BSL *PRO* Journal adds powerful rich text editing tools, offering advanced functionality common to most word processing programs. The following toolbar options are available within the Journal window:

- Font family
- Font style: bold, italic, underline
- Paragraph alignment: left, right, center, justify
- Font color

The following items can be pasted or embedded into the Journal text:

- Images
- Numbered lists
- Bulleted lists
- Tables
- Numerical statistics or expressions
- Hyperlinks
- PDFs

Images must reside within a document in order to be pasted into the Journal. Pasting image files directly from a location such as the Desktop is not currently supported.
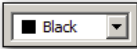
Journal Toolbar Buttons

The Journal toolbar controls all formatting functions within the Journal window. Although the settings customized in this toolbar are retained within a saved Journal, global default settings for subsequent Journals are not overridden. To change the global defaults, the overall Journal Preference settings must be modified. (Edit > Journal > Preferences). For more information, see Journal Preferences on page 335.

A full explanation of all Journal toolbar buttons appears on the following page.

Journal Toolbar Icon	Function	Explanation
	Clear	Clears text from Journal window
	Replace	Replaces Journal text with contents of external text file
	Save	Saves selected or full Journal text to an external text file
	Page Setup	Opens dialog for modifying Journal text print configuration
	Print	Prints the Journal text to the default printer
	Paste Measurement	Pastes selected measurements into the Journal
	Time stamp	Inserts current time into Journal
	Date stamp	Inserts current date into Journal
	Time AND Date	Inserts current time and date into Journal when Enter/Return key is pressed
	Font	Use to select font type and size for Journal session
	Text style	Use to bold, italicize or underline text
	Text alignment	Aligns paragraph text to left, center, right or justified position

■ Black	Font color	Selects color of Journal text
	Numbering	Toggles text numbering on and off
	Bulleting	Toggles text bulleting on and off
	Increase indent	Increases indent in a bulleted or numbered list*
	Decrease indent	Decreases indent in a bulleted or numbered list
	Insert link	Adds hyperlink to Journal
	Table	Inserts a table into the Journal
	Table row	Adds a row to the table **
	Table column	Adds a column to the table
	Delete table row	Removes selected row from the table
	Delete table column	Removes selected column from the table
	Merge cells	Merges selected cells within the table
	Split cells	Splits selected cells within the table
	Dock button	Docks the Journal at the right side of the graph window.
	Side-by-side view button	Splits the Journal window into separate panes for viewing PDF and Journal content side-by-side. Active only when PDFs are embedded.
	Close button	Closes the Journal view.

*Active only when cursor is positioned within a bulleted or numbered list.

**Additional table tools are active only when a table is present.

NOTE: If the BSL *PRO* graph or Journal windows are decreased in size, the Journal toolbar will become truncated and some buttons may no longer be in view. Buttons no longer visible on the toolbar can be found in drop-down menus indicated by arrows. (See below)
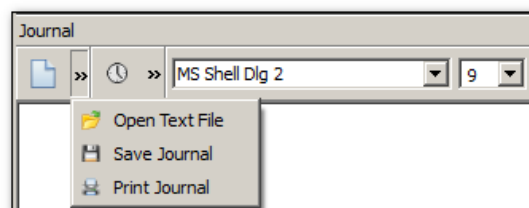
Journal Numerical Table Tools

The Numerical Table Tools function allows easy insertion of measurements and numerical data into a Journal table, which can then be computed and evaluated via basic mathematical operations and expressions. This eliminates the need to export data to a spreadsheet application in order to validate statistics gathered during the course of an experiment.

Numerical Tools operations permitted within a Journal table:

- Insert a single measurement value
- Insert all measurement values
- Insert all measurement values with header row
- Sum, Mean and Standard Deviation statistics for table rows and columns
- Expression evaluation
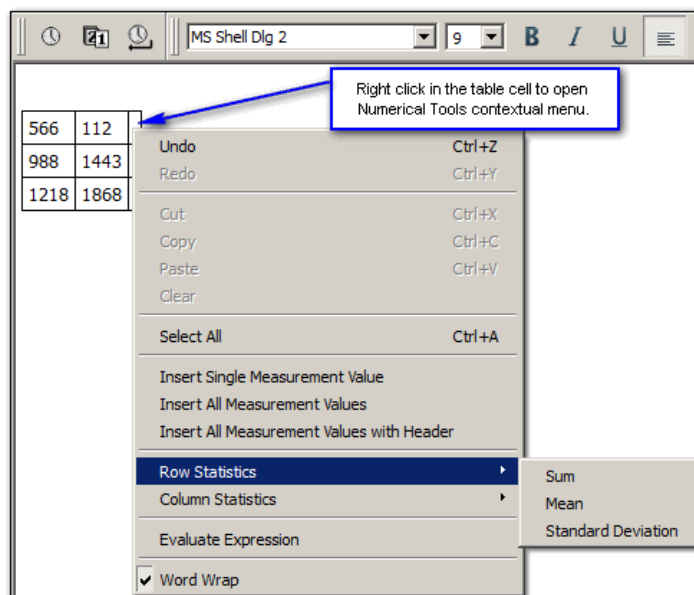
Menu Item	Function
Undo	Removes previous operation
Select All	Selects all cell contents
Insert Single Measurement Value	Pastes single selected measurement value into cell
Insert All Measurement Values	Pastes all measurement values into cells
Row Statistics	Performs Sum, Mean or Standard Deviation operations on row data
Column Statistics	Performs Sum, Mean or Standard Deviation operations on column data
Evaluate Expression	Performs mathematical operations and functions on cell contents
Word Wrap	Wraps text within visible Journal area. (Does not apply to table cells)

Example of Sum, Mean or Standard

Sum, Mean or Standard Deviation operations can be easily performed on table data. Right clicking within a cell opens a contextual menu containing available operations under –Rowø or –Columnø statistics. Choose an operation, and the result will appear in the selected cell. *(See sum example below)*
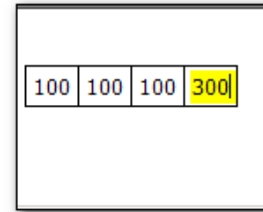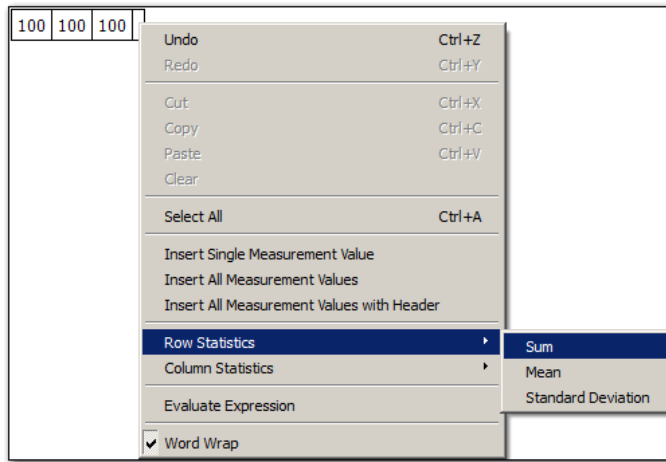
Example of Evaluate Expression:

This feature works very much like Excel[®.] Simply enter the cell identifiers into an empty cell, then right-click and choose ÷Evaluate Expressionö. The formula occupying the cell will be computed and be replaced by the result. The mathematical operations and functions available for standard Biopac Expression syntaxes may be used. (Transform > Expression). Expressions can be created beforehand then copied and pasted into a Numerical Tools Table cell.
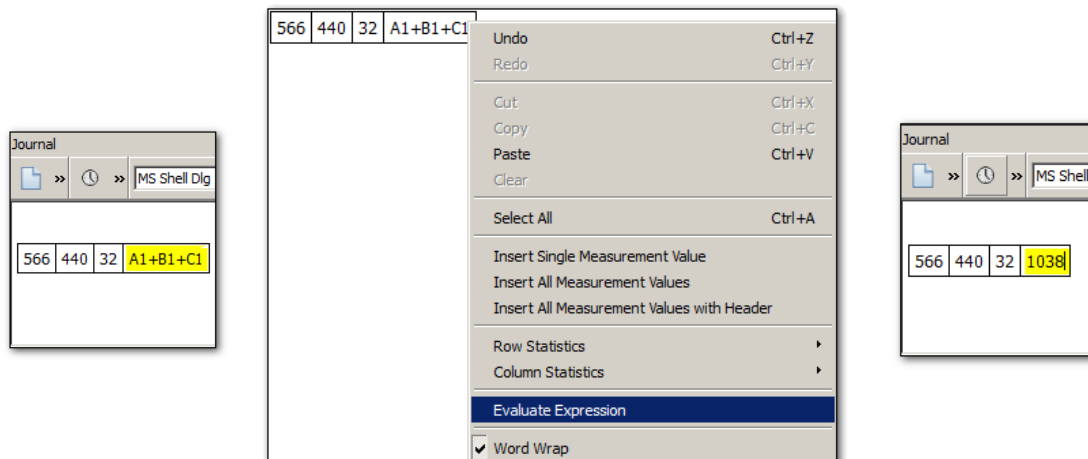
If the expression syntax used is incorrect or invalid, a warning dialog will appear.
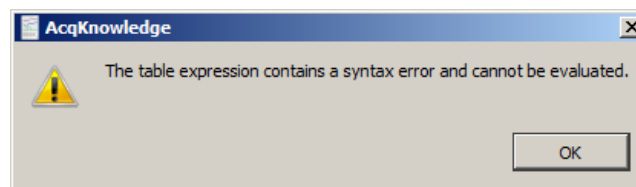
> **TIP**: To correct a mistake, use the Ctrl+Z (PC) or Command+Z (Mac) keystroke to restore the previous cell data. Multiple levels of undo are supported.

Adding a hyperlink to the Journal

Use the Journal hyperlink toolbar button to insert a link to a web address into the Journal. This operation is very similar to adding regular text.

1. Click into the Journal at the desired position for the link to appear.
2. Click on the õInsert linkö toolbar button
3. Add the web address and some text identifying the link into the URL and Text fields.

NOTE: For the link to be active, the **http://** designation must be entered before the web address.
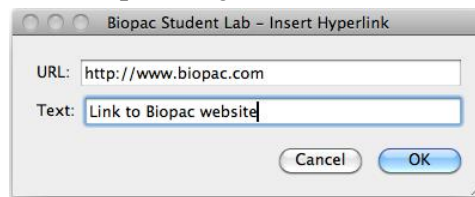
4. Click OK, and the live link will appear in the Journal.
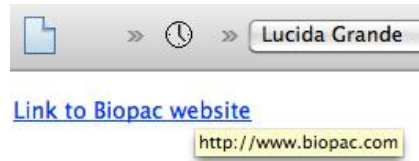
- To format the link text, select the link and use the Journal formatting tools.
- To edit the link text, position the cursor at the end of the link and use the arrow keys to navigate to the desired portion. Backspace to remove unwanted text and type in new text.
- To delete a link, select the text and use the Delete key.
- Once a link has been created, the URL portion cannot be edited from within the Journal, nor can the original õInsert hyperlinkö dialog be recalled. If the URL itself needs to be edited, a new link must be created using the õInsert Linkö button.

Embedding PDFs in Journals

Multiple PDF files can be pasted into a Journal as convenient tabbed windows with all formatting and graphics intact. To do this, simply choose Edit > Journal > Manage PDFs, browse to the location of the desired PDF files and choose õEmbed new.ö

TIP: PDFs may also be embedded in the Journal by right-clicking in the Journal window and choosing õManage PDFsö from the contextual menu.

For more details on managing embedded PDFs, see page 248.

▶ Watch the BIOPAC Journal Tutorial video for a detailed explanation of this feature.

Select a waveform / channel

Although multiple waveforms can be displayed, only one waveform at a time is considered õactive.ö Most software functions only apply to the active waveform, which is also referred to as the õselectedö channel. Selecting a channel allows highlighting of all or part of the waveform, and enables transformations to be performed on a given channel.

In the upper left corner of the graph window there is a series of numbered boxes that represent each channel of data. The numbers in the boxes correspond to the channel used to acquire the data (the specifics of setting up channels are discussed on page 101. In the sample file, ECG channels are represented by CH1 and PPG on CH2.
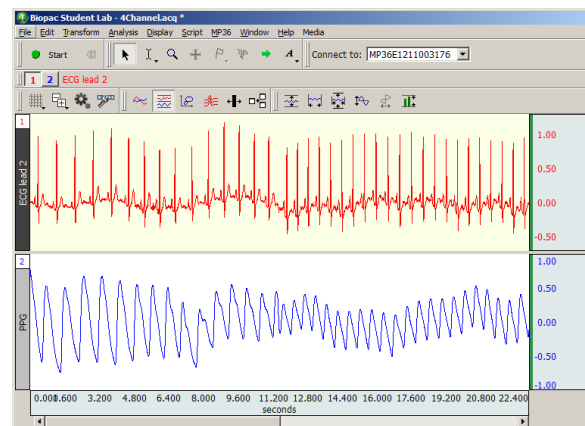
To select a channel, position the ▶ cursor over the channel box that corresponds to the desired channel and click the mouse button or position the ▶ cursor on the waveform of interest and click the mouse button.

Note that the selected channel box appears depressed and the channel label to the right of the channel boxes changes to correspond to the selected channel.

Additionally, the channel label in the display (on the left edge of the track) will be highlighted for the active channel.
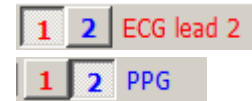
Channel Labels

Each channel has a label on the left and right edge of the graph window.

The left label is used to identify the contents of each channel (ECG, PPG, etc.).

The right label is used to denote the units for each channel's amplitude scale (usually scaled in terms of volts or millivolts).
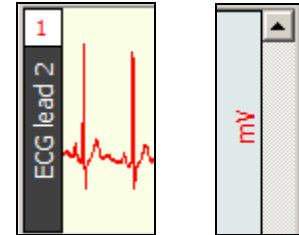
When a channel is active, its label is highlighted and also appears by the channel boxes.

To change the label for a given channel

- ▪ during or before acquisition
  (including Append mode)
  revise the MP menu > Set Up Channels label text

- ▪ post-acquisition / analysis only
  click the left label enter the desired text in the dialog
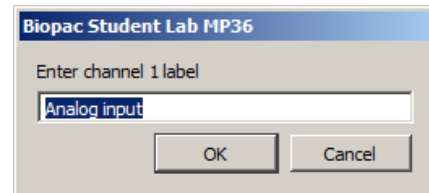
BSL *PRO* Channel label

Show/Hide Channel

A waveform display can be hidden without changing the data file. To hide a channel,

Windows: Alt+click in channel box.

Mac OS: Option+click in channel box.

When a channel is hidden, the channel box will have a slash through it. A hidden channel can be viewed by holding down the Alt or Option key and clicking the channel box again. Channels 2, 3, and 4 are hidden in the right example.

Measurements

None
Value
✓ Delta
P-P
Max
Min
Mean
Stddev
Integral
Area
Slope
Lin_reg
Median
Time
Delta T
Freq
BPM
Samples
Delta S
Median T
Max T
Min T
Calculate...
Correlate
Skew
Kurtosis
Moment...
Expression...
Evt_count...
Evt_loc...
Evt_ampl...
Sum
Rate_mean
Rate_median
Rate_stddev
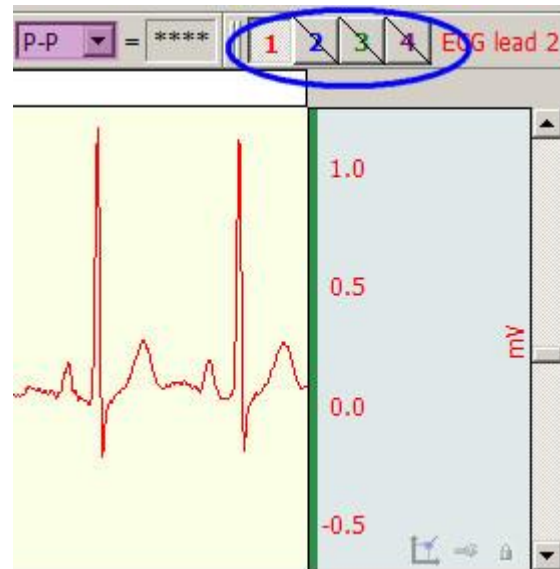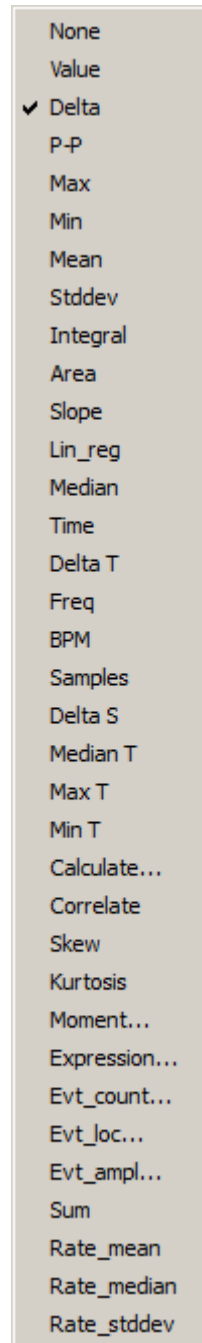
A convenient feature in BSL *PRO* is the popup measurement windows, with a wide variety of different measurements available for each channel . By default, BSL *PRO* displays measurements from the selected channel (as denoted by the õSCö in the measurement boxes).

To select a channel for measurement, position the cursor over the part of the measurement window that reads õSC.ö Click the mouse button and choose a channel number from the pull-down menu. The channel numbers in the pull-down menu correspond to the numbers in the channel boxes in the upper left corner of the graph window.

To select a measurement, position the cursor on a measurement box and click the mouse button. Choose a measurement from the pull-down menu; see page 89 for measurement functions and the minimum samples for each (some of the values are single point measurements while others require at least two points to be selected).

The measurements in the upper half of the menu reflect amplitude measurements, or measurements which contain information about the vertical (amplitude) scale. Other measurements use information taken from the horizontal axis (usually) and are found on the section of the pull-down menu below the dividing line. Some of the measurement options change (or are disabled) if units are selected for the horizontal scale.
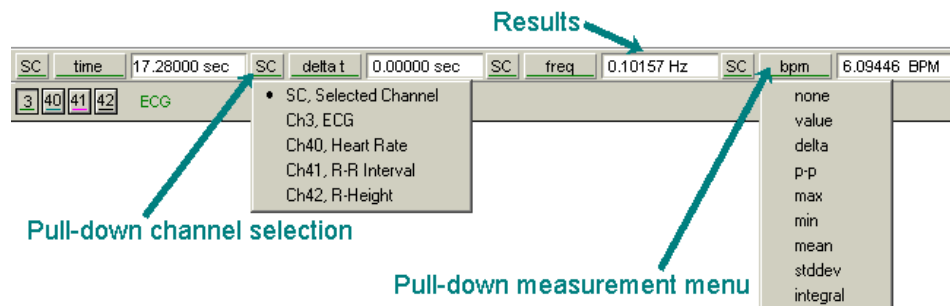
In some cases, the computations involved in the measurement can produce nonsensical results (such as dividing by zero, or calculating a BPM from a single point). In those cases, a measurement value like INF or **** may appear. This means the result was undefined at the point the measurement was taken.

Measurement menus are tinted to match the color of the corresponding waveform.
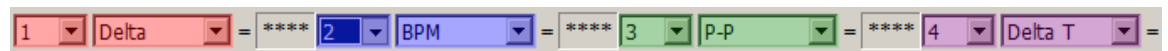
Measurement Display
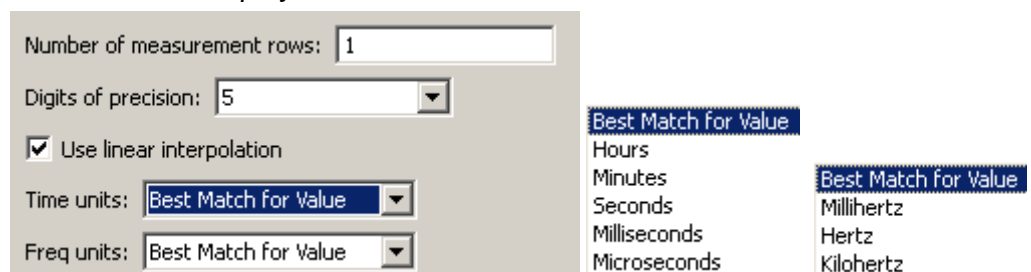
The number of measurement rows is set in Preferences > Measurements, as well as the precision and units.

Measurement Area

It is important to remember that BSL *PRO* is always selecting either a single point or an area spanning multiple sample points. If an area is defined and a single point measurement (such as *Time*) is selected, the measurement will reflect the last selected point.

▪ **Single-point measurements**

When a single point is selected, the cursor will õblink.ö The graph below shows how the I-beam is used to select a single point for measurements.
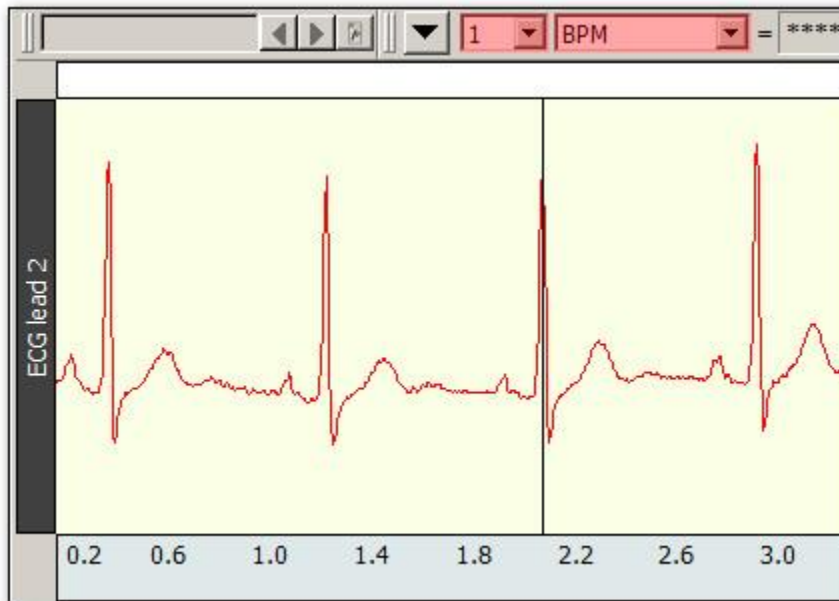
▪ **Selected range measurements**

Drag the I-beam cursor to select an area; the selected area will be highlighted.
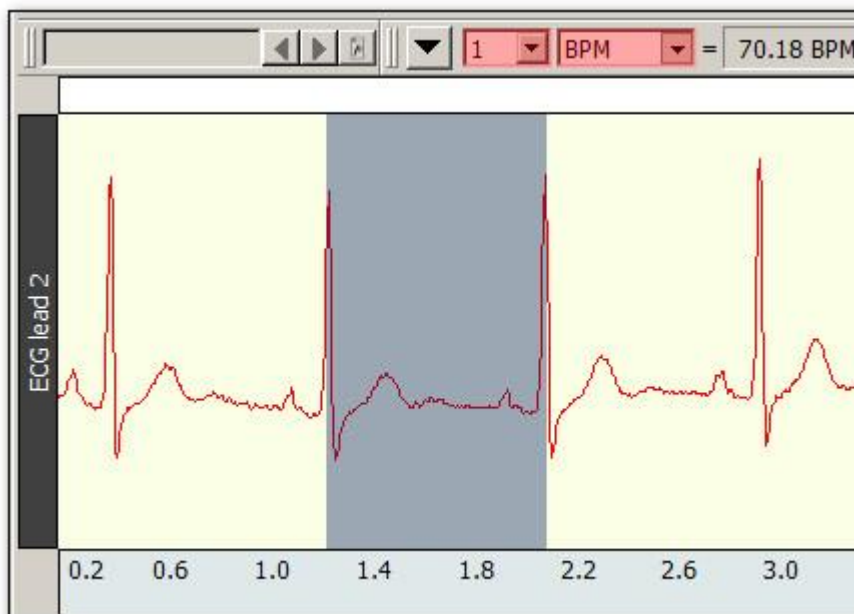
IMPORTANT!

The first data point is õplottedö at zero (on the left edge of the graph); the first visible data point is sample point 2. The selected areas below demonstrate this concept.
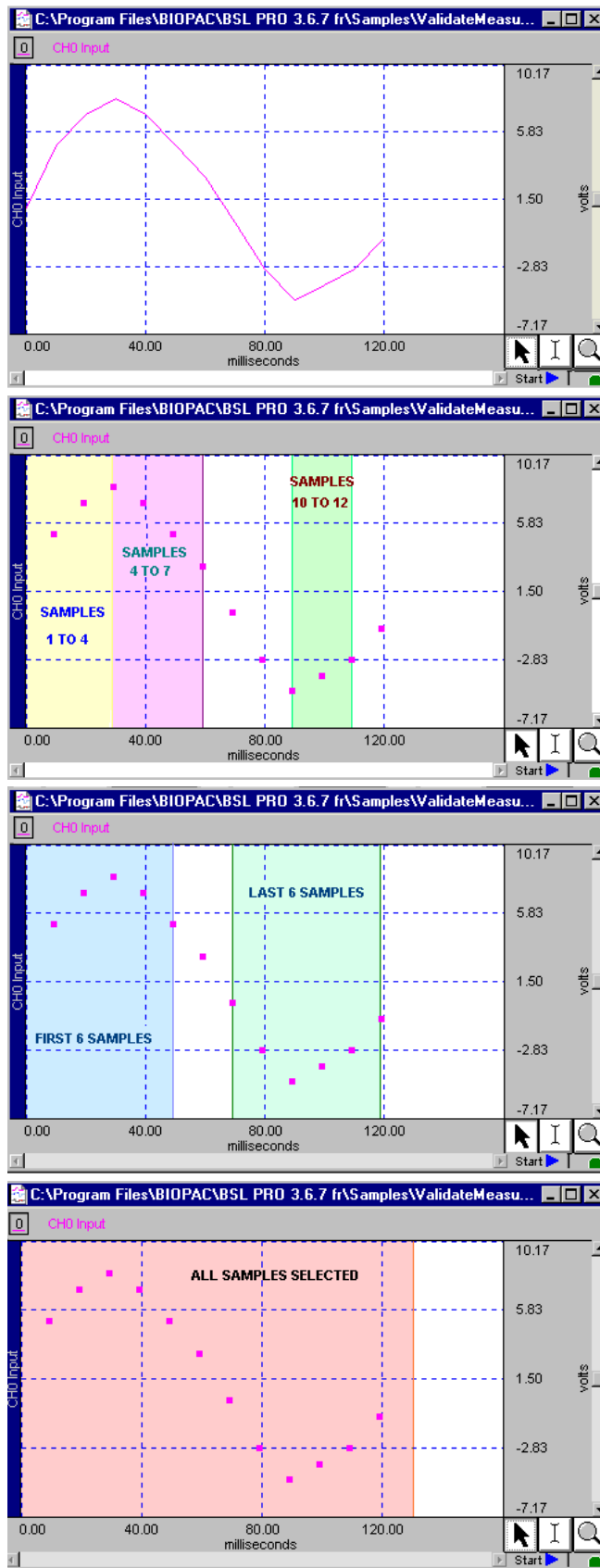
Measurements and Measurement Presets

Measurements are commonly used in conjunction with the cycle detector and other analysis protocols to perform data reduction. In complex data analysis using the cycle detector, often multiple different sets of measurements may be used to perform multiple extraction passes on the data. The measurement presets feature allows users to create multiple predefined measurement configurations and apply them to the graph to change between different configurations. All aspects of the measurement configuration are stored, including measurement functions, any parameters for the measurement, source channel, and number of measurement rows. For more details on this function see Measurements Toolbar section on page 58.

IMPORTANT: Calculations performed within expressions or measurement channels **DO NOT** incorporate units such as milli, micro, centi, deci, etc. All calculations are performed with numbers as they are exhibited within the text field. Time/frequency axis measurements may have their units fixed by using Preferences > Measurements > Time Units/Freq Units. Selecting õBest Match for Valueö will change the units based upon the magnitude of the value.

Measurement Validation

Validate measurements with the ValidateMeasurements.acq sample file included with the software. Pay attention to the õ*Sample data file*ö section of the measurement definitions that begin on page 89, and where included, note which sample points to use for validation (i.e., the first four sample points are used to validate the Correlate measurement using the ValidateMeasurements.acq file).

Measurement Info / Parameters

[SC ▲▼] [Calculate... ▲▼] ❶ = [166.66667] Measurements that have parameters have an õiö for info button next to the measurement type in the measurement bar. Click the button to generate a dialog to edit the parameters. To paste parameters, enable the Journal Preference via Display > Preferences > Journal > Measurement paste settings > Include measurement parameters.

Measurement Interpolation

On a down-sampled channel, the cursor can fall on a point between physical samples. In such cases, in the Line Plot mode only, some measurements will display interpolated values; the value is obtained by linear interpolation with respect to the two adjoining samples.

- To disable measurement interpolation, uncheck the õUse linear interpolationö option in the Display > Preferences dialog.

- If interpolation is disabled for Line Plot, or any time Step Plot or Dot Plot is selected, measurements take on the value of the first physical sample immediately to the left of the cursor or edge of the selection.

- When measurements are pasted to the Journal, there is no indication of interpolated measurements.

- A Calculation measurement can be an interpolated value. When a measurement uses an interpolated value, the result box background changes from gray to light purple.

- The õDelta Sö and õSamplesö measurements are never interpolated.

- Measurements will not be interpolated if all measurements are set to õSCö (selected channel); the cursor will snap to the left for the measurements.

- Measurement tooltips will reflect measurement interpolation.

Exporting Measurements

One of the most important reasons to take measurements is to save them; BSL *PRO* allows these measurements to be stored and exported in different formats.

- Copying measurements to the Journal:
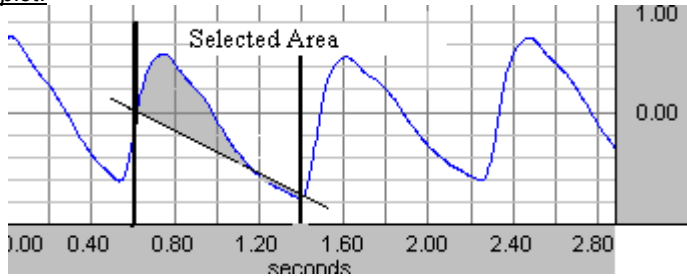
   To copy measurements (exactly as they appear in the measurement windows) and paste them to the Journal, select Edit > Journal > Paste measurement, or Paste measurement Journal toolbar button. Under the default settings, only the values themselves are copied to the Journal; the settings can be modified to include the measurement name and other options under Display > Preferences > Journal.
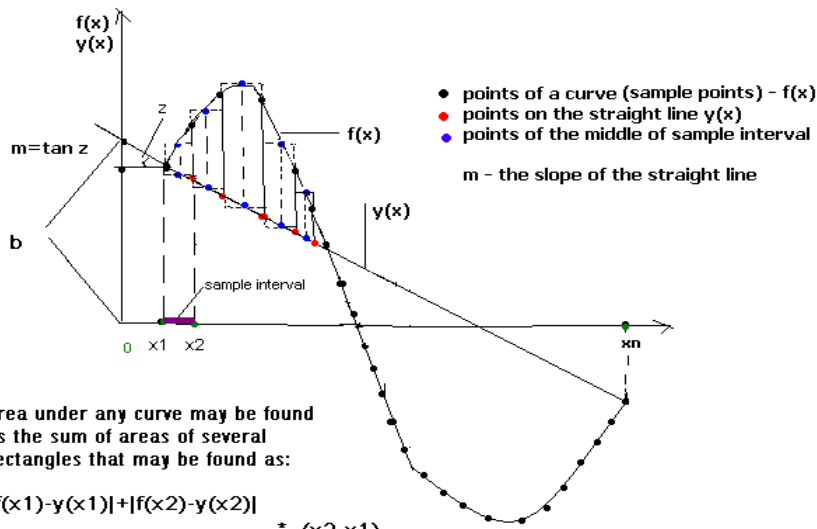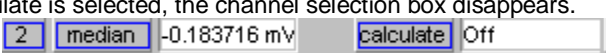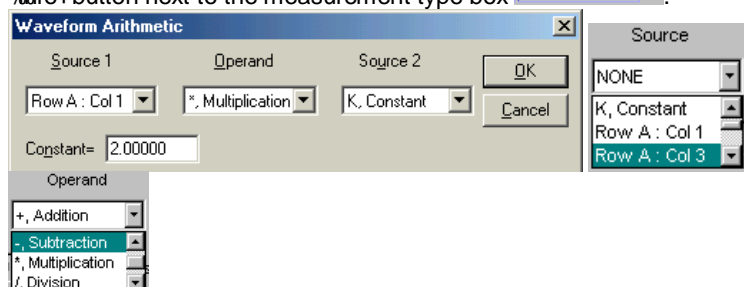
- ▪ Copying measurements to the Clipboard:

    To copy measurements (exactly as they appear in the measurement windows) to the clipboard and paste them into a word processor or other application, select Edit > Clipboard > Copy measurements. Under the default settings, only the values themselves are copied to the clipboard; the settings can be modified to include the measurement name and other options via Display > Preferences > Journal.

Measurement Definitions
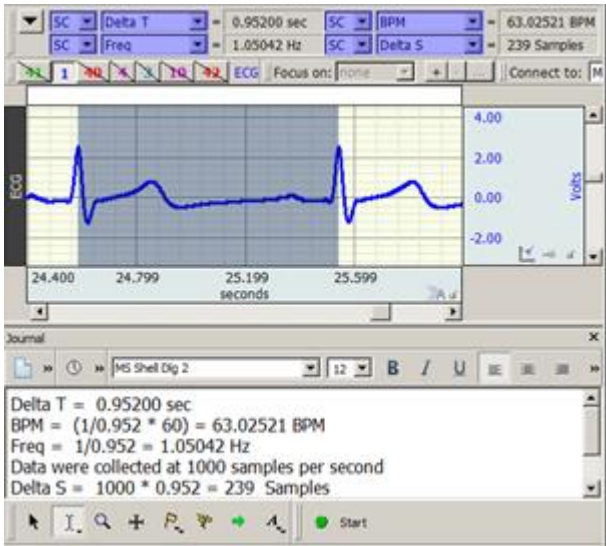
The table below explains the measurement options available and the range required for each. The default option is for time to be displayed on the horizontal axis, although it can be set to display frequency or arbitrary units (see page 321 for details on how to change the horizontal scaling options). Unless otherwise noted, all of the measurements described here relate to those displayed when the horizontal scale reflects time.
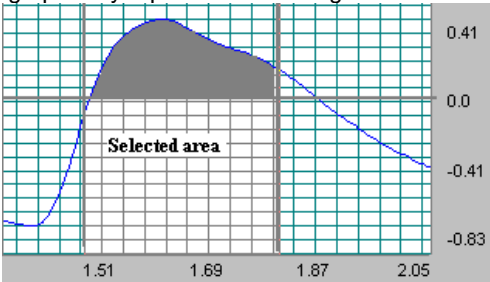
Measurement	Area	Explanation
Area	Minimum area: 3 samples Uses: All points of selected area	Area computes the total area among the waveform and the straight line that is drawn between the endpoints. Area is expressed in terms of (amplitude units multiplied by horizontal units) and calculated using the formula: $$Area = \sum_{i=1}^{n-1} \left(\left\| f(x_i) - y(x_i) \right\| + \left\| f(x_{i+1}) - y(x_{i+1}) \right\| \right) * \frac{\Delta x_i}{2}$$ *Where:* *n—number of samples;* *i—index (i = 1.n-1);* x_i, x_{i+1} *- values of two neighboring points at horizontal axis (* x_1 *– the first point,* x_n *– the last point);* $f(x_i)$, $f(x_{i+1})$ *- values of two neighboring points of a curve (vertical axis);* $y(x_i)$, $y(x_{i+1})$ *- values of two neighboring points of a straight line (vertical axis).* *At the endpoints y(* x_1 *)= f(* x_1 *) and y(* x_n *)= f(* x_n *).* $\Delta x_i = \dfrac{\Delta X}{n-1}$ *- horizontal sample interval;* *The value of a straight line can be found by formula:* $$y(x_i) = m * x_i + b$$ $b = f(x_1) - m * x_1$ *- intercept;* $m = \dfrac{\Delta Y}{\Delta X}$ *- slope of the straight line;* $\Delta Y = f(x_n) - f(x_1)$ *- vertical distance of increase at vertical axis;* $\Delta X = x_n - x_1$ *- Horizontal distance of increase at horizontal axis.* *Sample plot:* The area of the shaded portion is the result. *Note:* The Area measurement is similar to the *Integral* measurement except that a straight line is used (instead of zero) as the baseline for integration.

Measurement	Area	Explanation
		  Area under any curve may be found as the sum of areas of several rectangles that may be found as: $$\frac{|f(x1)-y(x1)|+|f(x2)-y(x2)|}{2} * (x2-x1)$$ *Results:* This calculation will always return a positive result. *Units: Volts - sec.* *Sample data file:* *"ValidateMeasurements.ACQ"* *Result: 0.4533 Volts - sec.*
BPM (Time domain only)	Minimum area: 2 samples Uses: Endpoints of selected area	BPM (beats per minute) computes the time difference between the first and last points and extrapolates BPM by computing the reciprocal of this difference, getting the absolute value of it and multiplying by 60 (60 sec). The formula for calculation of BPM is: $$BPM = \left(\frac{1}{|x_n - x_1|}\right) * 60$$ *Where:* x_1, x_n - *values of the horizontal axis at the endpoints of selected area.* *Note:* As mentioned, this measurement provides essentially the same information as the *Delta T* and *Freq* measurement. *Results:* Only a positive value. *Units: BPM.*
Calculate	Minimum area: 2 sources Uses: Results of measurements used in calculation	Calculate can be used to perform a calculation using the other measurement results. For example, the mean pressure can be divided by the mean flow. When Calculate is selected, the channel selection box disappears. The result box will read "Off" until a calculation is performed, and then it will display the result of the calculation. As the selected area is changed, the calculation will update automatically. To perform a calculation, generate the "Waveform Arithmetic" dialog via Ctrl-Click or right mouse click the Calculate measurement type box or click the "Info" button next to the measurement type box.

Measurement	Area	Explanation
		Use the pull-down menus to select Sources and Operand. Measurements are listed by their position in the measurement display grid (i.e., the top left measurement is Row A: Col 1). Only active, available channels appear in the Source menu. Calculation measurement Source operands are updated before a Calculation is performed, which means that Calculations can be based on measurements that are located after them in the measurement row/column ordering. Calculation measurements can include other Calculation measurements as their operands. • If a cyclic dependency is introduced, the result reads "Error." • When interpolation is being used, a Calculation measurement can also be an interpolated value. • If either of the operands of a Calculation is interpolated, the result will be displayed as an interpolated value (with a light purple background). The Operand pull-down menu includes: Addition, Subtraction, Multiplication, Division, Exponential. The Constant entry box is activated when "Source: K, constant" is selected and is used to define the constant value to be used in the calculation. To add units to the calculation result, select the Units entry box and define the unit's abbreviation. Click OK to see the calculation result in the calculation measurement box.
Correlate	Minimum area: 2 samples Uses: All points of selected area	Correlate provides the *Pearson* product moment correlation coefficient, r, over the selected area and reflects the extent of a linear relationship between two data sets: x_i - values of horizontal axis and $f(x_i)$ - values of a curve (vertical axis). Use Correlate to determine whether two ranges of data move together. <u>*Association*</u> <u>*Correlation*</u> Large values with large values Positive correlation Small values with large values Negative correlation Unrelated Correlation near zero The formula for the correlation coefficient is: $$\text{Correlate} = \frac{n*\sum_{i=1}^{n}(x_i * f(x_i)) - \left(\sum_{i=1}^{n}x_i\right)*\left(\sum_{i=1}^{n}f(x_i)\right)}{\sqrt{\left[n*\sum_{i=1}^{n}(x_i)^2 - \left(\sum_{i=1}^{n}x_i\right)^2\right]*\left[n*\sum_{i=1}^{n}(f(x_i))^2 - \left(\sum_{i=1}^{n}f(x_i)\right)^2\right]}}$$ <u>*Where:*</u> *n—number of samples;* *i—index (i = 1..n);* x_i · *values of points at horizontal axis (x_1 – the first point, x_n – the last point);* $f(x_i)$ *- values of points of a curve (vertical axis).* <u>*Results:*</u> Returns a dimensionless index that ranges from -1.0 to 1.0 inclusive. <u>*Units:*</u> *None* <u>*Sample data file:*</u> *"ValidateMeasurements.ACQ"* *Result: -0.74825(for whole wave) and 0.95917 (for first four sample points).*
Delta	Minimum area: 2 samples Uses: Endpoints of selected area	Delta returns the difference between the amplitude values at the endpoints of the selected area. $$\text{Delta} = f(x_n) - f(x_1)$$ <u>*Where:*</u> $f(x_1), f(x_n)$ *—values of a curve at the endpoints of selected area.* <u>*Results:*</u> If the data value at the starting location is greater than the data value at the ending location of the cursor, then a negative delta will result. Otherwise, a positive delta will result. <u>*Units:*</u> *Volts* <u>*Sample data file:*</u> *"ValidateMeasurements.ACQ"*

Measurement	Area	Explanation
		Result: -2 Volts (for whole wave). This result shows the absolute value of change of amplitude (2) and the minus sign means a decrease of amplitude.
Delta S	Minimum area: 1 sample Uses: Endpoints of selected area	Delta S returns the difference in sample points between the end and beginning of the selected area. *Results:* This calculation will always return a positive result. *Units: Samples*

Delta T(time)
Delta F (frequency)
Delta X (arbitrary unit)
	Minimum area: 2 samples
	
	Uses: Endpoints of selected area
		The Delta T/F/X measurement shows the relative distance in horizontal units between the endpoints of the selected area. *Only one of these three units* will be displayed in the pop-up menu at a given time, as determined by the horizontal scale settings.
		<table><tr><td>*Measurement*</td><td>*Horizontal Axis*</td></tr><tr><td>Delta T</td><td>Time</td></tr><tr><td>Delta F</td><td>Frequency (FFT)</td></tr><tr><td>Delta X</td><td>Arbitrary units (Histogram Bins)</td></tr></table>The formula for Delta T/F/X is:
		
		$$\text{Delta T} = x_n - x_1$$
		Where:
		x_1, x_n - *values of horizontal axis at the endpoints of selected area.*
		Results:
		If the data value at the starting location is greater than the data value at the ending location of the cursor, then a negative delta will result. Otherwise, a positive delta will result.
		   For Delta T measurements with the horizontal axis format set to HH:MM:SS.
		
		  ✓ Values less than 60 seconds will result in a value in decimal seconds.
		
		  ✓ Values greater than 60 seconds will result an HH:MM:SS format value
		  (See page 67 for details on how to change the horizontal scaling).
		Units:
		  Delta T: *Seconds (sec.)* Delta X: *"arbitrary unit"*
		  Delta F: *Hz*
		Sample data file: *"ValidateMeasurements.ACQ"*
		                    Result: 0.12 sec. (for whole wave).

Evt_ampl		Extracts the value of the measurement channel at the times where events are defined. The measurement result is unitless. Specify Type, Location, and Extract; see page 202 for details. 1. The amplitude is always taken from the measurement channel, which may be different from the channel on which events are defined. Evt_amp can be useful for extracting information such as the average T wave height within the selected interval.
Evt_count		Evaluates the number of events within the selected area. The measurement result is unitless. Specify Type and Location; see page 203 for details.
Evt_loc		Extracts information about the times of events. The measurement result uses the units of the horizontal axis. Specify Type, Location, and Extract; see page 203 for details.
Expression		Generates the Expression transformation dialog (page 135) and offers Source %MC+Measurement Channel instead of %SC+Selected Channel to build recursive formulas, i.e. result of the expression as it was evaluated x samples ago. Data within the selected area is not changed. Evaluation rules: When a new selection is made, the first step in evaluation searches through the measurement expression for any MMT() invocations. Any measurement whose value is needed by MMT () is computed at this time prior to the expression evaluation. This behavior is similar to calculation channels and successfully allows measurements to the right and bottom of the expression measurement to be used in the expression. The expression is subsequently evaluated from the leftmost sample in the selection to the right most sample. It is evaluated at the waveform sampling rate of its source channel. Interpolation is not used at the boundaries to maintain a

Measurement	Area	Explanation
		consistent sample interval for the expression. After each expression evaluation, the result is cached in memory for potential negative MC result references. The rightmost value of the final expression becomes the value of the measurement
Freq (time domain only) **It is important to noteŏ** This does not compute the frequency spectra of the data. To perform a spectral analysis, use the FFT function (see page 277).	Minimum area: 2 samples Uses: Endpoints of selected area	Freq computes the frequency in Hz between the endpoints of the selected area by computing the reciprocal of the absolute value of time difference in that area. The formula for Freq is: $$Freq = \left(\frac{1}{|x_n - x_1|}\right)$$ *Where:* x_1, x_n - *values of horizontal axis at the endpoints of selected area.* The information provided by this measurement is directly related to the *Delta T* and *BPM* measurements, and is related to a lesser extent to *Delta S* measurement. That is, if the *Delta T* interval between two adjacent peaks is calculated, the *BPM and Freq* measurement can be extrapolated. If the sampling rate is known, the *Delta S* can also be derived. In the following example, observe the *Delta T, Freq* and *BPM* measurements for the particular area. The *Delta S* can also be derived. *Selected area with measurements that describe the same interval in different terms.* *Note:* It is important to note that this does not compute the frequency spectra of the data. To perform a spectra analysis, use the FFT function (described on page 277). *Freq (or frequency) is only available in time domain windows.* *Results:* This calculation will always return a positive result. *Units: Hz* *Sample data file:* *"ValidateMeasurements.ACQ"* *Result: 8.33 Hz (for whole wave).*
Integral	Minimum area: 2 samples Uses: All points of selected area	Integral computes the integral value of the data samples between the endpoints of the selected area. This is essentially a running summation of the data. Integral is expressed in terms of (amplitude units multiplied by horizontal units) and calculated using the following formula. $$Integral = \sum_{i=1}^{n-1} \left[f(x_i) + f(x_{i+1}) \right] * \frac{\Delta x_i}{2}$$ *Where:* *n—number of samples;* *i—index (i = 1.n-1);* x_i, x_{i+1} - *values of two neighboring points at horizontal axis (x_1 – the first point, x_n – the last point);*

Measurement	Area	Explanation
		$f\left(x_i\right),\ f\left(x_{i+1}\right)$ - *values of two neighboring points of a curve (vertical axis);* $\Delta x_i = \dfrac{\Delta X}{n-1}$ - *horizontal sample interval;* $\Delta X = x_n - x_1$ - *horizontal distance of increase at horizontal axis.* The following plot graphically represents the Integral calculation. The area of the shaded portion is the result. *Results:* The Integral calculation can return a negative value if the selected area of the waveform extends below zero. *Units: Volts—sec.* *Sample data file:* "ValidateMeasurements.ACQ" *Result: 0.300 Volts -sec.(for first 6 sample points) and – 0.155 Volts -sec.(for last 6 sample points—the wave below zero).*
Kurtosis		Kurtosis indicates the degree of peakedness in a distribution, e.g. the size of the %tails+of the distribution. Distributions that have sharp peaks in their center have positive kurtosis; flatter distributions have negative kurtosis. A normal distribution has a kurtosis of 0. The following formula is used to extract kurtosis $$kurtosis = \dfrac{\dfrac{\sum\limits_{i=1}^{n}\left(x_i - \bar{x}\right)^4}{n}}{\left(\dfrac{\sum\limits_{i=1}^{n}\left(x_i - \bar{x}\right)^2}{n}\right)^2}$$ *Where* from a signal (x) containing n points:
Lin_reg	<u>Minimum area:</u> 2 samples <u>Uses:</u> All points of selected area	Linear regression is a better method to calculate the slope when noisy, erratic data is present. Lin_reg computes the non-standard regression coefficient, which describes the unit change in *f (x)* (vertical axis values) per unit change in *x* (horizontal axis). *For the selected area*, Lin_reg computes the linear regression of the line drawn as a best fit for all selected data points using the following formula: $$\text{Lin\_reg} = \dfrac{n * \sum\limits_{i=1}^{n}\left(x_i * f\left(x_i\right)\right) - \left(\sum\limits_{i=1}^{n} x_i\right) * \left(\sum\limits_{i=1}^{n} f\left(x_i\right)\right)}{n * \sum\limits_{i=1}^{n}\left(x_i\right)^2 - \left(\sum\limits_{i=1}^{n} x_i\right)^2}$$ *Where:* *n—number of samples;* *i—index (i = 1.n);* $x_i \cdot$ *values of points at horizontal axis (x_1 – the first point, x_n – the last point);* $f\left(x_i\right)$ *- values of points of a curve (vertical axis).* *Note: For a single point*, Lin_reg computes the linear regression of the line drawn between the two samples on either side of the cursor. *Results:* If the data value at the starting location is greater than the data value at the ending location of the cursor, then a negative delta will result. Otherwise, a positive delta will result.

Measurement	Area	Explanation

		Units: Volts/sec.
		This value is normally expressed in unit change per second (time rather then samples points) since high sampling rates can artificially deflate the value of the slope. If the horizontal axis is set to display *Frequency* or *Arbitrary units*, the slope will be expressed as unit change in corresponding vertical axis values (frequency or arbitrary units, respectively).
		Sample data file: *"ValidateMeasurements.ACQ"*
		     Result: 230.00 Volts/sec. (for 1-4 samples) and
		     −170.00 Volts/sec. (for samples 4-7).

Max	<u>Minimum area</u>: 1 sample <u>Uses</u>: All points of selected area	Max (maximum) shows the maximum amplitude value of the data samples between the endpoints of the selected area. To compare peak heights, select each peak· observe the maximum peak values or paste the results to the journal. Also, since measurements can be obtained simultaneously for different channels, values for different channels can be easily compared. *Note:* For a single point, Max shows the amplitude value in this point. <u>*Units: Volts*</u>
Max T	<u>Minimum area</u>: 1 sample <u>Uses</u>: All points of selected area	Max T shows the time of the data point that represents the maximum value of the data samples between the endpoints of the selected area. *Note:* For a single point, Max T shows the time value in this point. <u>*Units: Seconds*</u>
Mean	<u>Minimum area</u>: 2 samples <u>Uses</u>: All points of selected area	Mean computes the mean amplitude value of the data samples between the endpoints of the selected area, according to the formula: $$\text{Mean} = \frac{1}{n} * \sum_{i=1}^{n} f(x_i)$$ <u>*Where*</u>: *n—number of samples;* *i—index (i = 1.n);* x_i· *values of points at horizontal axis; (x_1 – the first point, x_n – the last point);* $f(x_i)$- *values of points of a curve (vertical axis).* <u>*Units: Volts*</u> *Sample data file:* *"ValidateMeasurements.ACQ"* *Result: 1.538462 Volts (for whole wave).*
Median	<u>Minimum area</u>: 2 samples <u>Uses</u>: All points of selected area	Median shows the median value from the selected area. *Note:* The median and calculation is processor-intensive and can take a long time, so this measurement option should only be selected when actually ready to calculate. Until then, set the measurement to %one.+ <u>*Units: Volts*</u>
Median T	<u>Minimum area</u>: 2 samples <u>Uses</u>: All points of selected area	Median T shows the time of the data point that represents the median value of the selected area. *Note:* The median and calculation is processor-intensive and can take a long time, so this measurement option should only be selected when actually ready to calculate. Until then, set the measurement to %one.+ <u>*Units: Seconds.*</u>
Min	<u>Minimum area</u>: 1 sample <u>Uses</u>: All points of selected area	Min (minimum) shows the minimum amplitude value of the data samples between the endpoints of the selected area. *Note:* For a single point, Min shows the amplitude value in this point. <u>*Units: Volts.*</u>
Min T	<u>Minimum area</u>: 1 sample <u>Uses</u>: All points of selected area	Min T shows the time of the data point that represent the minimum value of the data samples between the endpoints of the selected area. *Note:* For a single point, Min T shows the time value in this point. <u>*Units: Seconds.*</u>

Moment	Uses: All points of selected area	Central Moment is a general-purpose statistical computation that can be used to compute central variance and other higher-order moments of the data within the selected area. Specify the order as an integer (generally). The central moment is computed using the following formula: $$\mu_m = \frac{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^m}{n}$$ *Where:* *x—signal;* *n—points;* m· order.
None	n/a	None does not produce a measurement value. Itᶳ useful when copying a measurement to the clipboard or journal with a window size in which several measurements are shown and only one measurement is desired.
P-P	Minimum area: 2 samples Uses: All points of selected area	P-P (peak-to-peak) shows the difference between the maximum amplitude value and the minimum amplitude in the selected area. Results: The result is always a positive value or zero. Units: Volts Sample data file: ᵥ/alidateMeasurements.ACQ+ Result: 13 Volts (for whole wave).
Rate_mean	Uses: One sample for each cycle in selected area	Extracts the mean value of the rate outputs within the selected area. Using this measurement on rate data avoids any unintentional weighting due to time variation in the cycles. Unlike the amplitude "Mean" measurement, this measurement must be used on a rate analysis or calculation channel or it will be undefined (****). The units of this measurement will match the amplitude units of the measurement channel.
Rate_median	Uses: One sample for each cycle in selected area	Extracts the median value of the rate outputs within the selected area. Using this measurement on rate data avoids any unintentional weighting due to time variation in the cycles. Unlike the amplitude "Median" measurement, this measurement must be used on a rate analysis or calculation channel or it will be undefined (****). The units of this measurement will match the amplitude units of the measurement channel.
Rate_stddv	Uses: One sample for each cycle in selected area	Extracts the standard deviation value of the rate outputs within the selected area. Using this measurement on rate data avoids any unintentional weighting due to time variation in the cycles. Unlike the amplitude "Stddv" measurement, this measurement must be used on a rate analysis or calculation channel or it will be undefined (****). The units of this measurement will match the amplitude units of the measurement channel.
Samples	Minimum area: 1 sample Uses: All points of selected area	Samples shows the exact sample number of the selected waveform at the cursor position· the first data point is not displayed, but is plotted at zero. See page 86 for examples of selected area Samples. *Note:* When an area is selected, the measurement will indicate the sample number at the last position of the cursor. Units: Samples.
Skew		Skew is a statistical measure of the degree of asymmetry in a distribution (away from normal Gaussian distribution), e.g. if the distribution is weighted evenly or trends toward an edge. • A normal distribution has a skew of 0. • A distribution with a prominent left tail has a negative skew. • A distribution with a prominent right tail has a positive skew The following formula is used to extract skew: $$skew = \frac{\dfrac{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^3}{n}}{\left(\sqrt{\dfrac{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}{n}}\right)^3}$$ *Where* a signal (x) contains n points:

| Slope | Minimum area:
2 samples

Uses:
All points of
selected area | Slope computes the non-standard regression coefficient, which describes the unit change in *f (x)* (vertical axis values) per unit change in *x* (horizontal axis).
For the selected area, Slope computes the slope of the straight line that intersects the endpoints of the selected area, using the formula:

$$\text{Slope} = \frac{f(x_n) - f(x_1)}{x_n - x_1}$$

<u>Where:</u>
$f(x_1), f(x_n)$—*values of a curve at the endpoints of selected area.*

x_1, x_n - *values of horizontal axis at the endpoints of selected area.*

This value is normally expressed in unit change per second (time rather then samples points) since high sampling rates can artificially deflate the value of the slope.
<u>Note</u>: Lin_reg (linear regression) is a better method to calculate the slope when noisy, erratic data is present.
For a single point, Slope computes the slope of the line drawn between the two samples: the selected sample point and the sample point to its left.
<u>Results</u>:
If the data value at the starting location is greater than the data value at the ending location of the cursor, a negative delta will result. Otherwise, a positive delta will result.
<u>Units</u>: *Volts/sec.* (or corresponding to Freq or Arbitrary setting)
<u>Sample data file:</u>   *"ValidateMeasurements.ACQ"*
                    Result: 233.33333 Volts/sec. (for samples 1-4)
                    -166.66667 Volts/sec. (for samples 4-7) and
                    -16. 66667 Volts/sec. (for whole wave). |

Stddev	Minimum area: 2 samples
	
	Uses: All points of selected area
		Stddev computes the standard deviation value of the data samples between the endpoints of the selected area. Variance estimates can be calculated by squaring the standard deviation value.
		The formula used to compute standard deviation is:
		
		$$\text{Stddev} = \sqrt{\frac{1}{n-1} * \sum_{i=1}^{n}\left(f(x_i) - \bar{f} \right)^2}$$
		
		Where:
		n—number of samples;
		i—index (i = 1.n);
		$x_i \cdot$ *values of points at horizontal axis (* x_1 *– the first point,* x_n *– the last point);*
		$f(x_i)$ *- values of points of a curve (vertical axis);*
		
		$$\bar{f} = \frac{1}{n} * \sum_{i=1}^{n} f(x_i)$$ *- the mean amplitude value of the data samples between*
		the endpoints of the selected area.
		Results: The result is always a positive value or zero.
		Units: Volts
		Sample data file: *"ValidateMeasurements.ACQ"*
		      Result: 3.09570 Volts (for samples 1-4),
		      1.000 Volts (for samples 10-12).

Sum	Minimum area: 2 samples Uses: All points of selected area	Sum extracts a mathematical sum of the amplitudes of all of the samples within the selected area. This straight sum can be used as a building block for more complicated formulas. Examples of its utility include HRV measurements, various statistical measurements, and simple criteria for clustering. Sum is available from within the measurement popup menus and from analysis scripts that allow for extraction of measurements.
Time	Minimum area: 1 samples Uses: All points of selected area	See the X-axis: T measurement for explanation.
Value	Minimum area: 1 sample Uses: All points of selected area	Value shows the exact amplitude value of the waveform at the cursor position. *For the selected area,* Value indicates the value at the last position of the cursor, corresponding to the direction the cursor was moved (the value will be the left-most sample point if the cursor was moved from right to left). *Units: Volts*

Part B—Acquisition Functions: The MP menu

Overview

The BSL *PRO* software adds acquisition and control capability to the complete MP System (MP36, MP35 or MP45). This section describes the commands and procedures used to establish the various acquisition parameters for the MP System including how to:

- Set up channels for data acquisitions
- Control acquisition parameters such as sampling rate and duration
- Perform online calculations and digital filters
- Set acquisitions to begin on command from a mouse click or external trigger
- Display values numerically and graphically during an acquisition
- Output waveforms and digital signals during an acquisition
- Control the on-screen waveform display characteristics

Some of the basic functions involved in setting up an acquisition were covered in *Part A—Getting Started*, but this section will cover them in more detail, as well as describe some additional features. All the commands covered here can be found under the MP menu.
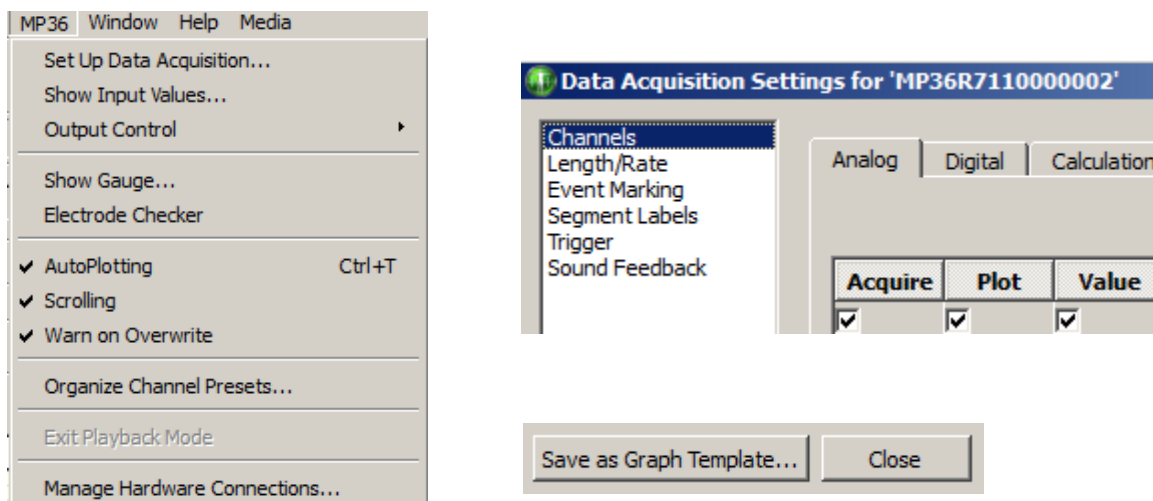
Set Up Data Acquisition > Data Acquisition Settings

In BSL 4.1 and higher, many key setups are accessed with Hardware menu > Set Up Data Acquisition. This option displays the Data Acquisition Settings window, comprised of the following items:

- Channels ó all analog, digital and calculation channel setups ó see page 101.
- Length/Rate ó all acquisition setup parameters for the hardware ó see page 151.
- Event Marking ó for setting up hotkeys to insert custom events during acquisition ó see page 191.
- Segment Labels ó for creating custom append segment labels ó see page 207.
- Trigger ó for configuring all triggering setups see page 207. (Not supported in MP45)
- Sound Feedback ó for setting up audio output of channel data ó see page 208.
- Clicking a listed item populates the Data Acquisition Settings window with the selected itemøs setup dialog. At the bottom right of the Data Acquisition Settings window is a õSave Graph Templateö button. This enables unique settings from any selected feature to be saved into a graph template for future use.

User-defined default settings for new graphs can be saved by choosing Display > Preferences > Hardware and choosing õUser-defined default channel setup.ö

Following this, each selected parameter change must be accepted by clicking õYesö to the resulting õsave default settingsö dialog. Once the settings are accepted, this dialog does not reappear unless the settings are subsequently modified.

Acquisition is defined as data collection from an external source (such as electrodes connected to an amplifier).

➢ Before starting an acquisition, make sure the MP data acquisition unit is turned on and connected to the computer. Please refer to the BIOPAC Hardware Guide for more information on connections.

To begin collecting data and display data as it is being collected:

1. Launch the BSL *PRO* application.
2. Choose File > New and select document type õGraph Window.ö
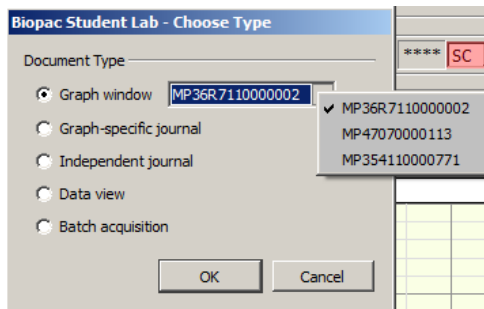
NOTE: If more than one hardware type has been previously added via the õConnect toö menu, these will also appear in the õChoose Typeö dialog (left).For details on connecting additional hardware types, see page 215.
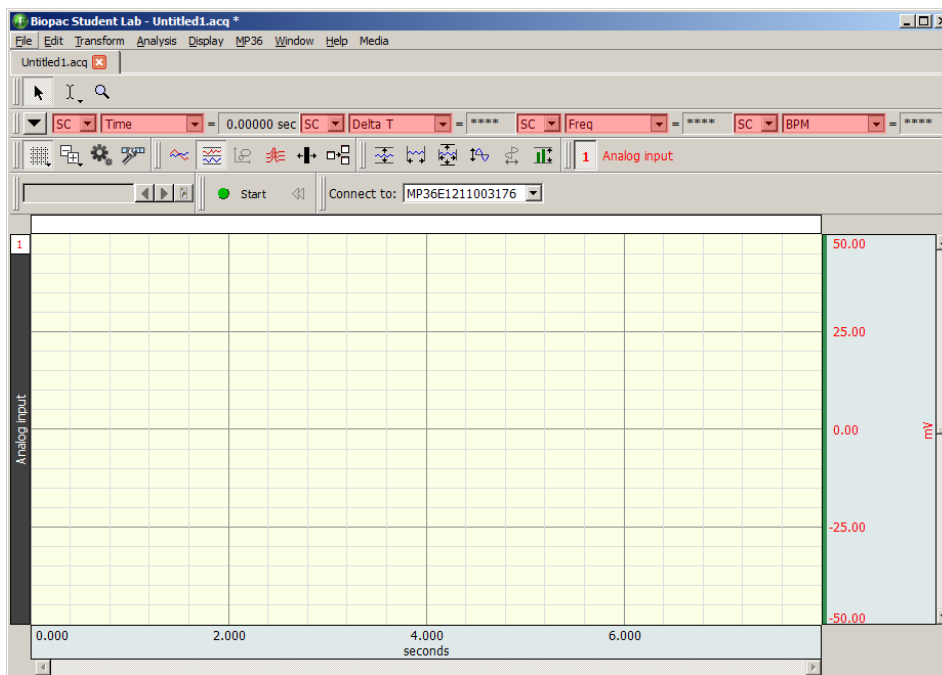
3. Set up the specific channels to acquire before starting the acquisition. See the Set Up Channels chapter (page 101) or Set Up Acquisition chapter (page 151) for details.
4. Set up the acquisition parameters (such as sampling rate, acquisition length, and data storage options. See the Set Up Acquisition chapter (page 151) for details.

Edit menu functionality during acquisition

The following Edit menu functions may move or alter memory and cannot be performed during acquisition: Undo, Cut, Clear, Clear All, Paste, Insert Waveform, Duplicate waveform, and Remove Waveform.

Chapter 5   Set Up Channels
Set Up Channels—The Basics

Before collecting data, itøs necessary to specify how many channels data will be collected on, and at what sample rate data is to be collected. To enable collection on a given channel, select Set Up Channels from the MP menu. (The setup dialog is also presented by default when launching a new graph in the *PRO* application.

Channel Type

To specify the channel typeô Analog, Digital, or Calculationô click its tab at the top of the dialog.
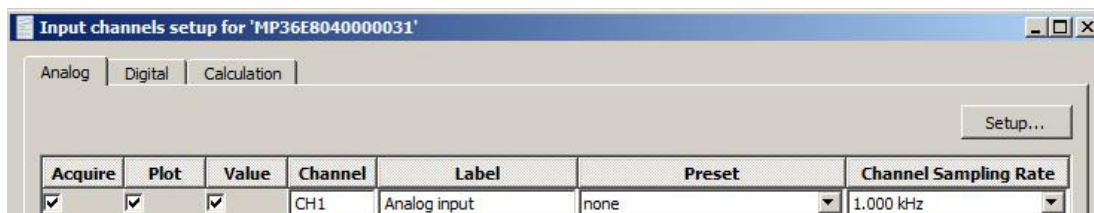
Each channel has three options for channel setup: acquire, plot, and values. These options appear as boxes on the left side of the Input Channels dialog.

Acquire

When the Acquire box is checked for a given channel that means data will be collected on that channel.

To leave hardware connected to the data acquisition unit, but have the software essentially õignoreö the channel, leave the acquire box unchecked. For example, if an input device is set to Channel 3, data from that channel will not be collected unless the Acquire box is checked.

Plot

Determines if data will be plotted in real-time during the acquisition. If the plot box is unchecked, data will still be recorded, but the associated channel will remain hidden. The channel (and data) can be õunhiddenö by positioning the mouse pointer over the channel number box and Alt+clicking.

Checking this option instructs the software to plot data on the computer display.

In most cases, checking this option is recommended. However, in large-scale acquisitions (i.e., many channels and/or high sampling rates) unchecking this option for some channels is useful for increasing the display area for important channels (see Appendix Bô Hints for working with large files). Alternatively, use a separate data view and enable channels as desired for optimum viewing.

Value

The third option enables incoming data values to be displayed either numerically and/or in a õbar chartö format in a separate window during an acquisition. Checking this option enables access to a window (by selecting MP menu > Show Input Values...) that displays the numeric value for each input with the õValuesö option checked. This option is especially useful for tracking slowly changing values such as heart rate, respiration rate, or concentrations of chemicals in a substance. For more information on how input values are displayed, please turn to page 206.

Channel

Click the channel number box (i.e. A1) to make that channel active (õselectedö) so its settings can be established or edited.

Label

Editable õlabelsö may be assigned to each channel. To change the label for any channel, position the cursor in the area to the right of the channel numbers under the õLabelö heading and text. To edit the label after setup, use the Set Up Channel dialog at any time, or double click the active channel label in the graph window to generate the Assign Channel Label dialog.

Preset

The Analog channel Setup dialog features a õPresetö pop-up menu for each channel ⬇. Available onboard presets include pre-configured settings for a wide range of BSL transducers and hardware interfaces that connect to the channel inputs of the MP36/35/45 hardware. Choose a preset and the software automatically sets the gain, offset, scaling, etc. appropriate for the selected application.

Upon initial Analog channel selection, the Preset setting will be displayed as õnoneö until a specific option is selected. Choosing the õDefaultö setting applies basic settings that can can be configured manually and saved as a custom preset if desired. (Any selected onboard preset can also be modified and saved as a custom preset by choosing the Setup > New Channel Preset option.)

The following Analog channel preset options are available for current MP36 hardware. (Avaialable presets will vary if using earlier MP hardware types such as MP35 or MP45.)

none	Cardiac Output - Z	Electrocardiogram (ECG), .05 - 100 Hz, AHA
✔ Default	Cardiac Output - dZ/dt	Electrocardiogram (ECG), .05 - 150 Hz
Accelerometer (SS26LB, 5 G max)	Clench Force - kg (SS25LB)	Electrodermal Activity (EDA, SS57LA), 0 - 35 Hz
Accelerometer (SS26L/SS26LA, 5 G max)	Clench Force - lbs (SS25LB)	Electrodermal Activity (EDA, SS3L/SS3LA/SS57L), 0 - 35 Hz
Accelerometer (50 G max)	Clench Force - N (SS25LB)	Electroencephalogram (EEG), .5 - 35 Hz
Accelerometer (SS34L, 200 G max)	Clench Force - kg (SS25LA)	Electroencephalogram (EEG), .5 - 100 Hz w/notch
Airflow (SS11LA)	Clench Force - lbs (SS25LA)	Electrogastrogram (EGG)
Airflow (SS11LB, ATP)	Clench Force - N (SS25LA)	Electromyogram (EMG), 5 - 250 Hz w/notch
Airflow (SS52L)	Clench Force - kgf/m^2 (SS56L)	Electromyogram (EMG), 5 - 500 Hz
Blood Pressure Cuff (SS19L)	Clench Force - kpa (SS56L)	Electromyogram (EMG), 5 - 1000 Hz
Blood Pressure Cuff (SS19LA)	Clench Force - psi (SS56L)	Electromyogram (EMG), 30 - 250 Hz w/notch
Blood Pressure Cuff (SS19LB)	CO2 Expired (GASSYS2)	Electromyogram (EMG), 30 - 500 Hz
BNC (SS9LA, -10 to +10 Volts max)	O2 Expired (GASSYS2)	Electromyogram (EMG), 30 - 1000 Hz
BNC (SS9L, -10 to +10 Volts max)	Electrocardiogram (ECG), .5 - 35 Hz	Electrooculogram (EOG), .05 - 35 Hz
BNC (SS9L, -50 to +50 Volts max)	Electrocardiogram (ECG), .05 - 35 Hz	Finger Displacement (cm)
BNC (SS70L, -10 to +10 Volts max)		Finger Displacement (inches)

Force Transducer - Eyelets - kg (SS25L)	Reflex Hammer (Intellitool - Flexicomp)	Airflow (rat/guinea pig)
Force Transducer - Handle - kg (SS25L)	Respiration (SS5LB)	Airflow (cat/rabbit)
Goniometer	Stethoscope (Heart Sounds)	Airflow (small dog)
Goniometer (Intellitool - Flexicomp)	Stethoscope (Korotkoff Sounds)	Airflow (medium dog)
Heel-Toe Strike	Stimulator-BSLSTM (0-10 Volts)	Airflow (large dog)
Microphone (SS17L, .5 - 200 Hz)	Stimulator-BSLSTM (0-100 Volts)	Blood Pressure (Arterial)
Microphone for Speech (SS62L)	Stroboscope Flash (TSD122)	Circuit Probe (Breadboard)
MP100/150 Interface (BSLCBL14)	Switch	Current Monitor (BSLCBL10)
OXYSSH - SpO2	Temperature (deg. C)	Displacement (cm)
OXYSSH - Rate (BSLCBL16)	Temperature (deg. F)	Displacement (inches)
OXYSSH - Pulse (BSLCBL15)	Temperature Change (deg. C)	Displacement (AD Inst. DT-475)
OXYSSH - Status	Temperature Change (deg. F)	Dissolved O2 (BSL-TCI16)
Psychological Response	Torsiometer	Earthworm Action Potential
Pulse Plethysmograph (PPG)	Airflow (small mouse)	Force (0 - 50 grams)
Reflex Hammer Strike	Airflow (mouse)	Force (0 - 100 grams)
		Force (0 - 200 grams)

Force (0 - 500 grams)	none
Force (0 - 1000 grams)	✔ Default
Force (iWorx FT-100)	Accelerometer (SS26LB, 5 G max)
Microelectrode Amp (SS72L)	Accelerometer (SS26L/SS26LA, 5 G max)
Nerve Response (BSLCBL3/4/9)	Accelerometer (50 G max)
Nerve Response (BSLCBL8)	Accelerometer (SS34L, 200 G max)
pH (BSL-TCI21)	Airflow (SS11LA)
Pneumogram	Airflow (SS11LB, ATP)
Pressure (+-2.5 cm H2O)	Airflow (SS52L)
Pressure (+-12.5 cm H2O)	Blood Pressure Cuff (SS19L)
Pressure (+-25 cm H2O)	Blood Pressure Cuff (SS19LA)
Tobacco Hornworm (BSLCBL8)	Blood Pressure Cuff (SS19LB)
	BNC (SS9LA, -10 to +10 Volts max)
	BNC (SS9L, -10 to +10 Volts max)
	BNC (SS9L, -50 to +50 Volts max)
	BNC (SS70L, -10 to +10 Volts max)

MP36 Analog Channel Preset options

<u>Channel Sampling Rate</u>

The Variable Sampling Rate feature allows different channels of data to be down-sampled from the acquisition sampling rate; calculation channel must use sampling rate less than or equal to the source channel. Choosing lower sampling rates for signals where data falls below the Nyquist frequency of the acquisition sampling rate allows more data to be stored in memory or on disk.

Offline operations involving multiple channels must use the same sampling rate for all Source and Destination channels. These operations include waveform editing, Waveform math, Expression calculations and Template functions; notable exceptions are õOff-line Averagingö under Find Cycle and õReset via a Control Channelö under Integrate.

When copying wave data to the clipboard or journal, data values will be inserted at the highest sampling rate (channels with a lower sampling rate will snap to the left).

To set an arbitrary channel sample rate for analysis, use Transform > Resample (see page 270).

There is no restriction on the acquisition length when using Variable Sampling Rates.

When Variable Sampling Rates are used in conjunction with the Append mode, and the mode is started and stopped manually, it is statistically possible that, prior to the next pass of the Append, extra data points may be inserted in various data channels to õline upö the data (see sample on page 103). These extra data points simply replicate the last sample in any affected channel.

To minimize the impact of the extra data points, make sure the lowest sampling rate is on the order of 10 Hz or higher, or donøt use Variable Sampling Rates.

<u>Calculation Channel Presets</u>

When a new Calculation channel is enabled for the first time, a setup dialog is presented to assist in setting the correct preset type, source channel and preset parameters.

To set an initial calculation channel preset:

1.   Click the Calculation tab.
2.   Enable the desired Calculation channel by checking the õAcquireö checkbox.
3.   The following setup dialog will appear. Select the desired Calculation preset, analog source channel, Plot and/or Show input values checkboxes, and click OK.
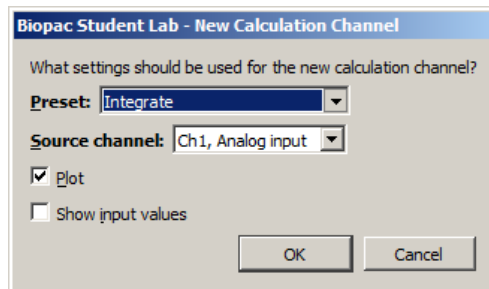
4.   After clicking OK, the setup dialog for the selected preset will appear. Set the desired parameters and click OK. (For detailed information about setting Calculation channel parameters, see Chapter 6 on page 116.

Calculation Presets are like õtemplatesö for calculation channels. Each Preset stores:
   a) Calculation channel type
   b) Calculation parameters
   c) Channel-specific scaling
   d) Channel-specific sampling rate
   e) Channel name

Calculation Presets establish settings to target application-specific analysis. Presets exist for a broad range of analysis functions. Start with existing presets for a specific species or protocolô for example, human vs. small animal, or stationary vs. exercising measurements.

The Channel Setup dialog contains a õPresetö pop-up menu by each channel that lists the current Preset or, if no Preset has been selected for that channel, the Calculation type (Integrate, Difference, etc.). When selecting a Preset for a particular channel, the channel will be configured with the settings associated with that Preset.

✔ Integrate	dp/dt @ 200 samples/sec.	EMG Integrated	Respiration Rate
Smoothing	dp/dt @ 500 samples/sec.	EMG Root Mean Square	Segment Timer
Difference	dp/dt @ 1000 samples/sec.	Heart Rate (from ECG)	Small Animal dp/dt Minimum
Rate	ECG R-R Interval	Large Animal dp/dt Minimum	Small Animal dp/dt Maximum
Math	ECG R Wave Amplitude	Large Animal dp/dt Maximum	Small Animal Systolic BP
Function	EEG Alpha (8 - 13 Hz)	Large Animal Systolic BP	Small Animal Diastolic BP
Filter - IIR	EEG Beta (13 - 30 Hz)	Large Animal Diastolic BP	Small Animal Mean BP
Expression	EEG Theta (4 - 8 Hz)	Large Animal Mean BP	Small Animal Heart Rate
Delay	EEG Delta (0.5 - 4 Hz)	Large Animal Heart Rate	Vibromyography
Control	EEG Gamma (30 - 90 Hz)	Lung Volume	
Adaptive Filter	EGG (.02 - .125 Hz)	Pulse Rate	
Comb Band Stop Filter			
Metachannel			
Rescale			
Run Macro			
Slew Rate Limiter			
Filter - FIR			

Calculation Presets

When selecting a Preset, the Setup dialog is updated with the corresponding information.

- New Presets can be created from existing Calculation channels. Click õSetupö to display the Calculation Setup dialog and click the õNew Presetö button. The settings will be applied to the current channel, and a prompt will appear for entering a name for the new Preset. Preset names cannot be duplicated, which also means that the name of a default Calculation channel type (Integrate, Difference, etc.) cannot be used. The new Preset will be included in the pop-up menus and saved with the file.

- To reorder channel Presets (by type, use, etc.), choose MP > Organize Channel Presets and then use the up/down buttons as appropriate (see page 214).

- Presets are not applicable to and therefore not selectable on Digital channels.

Set Up Channels—Advanced

The previous section covered the basic options used in almost all acquisitions. In addition to the features described above, a number of other options are available in terms of setting up channels. These advanced features are also found under the Set Up Data Acquisition > Channels menu item.

Most acquisitions involve collecting analog signals and then displaying them on screen. It is frequently useful, however, to collect other types of data (digital data, for instance) or to perform transformations on analog data as it is being acquired. Channels containing digital signals and transformed analog signals can be collected in addition to the 4 analog channels.

In the upper left corner of the Channels setup dialog, note the tabs titled Analog, Digital, and Calculation. The general features (acquiring, plotting, and the like) are the same for each type of channel, although there are considerable differences between the type of data each channel is designed to handle. Analog channels can acquire up to 4 channels of data, Digital, 8 channels and Calculation, 16 channels. Analog and digital channels may be acquired in any combination, and the only requirement for Calculation channels is that at least one input channel (either analog or digital) must be present.

Analog channels

Analog channels are the most common type of acquired channel and should be used to acquire any data with õcontinuousö values. Examples of this include nearly all physiological applications where input devices (transducers and electrodes) produce a continuous stream of varying data. The range of values for analog channels is ±10 Volts.

BSL *PRO* also supports rescaling of the analog channel signal to more meaningful numbers. As an example, imagine a temperature transducer is connected with a gain setting of 5°/Volt, and output set to channel 1. Ordinarily, the values from the amplifier would be read in as Volts or milliVolts. For this acquisition, the signal from the transducer needs to be expressed in terms of degrees Fahrenheit. To do this, choose õTemperature (Deg. F)ö from the selected channeløs Preset list (below).
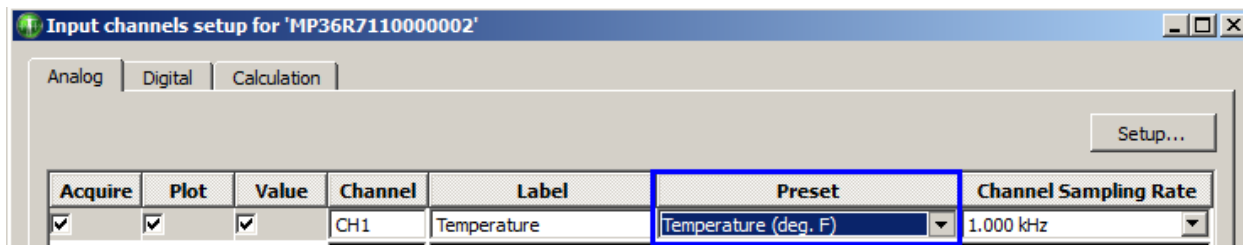
To calibrate the transducer, bring it to two known temperatures. At the first temperature, take a voltage reading by selecting Show input values from the MP menu (see page 206 for a description of the Show Input Values options). 90° F, results in a reading of 0 Volts. The transducer is then brought to a temperature of 95° F, and yields a reading of +1 Volts.

To scale the incoming signal to degrees F, click the Setup > **Scaling…** button in the *Input Channels* dialog.
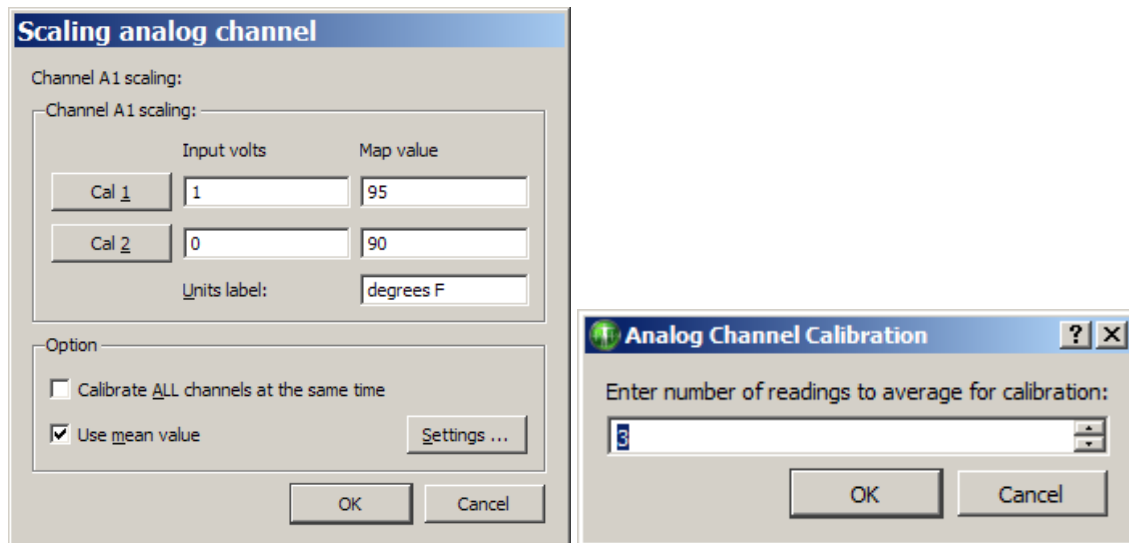
Scaling dialog set to rescale Volts to degrees Fahrenheit and Use Mean Value Settings dialog

The Input Volts and Map (Scale) Value boxes reflect the value of the incoming signal and how it will be plotted on the screen, respectively. Thus, an incoming signal of +1 Volts would be plotted as 95° F, whereas a signal of 0 Volts would be plotted as 90° F. BSL *PRO* will perform linear extrapolation for signal levels falling outside this range (i.e., -2 Volts will be scaled to 80° F), as well as perform similar interpolation for values between this range. Enter these numbers in the scaling dialog, type in õdegrees Fö for Units, and click OK.

As a shortcut for scaling channels, use the Cal 1 and Cal 2 buttons. Click either of these buttons to read in the current voltage for the selected channel. In the above example, the transducer could simply be set to a known temperature, then Cal 1 could be clicked, and then the temperature could be entered in the Map (Scale) value box for Cal 1.

Next the transducer could be brought to another known temperature that is considerably higher or lower than the first and click Cal 2 and the new known temperature could then be enter in the Map (Scale) value box for Cal 2. BSL *PRO* calculates the slope and offset from the two points entered. Each data sample from channel 1 will now be scaled according to the slope and offset calculations previously made. When an acquisition is performed, the amplitude scale (vertical axis) will reflect the rescaled units.

> *It is important to note* that Cal 1 and Cal 2 cannot be used when data is being acquired. In other words, a channel must be calibrated before it can be acquired. To set the calibration for a given channel, connect the input device to the MP data acquisition unit and power up the MP System, and then perform the calibration before starting data acquisition.

The Calibrate all channels at the same time option is used when identical types of transducers or signals are being simultaneously recorded on two or more channels.

If this option is selected, when Cal 1 or Cal 2 is pressed:

- Map (Scale) Value will be updated for all active channels
- Input Volts need to be updated for each channel individually.

The **Use mean value** option is useful if the input voltage signal is noisy around a mean value. The õInput Voltsö value returned will be the mean value over the specified number of readings. When this option is selected, a Settingsí   button is activated and generates an õAnalog Channel Calibrationö prompt for the number of readings.

The data is read the number of times indicated in the prompt and then the readings are averaged. The rate of obtaining these readings is indeterminate because the rate depends on the actual hardware unit as well as the communication type.

Analog channels MP36/MP35/MP45

The MP analog channel scaling setup works as shown above, but additionally allows the channel gain to be configured directly with a variety of input ranges.

Gain settings are accessible via a pop-up menu in the Channel setup dialog. (MP > Set Up Data Acquisition > Channels) The **Gain** setting specifies the extent to which an incoming signal is amplified. The Gain is automatically set when a data type is selected from the available **Presets**. The preset Gain settings are only educated guesses and should be used as initial starting values. It may be necessary to adjust the gain settings depending on how the amplified signal appears once sample data is collected.
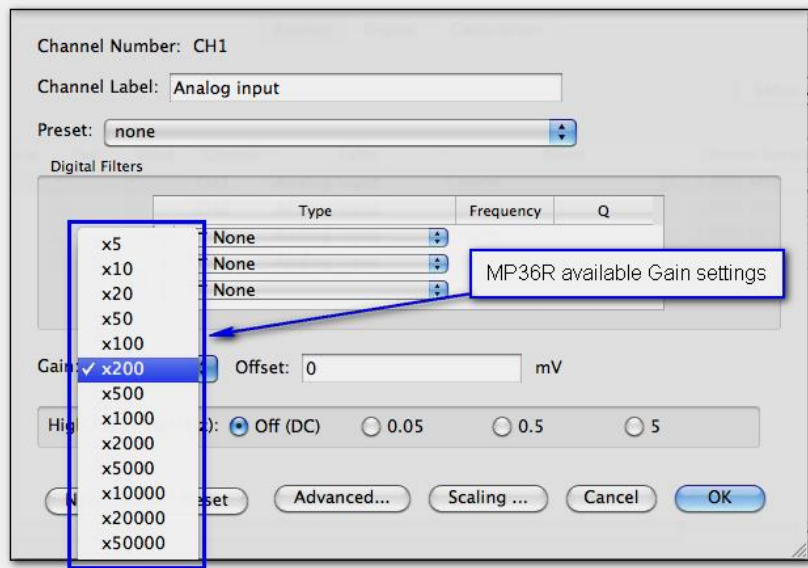
Offset

To correct the offset of an incoming analog signal, add or subtract a constant to the signal prior to amplification. Offset can occur if a transducer or electrode has inherent offset. By default, **Offset** is set to zero, and the allowable entry range will vary depending on the **Gain** and **Scaling** values.

To make inputting voltages easier, the analog channel scaling dialog for the MP3X displays the input voltages in units that adapt to the gain setting. (x200 is the default)

The scaling units will adjust dependent upon the gain setting as follows:

- If the gain is set to < x1000, the Scaling input units will display as millivolts (mV).
- If the gain is set to > x1000, the Scaling input units will display as microvolts (V).
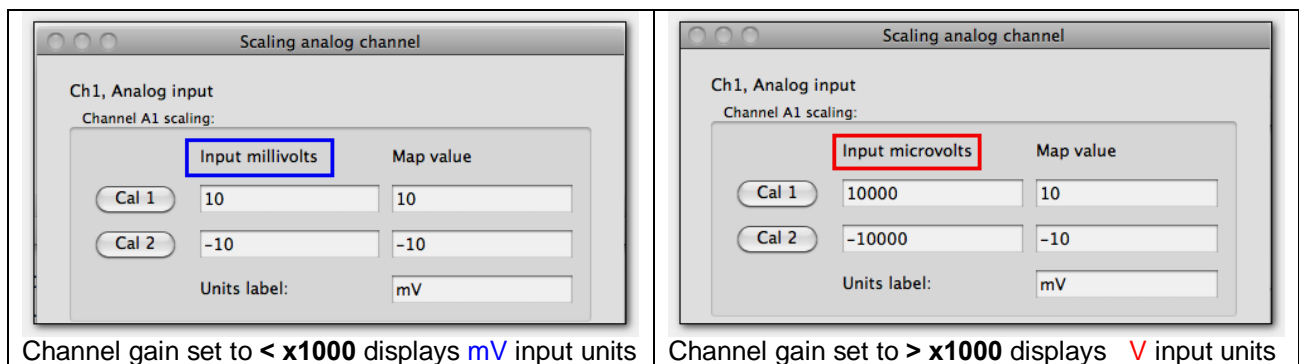
Channel gain set to **< x1000** displays mV input units | Channel gain set to **> x1000** displays V input units

Adjustable, user defined digital IIR Filters for MP36/35/45

The MP unit allows up to three user-configurable, sequential, biquadratic (second order) Infinite Impulse Response (IIR) filters per MP unit channel. These filters are typically configured by choosing a **Preset** but can be changed manually via the Input Channel Parameters dialog (MP3X > Set Up Data Acquisition > Channels > Setup button).

Each of these three filters can be uniquely set up as a low pass, band pass, high pass or notch (band reject) filter.

In the õDigital Filtersö section, select Filter 1, 2, and/or 3 and then adjust the *Type*, *Freq*, and *Q*.
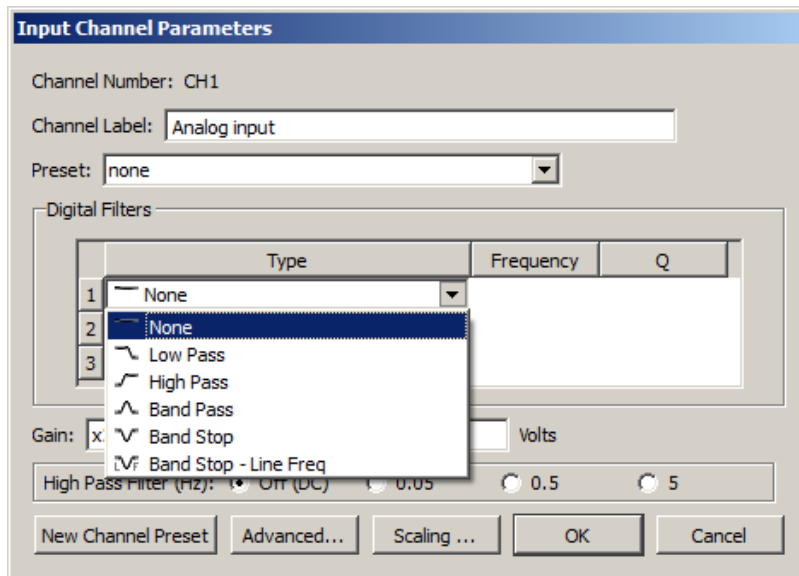
The default setting is no filters applied.

High Pass Hardware Filters

These filters are implemented using resistors and capacitors in the front end circuitry of the MP3X unit. They are set via the õ**High Pass**ö section of the Input Channel Parameters dialog (MP UNIT > Set Up Data Acquisition > Channels > Setupö).
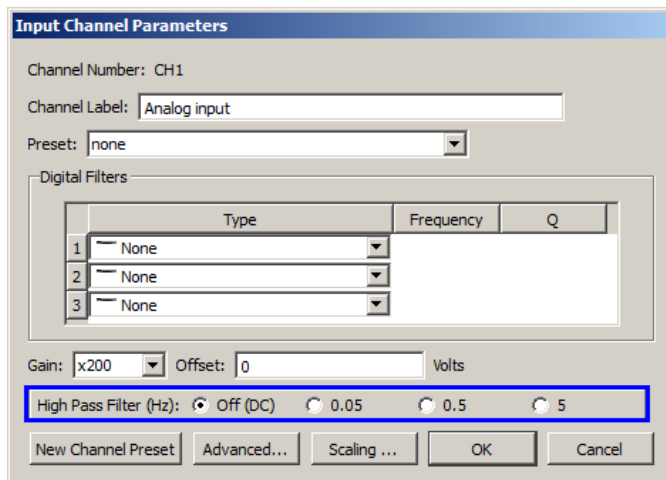
High Pass Filter	Appropriate use
0.05 Hz HP	ECG Respiration data
0.5 Hz HP	ECG when there is a lot of motion artifact causing a shifting baseline EEG Pulse plethysmograph Most other types of AC Coupled data
5 Hz HP	EMG Heart Sounds

Additional controls in MP3X Input Channel Parameters

Button	Explanation
New Channel Preset	Allows a custom Preset to be saved under a unique name
Advanced	Opens Advanced dialog. The Advanced dialog may be used to specify additional settings, requirements, and dependencies for the preset. See below for complete explanation of all Advanced options.
Scaling	Use to configure the value of the incoming signal and how it will be plotted on the screen

Advanced Preset Settings

Click the Advanced button to open a dialog containing the following optional preset configuration options.
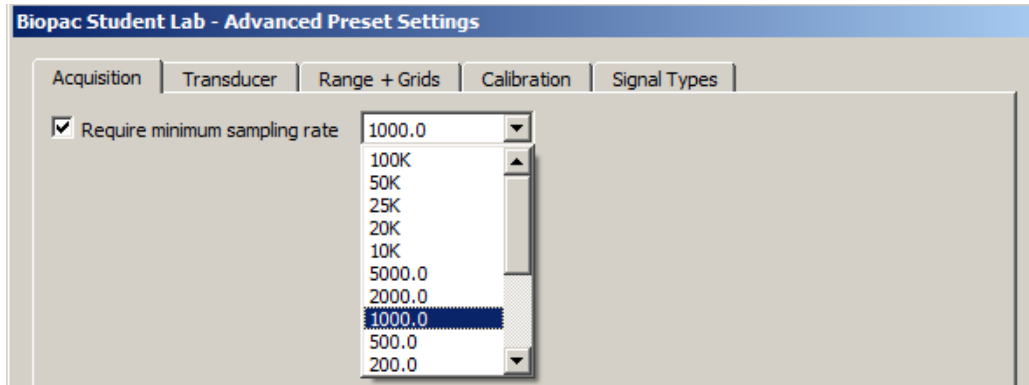
Acquisition Tab	Explanation
Require minimum sampling rate	When enabled, specifies that a minimum sampling rate must be selected in order for acquisition to continue.
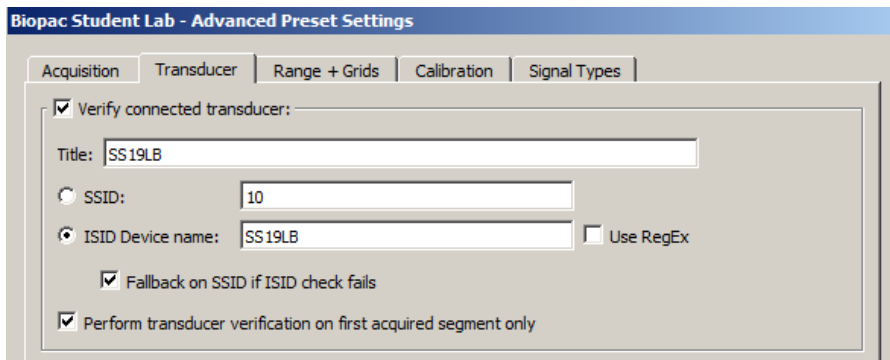
Transducer Tab	Explanation
Verify connected transducer	The software will check for a specific transducer according to the settings in this group box prior to the start of each appended segment. This option is enabled by default.
Title	Editable text field used to identify transducer name.
SSID	Indicates which SmartSensor resistor ID (SSID) will be validated for this channel prior to each acquisition. The ID must be an integer between 1 and 23. This option is checked by default for all transducers. **See page 110 for a table of BIOPAC SSID numbers.**
ISID Device Name	If checked, indicates that the internal transducer description should be validated for this channel prior to each acquisition.
Fallback on SSID if ISID check fails	If the ISID device name check is unsuccessful for a connected transducer, fall back and check the SmartSensor resistor ID.
Perform transducer verification on first acquired segment only	When enabled, the validation is only performed on the first recorded segment. If disabled, verification is performed at the start of every data acquisition.
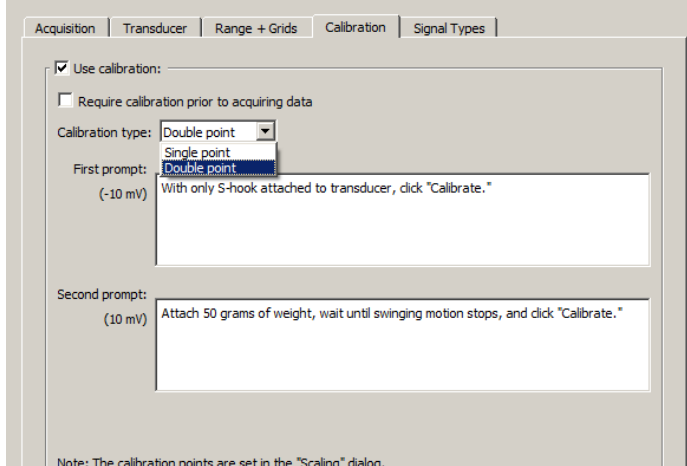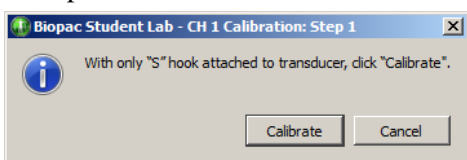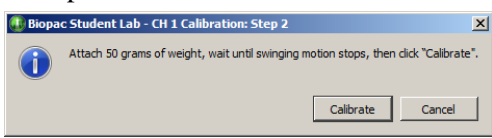
Biopac Student Lab Device SSID Table

Device Part #	Description	SSID	ISID Name
BSLCBL3A, BSLCBL4B	Recording cable	1	
BSLCBL5	3.5mm phone plug adapter	6	
BSLCBL8, BSLCBL9	High-impedance recording cable	1	
BSLCBL14A	3.5mm phone plug adapter to MP35 Input.	6	
BSLSTMB/A	10 V setting	18	
BSLSTMB/A	100 V setting	19	
BSL-TCI13	Piezo interface cable	1	
BSL-TCI21	pH probe interface	12	
SS1L, SS2L, SS2LA	Electrode lead set	1	
SS2LB	Electrode lead set	N/A	SS2LB
SS3LA	EDA (GSR) finger electrodes	2	
SS4LA	Pulse Plethysmograph finger transducer	3	
SS5L, SS5LA, SS5LB	Respiration Belt (for Chest)	4	
SS6L, SS7L, SS8L	Temperature transducer	5	
SS9L, SS9LA	BNC Adapter	6	
SS10L	Pushbutton switch	7	
SS11LA	Airflow transducer	8	
SS12LA	Variable range force transducer	9	
SS13L	Blood Pressure (Arterial)	10	
SS14L	Displacement transducer	11	
SS17L	Piezo microphone	14	
SS19L	Blood Pressure cuff (with Gauge)	10	
SS19LA	Blood Pressure cuff	N/A	SS19LA
SS19LB	Blood Pressure Cuff	N/A	SS19LB
SS20L, SS21L, SS22L, SS23L, SS24L	Goniometer	16	
SS25L, SS25LA	Hand Dynamometer	9	
SS25LB	Hand Dynamometer	N/A	SS25LB
SS26L, SS26LB, SS27L	Accelerometer	17	
SS28L	Heel Toe Strike assembly	9	
SS29L	Multilead ECG cable	1	
SS30L	Stethoscope, electronic	14	
SS31L	Non-Invasive Cardiac Output Module	15	
SS32L	Dissolved Oxygen probe	20	
SS33L	GAS . O_2 (Used on GAS-System2)	21	
SS34L	GAS . CO_2 (Used on GAS-System2)	22	
SS35L	Flow transducer	18	
SS36L	Reflex Hammer	9	
SS39LA	MP3X Circuit Probe and Power Cable for Breadboard	6	
SS40L, SS41L, SS42L	Diff. Pressure transducer	10	
SS43L	Phychological response indicator	11	
SS56L	Clench Force (Bulb) transducer	N/A	SS56L
SS57L	EDA (GSR) with electrode pinch leads	2	
SS57LA	EDA (GSR)	N/A	SS57LA
SS59L	Superlab Interface cable for MP35	6	
SS61L	Finger Twitch transducer	16	
SS62L	Microphone	14	
SS63L, SS64L, SS65L, SS66L	Fixed Range Force Transducer	9	
SS67L	Pneumogram transducer	10	
SS68L	Ph Probe	12	
SS70L	BNC Adapter (for MP35), Isolated version	6	

Range + Grids Tab	Explanation
Apply initial visual range	The initial vertical axis range of plotted data will be set as indicated at acquisition start of the first data segment.
Top	Indicates the maximum vertical visual range in destination channel units.
Bottom	Indicates the minimum vertical visual range in destination channel units.
Apply locked vertical grid	Locked vertical grid settings are applied for the channel. For more details on grid setups, see Grid Details on page 73.
First grid line	Provides the fixed location of the origin of the vertical grid.
Grid spacing	Sets the spacing interval between major vertical grid divisions.
Apply locked horizontal grid	A channel-specific independent horizontal grid will be applied when the channel is added to a graph.
First grid line	Sets the origin location of the horizontal grids.
Grid spacing	Sets spacing between major horizontal grid lines based on the time domain.
Apply grid appearance	Enables options for setting grid color/appearance of major and minor grid lines.
Major line color	Allows customization of major grid line color.
Minor line color	Allows customization of minor grid line color.
Show minor grid	Shows/hides minor gridlines
Vertical precision	Indicates number of digits displayed on vertical axis.
Num minor divisions	Sets the number of minor grid divisions for the channel.
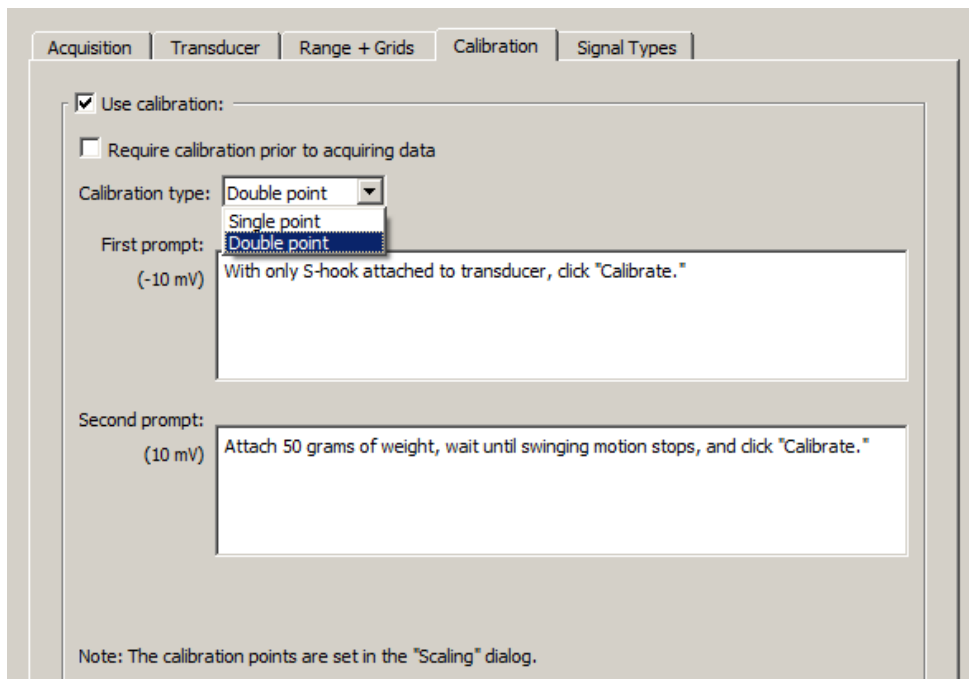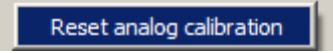
Calibration tab options are designed to assist in channel setup. They allow õcustomö calibration prompts to be used to guide users through the setup/calibration process. These prompts will appear in the main graph window after clicking the graphøs Calibration ⇷ icon (or ÷Startø button, if õRequire calibrationö is checked.) The ÷Calibrateø button in the prompts are linked directly to the Cal 1 and Cal 2 input values found in the standard õScalingö dialog (see page 106) and offers an alternate method of setting these values. If multiple channels use the calibration option, the calibration prompts will be presented in sequential channel order.

Calibration Tab Setup Example:	Resulting User Prompts:
	Prompt 1: Prompt 2:

See table for detailed explanation of calibration options.

Calibration Tab	Explanation
Use Calibration	Calibration procedure is applied after clicking the %Calibrationq icon in the graph channelœs vertical scale region. One (if single point) or two (if double point) custom prompts are presented in place of the usual ÷Scaling analog channel+ dialog. Each prompt has a £Calibrateq and %Cancelq button, one of which must be responded to in order to continue.
Require calibration prior to acquiring data	The above procedure is applied, except calibration prompts are presented as follows when the ÷Startq button is clicked. • Append mode: Calibration required at start of first segment recording only.

	• Save Once or Autosave mode: Calibration required at start of first recording only. (Subsequent passes do not require re-calibration.) **NOTE:** The "Require calibration prior to acquiring data" option has been modified in BSL 4.1.2 to improve usability when using transducers that require calibration and the rewind mode. After initial calibration of the first data segment, that calibration will be retained even after rewinding the data to remove the segment. This allows users to perform a calibration and verification acquisition, and then remove that verification segment prior to the next data acquisition. **If recalibration is desired**: Press the Shift key when clicking the Rewind toolbar button, or right-click the rewind toolbar button and choose "Reset analog calibration" from the contextual menu. Reset analog calibration
Calibration Type	Specifies calibration option to be performed. Two types are available: • Single point . Useful for quickly zeroing the baseline offset or establishing a preload offset value. Presents a single prompt to the user. Upon click of "Calibrate", the input voltage is set as the new "Cal2 Input voltage" in the Scaling dialog (equivalent to clicking "Cal2"). It then calculates the difference between the old and new Cal2 Input values then adds this to the Cal1 Input value. In other words, it preserves the Scaling's slope while shifting the offset. • Double point . records two independent voltages in a sequence of two prompts and records the first as the input voltage for Cal2 and the second for the input voltage in Cal1 For more details see examples below
Prompt	Use to input "custom" calibration prompt text. Up to 500 characters can be entered and carriage returns can be used. The resulting prompts will be dynamically sized according to the amount of text entered. Note: The Scaling dialogs "map values" are displayed for reference to the left of the Prompt field and can only be modified in the Scaling dialog. Any changes will be dynamically updated in the Calibration dialog.

Examples of how to use the Calibration option

Example of "Double point" calibration for the SS12LA Force Transducer:

1. Connect the SS12LA to the MPs CH 1 input and choose MP > Set Up Channels.

2. Select õForce 0-50 gramsö from the Preset pull-down menu then click õSetupö.

3. From the õInput Channel Parametersö dialog, click õAdvancedö then click on the õCalibrationö tab.

4. Check õUse calibrationö, õRequire calibration prior to acquiring dataö and choose õDouble pointö as the Calibration type.

5. Enter the desired õFirst promptö text. For example,

"With only "S" hook attached to transducer, click "Calibrate".

6. Enter the desired õSecond promptö text. For example,

"Attach 50 grams of weight, wait until swinging motion stops, then click "Calibrate".

7. Click OK and exit the õInput Channel Parametersö dialog.

8. Click the Start button. The first prompt will appear:
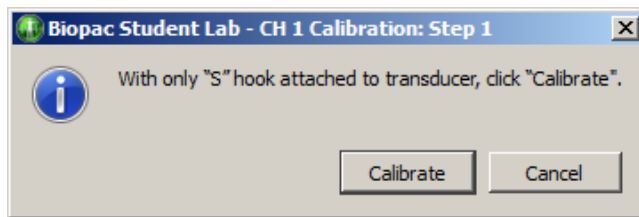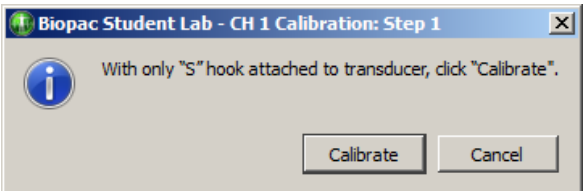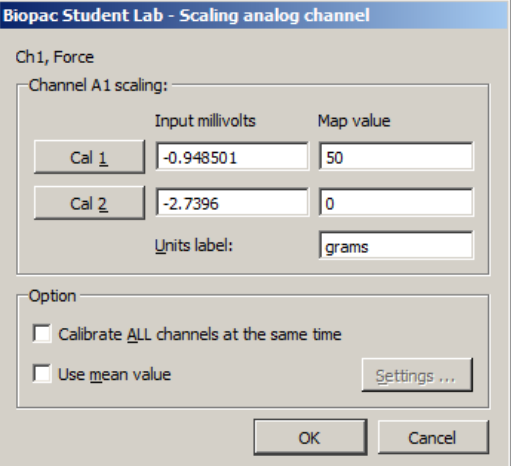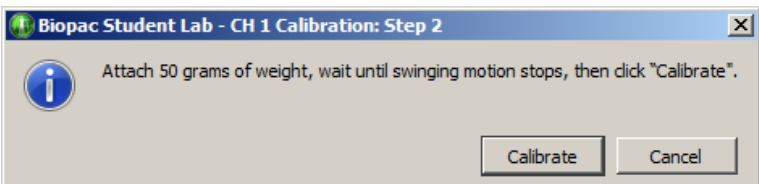
9. Follow the directions and click ―Calibrate‖ The second prompt will appear:
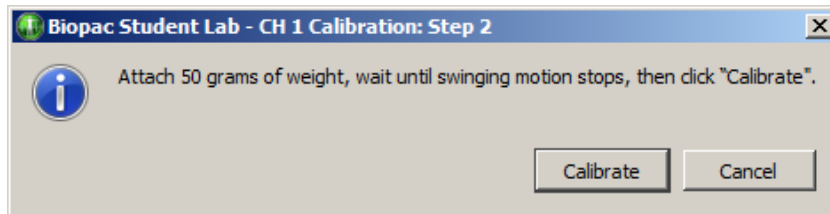
10. Follow the directions and click ―Calibrate‖ Calibration is complete and data recording will start.

Note: The Scaling dialogs Map values (i.e. 0 and 50 grams) are assigned to the calibration prompts as follows: Cal 2 Map value is assigned to Prompt 1 and Cal 1 Map value is assigned to Prompt 2.

"Calibrate" in Prompts	Correlates to Cal buttons in Scaling dialog
Prompt 1: õCalibrateö = õCal 2ö in Scaling. **Prompt 2:** õCalibrateö = õCal 1ö in Scaling.	

Example of "Single point" calibration for the SS11LA Airflow Transducer:

1. Connect the SS11LA to the MPs CH 1 input and choose MP > Set Up Channels.

2. Select õAirflow (SS11LA)ö from the Preset menu then click õSetupö.

3. Click õScalingö and change both the õCal 2ö Input and Map values to õ0ö, then click õOkö.
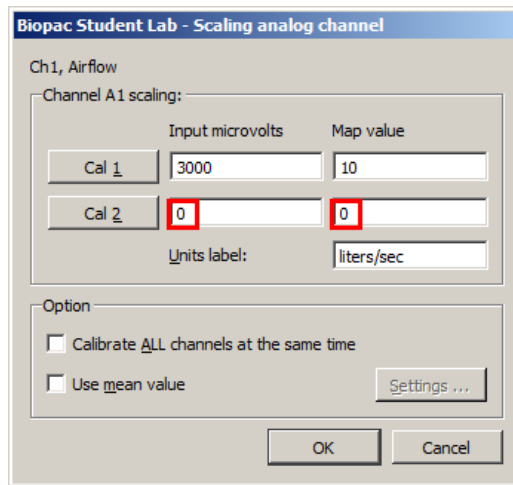
4. From the õInput Channel Parametersö dialog, click õAdvancedö then click on the õCalibrationö tab.

5. Check õUse calibrationö, õRequire calibration prior to acquiring dataö and choose õSingle pointö as the Calibration type.

6. Enter the desired õpromptö text. For example,

"Make sure no air is flowing through the transducer and click "Calibrate"."

7. Click OK and exit the õInput Channel Parametersö dialog.

8. With the SS11LA held upright, click the Start button. The single prompt will appear:
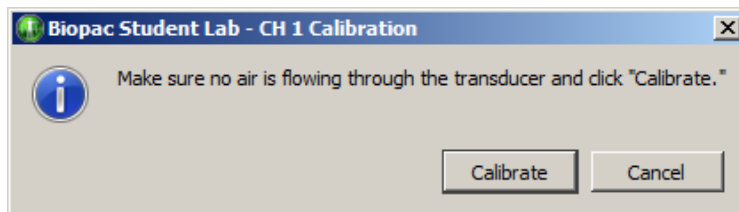
The recording should show 0 liters/second with no air flowing through the transducer.

Biopac Student Lab - Advanced Preset Settings

| Acquisition | Transducer | Range + Grids | Calibration | Signal Types |

Type: ECG ▼   Subtype: None ▼

None
1st Derivative
2nd Derivative
3rd Derivative
Lead I
Lead II
Lead III
V1
V2
V3
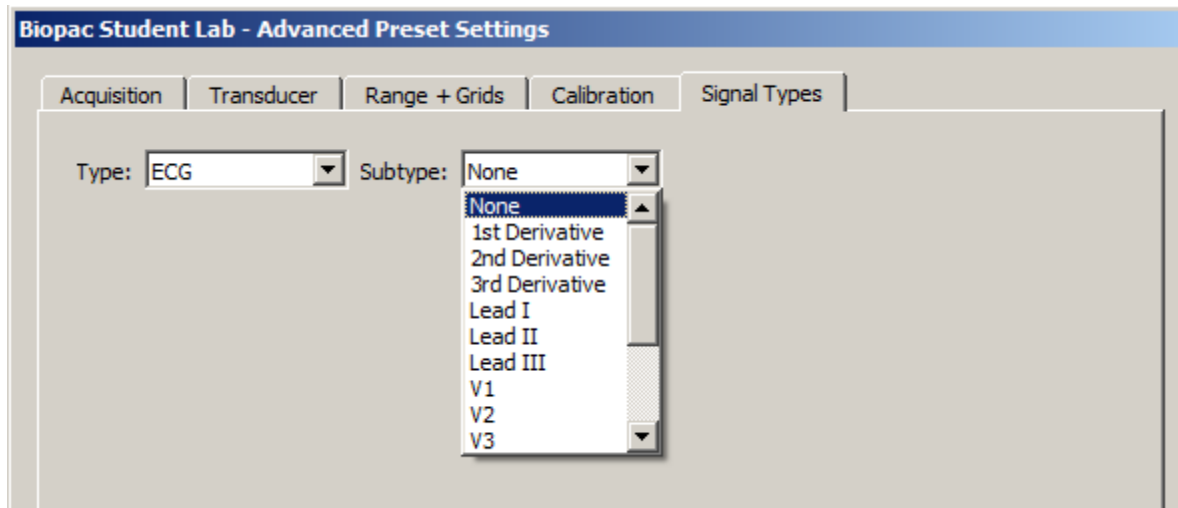
The Signal Types tab offers advanced options or õsubtypesö to add to the selected preset or signal type. The subtype options available are dependent upon the type of signal selected. For example, the ECG type contains a variety of ECG lead configurations and common ECG signals, whereas Respiration offers various airflow options. The subtypes are used for cases when users wish to retain specific information about lead configuration or other details about the signal.Also see the Analysis Shortcuts section on page 218.

Digital channels (Not supported in MP45 hardware)

In contrast to analog channels, digital channels are designed to collect data from a signal source with only two values (0 and 1). This type of data can be useful in recording whether a switch is open or closed, and ascertaining if a device is on or off. Input values for digital channels have two values, +5 Volts and 0 Volts. The MP3X interprets +5 Volts as a digital 1 and interprets 0 Volts as a digital 0. Since digital channels have a fixed value, the scaling option is disabled for these channels. The main function of digital channels is to track on/off devices such as push-button switches and/or to receive digital signals output by timing devices. Similarly, these channels are also used to log signals from devices that output auditory/visual stimulus for examination of stimulus response patterns.

+5 volts
(binary "1")

0 volts
(binary "0")

Positive edge   Negative edge
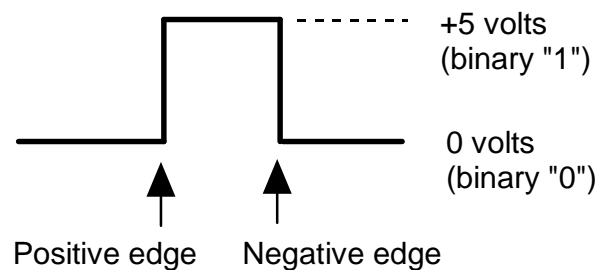
Calculation channels

Compared to either analog or digital channels, Calculation channels do not collect external data, but transform incoming data in some way. These channels do not alter the original data, but create new channels (with channel numbers starting at CH40) that contain the modified data.

Calculation channels can be used to to compute a host of new variables by applying transformations (including BPM, integration calculations, and math functions). The channels are set up in much the same way (using Acquire/Plot/Values boxes) as analog or digital channels, with the exception of the pull-down menu next to the Calc button and the Setup dialog.

To acquire a Calculation channel, click the Calc button and check the Acquire box for each Calculation channel to be computed (the Plot and Value boxes are optional). By default, all Calculation channels have the label õCalculationö and entering more descriptive channel labels might prove useful, especially when multiple Calculation channels are being acquired.

Each of these functions requires some additional parameters to be specified, and these options can be set by clicking the Setup button in the Input Channels dialog. For any Calculation channel, itøs necessary to specify the source channel to be transformed and the nature of the transformation.

Up to 16 Calculation channels can be acquired. The output of one Calculation channel can be used as the input for another channel, as long as the output channel has a higher channel number than the input channel. In other words, itøs possible for Calculation channel 3 to include the result of Calculation channel 1, but not the other way around. This allows for complex Calculations to be performed that involve two or more Calculation channels such as filtering ECG data then computing BPM.

Although Calculation channels can be useful in many cases and indispensable in others, each Calculation channel acquired will somewhat reduce the maximum possible sampling rate, and add to the amount of memory required to store data both during and after an acquisition. Thus, it may be helpful to perform some of these functions after the fact if high sampling rates are needed for a particular application.

> TIP: All of the operations (except Control) that can be performed online can also be performed after an acquisition has been completed. These options are available under the Transform and Analysis menus.

Metachannel

Calculation metachannels provide a method for expanding the 16 available calculation channels to allow for more complex online analysis. The metachannel calculation channel type combines multiple steps into a single calculation channel so that a chained computation can be performed using a single calculation metachannel.

- BSL *PRO* can display the results of up to 16 metachannels, allowing for a total of 256 intermediate subchannel steps.
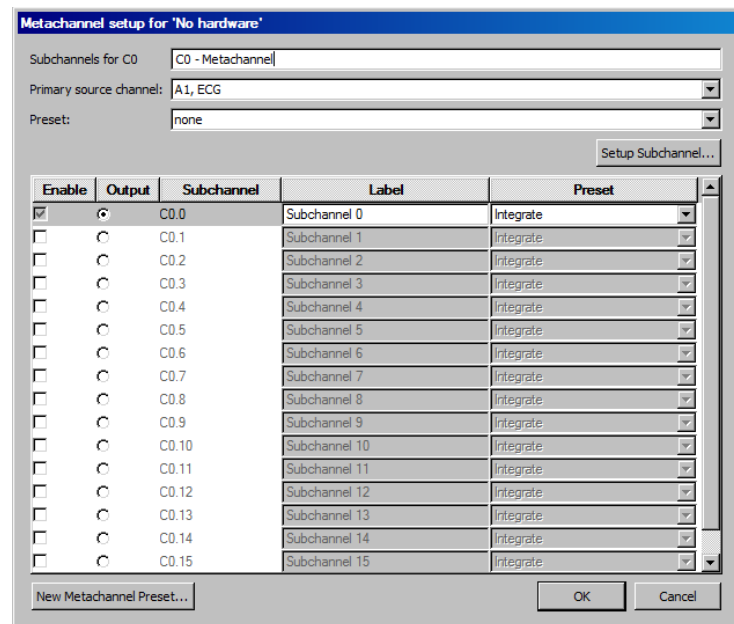
One metachannel can contain up to 16 subchannels, each of which can be individually configured. Subchannels can perform any of the functions of top-level calculation channels.

Each metachannel has one user-defined output channel. The output subchannel is the only waveform data that will be recorded in the graph for that metachannel. All other subchannels associated with that metachannel are temporary; they do not display in the graph and require no extra space in the graph file to compute.

Metachannels alleviate the need to use top-level calculation channels for computing intermediate steps where only the final computation is desired. Metachannels also can be used as the basis of presets, allowing multi-step analyses to be applied with a single preset.

Computation takes place at the lowest waveform sampling rate of all of the referenced source channels, and all subchannels are computed at this rate.

Metachannels labels display in the graph as C#.#

To have BSL *PRO* perform a Metachannel calculation in real time:

1. Choose MP > Set Up Data Acquisition > Channels.

2. Click the Calculation tab.

3. Check an Acquire box for the Calculation channel to contain the filtered data. Check the Plot and Values boxes as appropriate for each channel.

4. Click the Preset pull-down menu and select Metachannel.

5. Click the Setup button in the Input Channels dialog to generate the Metachannel dialog.

Primary Source

The primary source for a metachannel can be set to any analog, digital, calculation, or subchannel with a lower index (index 0-15, with 15 being lowest).

Set Up Subchannel

Click this button to display the calculation setup dialog for the selected subchannel and then set the calculation parameters and the source channel.

Destination:	C0.4, Subchannel 4	Volts
Label:	Subchannel 4	
Source channel:	Primary Source Cha...	mV
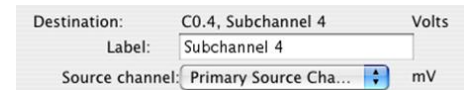
Source channel: Each subchannel can be set to use the primary source channel as its data source or another channel (analog, digital, or lower-index calculation channel). When the primary source channel for the metachannel is changed, the source channel of each subchannel will implicitly be changed.

Limitations on Subchannels

Subchannels are allowed to take on any of the main calculation channel types. All calculation types are available, with some restrictions.

- Output of reset events is not supported for Integrate and Rate subchannels.

- For Expression subchannels, the expression language will be enhanced to allow for "PSC" to be typed into the expression to refer to the data of the primary source channel.

- Unlike regular calculation channels, the actual data for subchannels is not retained in memory. Subchannels are only used as temporary data and the results discarded after the value of the output subchannel has been computed.

PRO Lessons

PRO Lessons illustrate the scope of the BSL *PRO* System. Each lesson describes the required hardware and software setup (channel setup, acquisition setup, gain, scaling, etc.) and outlines the basic procedure necessary to record and analyze a variety of applications on human and animal subjects.

When applicable, a downloadable template file (***.gtl**) is included with the lesson to further simplify setup. The template file includes all the appropriate settings for the lesson ô just open the file, connect the hardware and begin recording!

If you have developed lessons for your course, we invite you to make your lessons available to other users. *You will receive full credit for the lesson*. Just provide us with a copy of your lesson plan and a sample data file. We will add your lessons to the list and other users can benefit from your efforts. Please don't worry about formatting issues ô the important part is the lesson plan and instructions. We'll take care of the formatting. Human *PRO* Lessons graph templates are included in the BSL *PRO* Lessons folder and easily accessible from the Startup Wizard. Or visit our website or quick-click to the Lessons menu using Help>*PRO* Lessons from web for the most up-to-date listing and downloadable files.

- See Higher Education > Curriculum section online for the full list of available lessons.

Application Notes

Visit the Support > Application Notes section online for the full list of available application notes.

Creating a Modified Lesson

The multi-level learning features of the BSL software full control of the material and method of each experiment. Use the 18 guided BSL Lessons for introductory concepts, modify them with custom lab procedures or analysis techniques, choose from 35+ *PRO* Lessons* for advanced concepts, or create custom lessons. BSL lesson experiments are included in a number of the leading published lab manuals and have been successfully used to study:

ECG	Biofeedback	Nerve Conduction
EEG	Bioimpedance/Cardiac	Pulmonary Function
EMG	Output	Respiration
EOG	Blood Pressure	Reaction Time
EDA (GSR)	Heart Sounds	Temperature

By combining two of the new features it is possible to create modified lessons. The graph template function (described on page 224) supports saving of custom settings.

*In BSL 4.1 and higher, 11 animal *PRO* Lessons are also included but are hidden by default. To enable access to these lessons, check the appropriate boxes in the õShow the following *PRO* Lessonsö list in the Lessons Preferences.

TO CREATE A MODIFIED LESSON:

1) Set the required channel, acquisition, and display options.
2) Type any comments and/or instructions for students into the Journal window.

> ➢ To open a journal window: Select Display > Show > Journal or click the ⊞ toolbar icon.

3) Select õFile > Save asö and choose õ**Graph Template**ö from the file type options in the dialog.
4) **Create a new folder**, and then name it appropriately for the lesson.
5) Save as a **graph template** (.gtl) file in the new folder for the lesson. To further protect the file settings, set the Read-only attribute in the file Properties dialog.
6) Clear the Journal window using the **clear Journal icon** in the journal tools section.

Journal tools =

clear journal / open file /save file /print journal
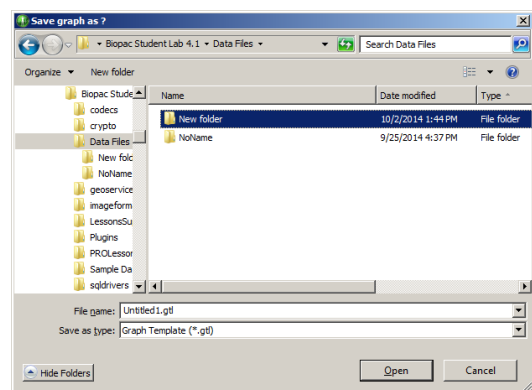
➲ For customization details, see the **Instructor's Guide** installed with the program to the User Support folder or at the root level on the BSL *PRO* installation CD.
➲ For enhanced levels of lesson customization, see the BSL Curriculum Manager licensed feature chapter on page 348.
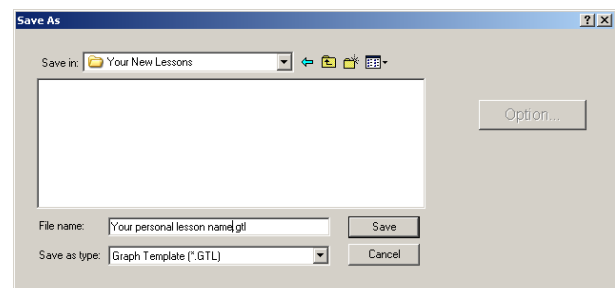
Chapter 6   Calculation Channel Presets

✓ Integrate	Small Animal Heart Rate
Smoothing	Vibromyography
Difference	
Rate	
Math	
Function	
Filter - IIR	
Expression	
Delay	
Control	
Adaptive Filter	
Comb Band Stop Filter	
Metachannel	
Rescale	
Run Macro	
Slew Rate Limiter	
Filter - FIR	

dp/dt @ 200 samples/sec.
dp/dt @ 500 samples/sec.
dp/dt @ 1000 samples/sec.
ECG R-R Interval
ECG R Wave Amplitude
EEG Alpha (8 - 13 Hz)
EEG Beta (13 - 30 Hz)
EEG Theta (4 - 8 Hz)
EEG Delta (0.5 - 4 Hz)
EEG Gamma (30 - 90 Hz)
EGG (.02 - .125 Hz)
EMG Integrated
EMG Root Mean Square
Heart Rate (from ECG)
Large Animal dp/dt Minimum
Large Animal dp/dt Maximum
Large Animal Systolic BP
Large Animal Diastolic BP
Large Animal Mean BP
Large Animal Heart Rate
Lung Volume
Pulse Rate
Respiration Rate
Segment Timer
Small Animal dp/dt Minimum
Small Animal dp/dt Maximum
Small Animal Systolic BP
Small Animal Diastolic BP
Small Animal Mean BP

Calculation Presets establish settings to target application-specific analysis. Presets exist for a broad range of analysis functions. Start with existing presets for a specific species or protocolô for example, human vs. small animal, or stationary vs. exercising measurements.

The Channel Setup dialog contains a õPresetö pop-up menu by each channel that lists the current Preset or, if no Preset has been selected for that channel, the Calculation type (Integrate, Difference, etc.). When selecting a Preset for a particular channel, the channel is configured with the settings associated with that Preset.

The Setup dialog has a õPresetsö pop-up menu that contains all of the Presets for the Calculation type being configured. To enable the Preset pop-up menu, set at least one analog channel to õAcquireö (calculation channels require a source channel). For example, if a Difference Calculation channel is being configured, all Presets for the Difference Calculation will be listed. Just click the Presets head and scroll to select the desired preset.

When selecting a Preset, the Setup dialog is updated with the corresponding information.

- The Setup dialog reads õnoneö if the channel configuration doesnøt match any Preset. The menu will flip to õnoneö when the settings for a channel are changed such that they no longer match a Preset.

- To create a new Preset from existing Calculation channels: Click õSetupö to display the Calculation Setup dialog and click the õNew Presetö button. The settings will be applied to the current channel, and a prompt will be generated for entering a new Preset name. Preset names cannot be duplicated, nor can the the default Calculation channel names be reused (Integrate, Difference, etc.). The new Preset will be included in the pop-up menus and saved with the file.

- To reorder channel Presets (by type, use, etc.), choose MP > Organize Channel Presets and then use the up/down buttons as appropriate (see page 214).

- Presets are not applicable to and therefore not selectable on Analog or Digital channels.

Integrate Calculation
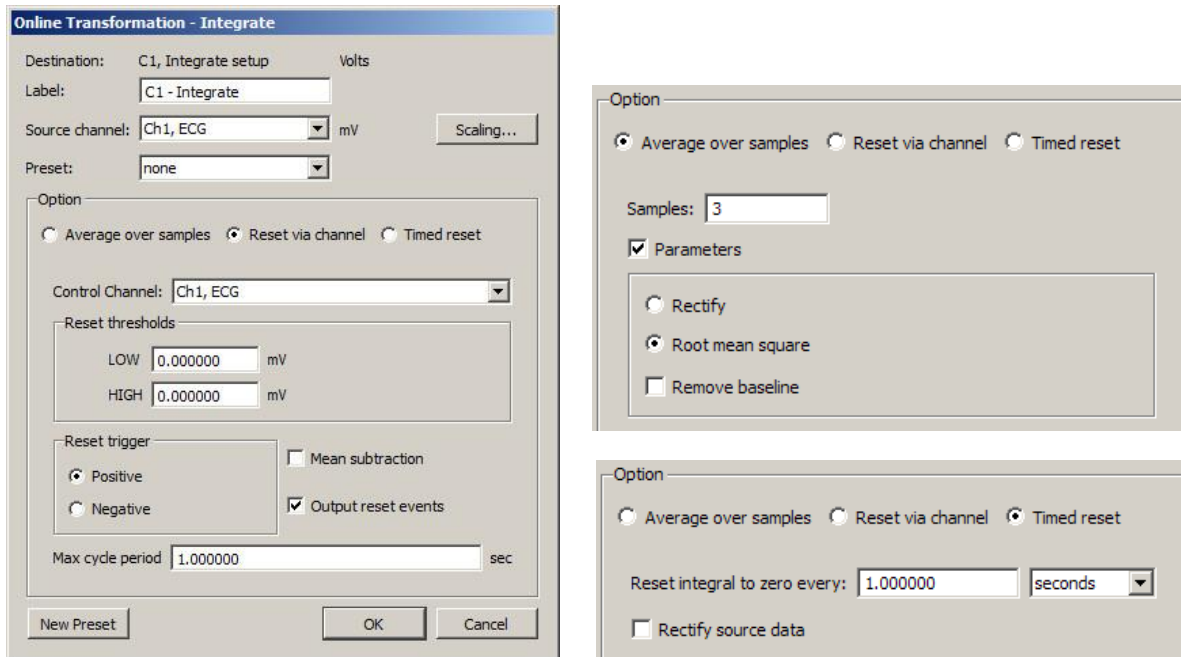
The online Integrate Calculation offers three basic options:

Reset via channel. Perform a real-time integration of input data over a variable number of sample points. This option is extremely useful for converting flow signals into volumetric equivalents. The integral of flow is volume. For example, when recording airflow with a pneumotach, volume can be precisely calculated as the flow varies in a cyclic fashion:

  a) Real-time conversion of flow signals into volume signals (i.e., Blood flow → Blood volume; Air flow → Air volume).

  b) Any processing involving a need for a cyclic, continuous integral calculated in real time. For example: Acceleration → Velocity; Velocity → Distance; Frequency → Number of cycles; Power → Energy.

Average over samples. Perform a moving average (mean) and associated processing (Rectify; Root mean square) over the specified number of sample points. This option is useful to process EMG signals to:

  a) Smooth noisy data

  b) Display the real-time õintegrationö (rectified, then sample averaged) of the raw EMG data

  c) Display the real-time õroot mean squareö calculation of the raw EMG data.

  d) Return real-time windowed standard deviation.

Timed reset. This option is available in the Integrate calculation channel and transformation. This mode computes a straight sum of the source data points and resets this sum after a fixed amount of time has elapsed. This periodic integral is used in several types of analysis, such as EMG analysis where it can generate an EMG signal or estimate the power in fixed time intervals. The time interval at which the integral resets to zero may be specified in seconds or in samples. The timed integrate reset functionality may also be used in calculation channel presets and by the Mac OS Integrate automator action.

To have BSL *PRO* perform an Integrate calculation in real time:

 1. Choose MP > Set Up Data Acquisition > Channels.

  2. Click the Calculation tab.

  3. Check an Acquire box for the Calculation channel to contain the filtered data. Check the Plot and Values boxes as appropriate for each channel.

  4. Click the Preset pull-down menu and select Integrate.

  5. Click the Setup button in the Input Channels dialog to generate the Integrate dialog.

Destination

> Determined by the calculation channel selected when the Scaling button was pressed.

Source

> The source channel is selected from a popup menu that includes any channels being acquired and any enabled Calculation channels.

Reset via channel (Integrate option)

This feature is used to integrate data over a data-dependent interval. Either the source channel or a different channel can control the integration process.

Control channel

Allows user to select any active channel as the integration control channel.

Reset Thresholds

The threshold is to be set at points surrounding the flow level. Typical values are:

LOW: a negative value close to 0.00   HIGH: a positive value close to 0.00

For airflow to volume conversion, the flow signal will vary positively and negatively around zero flow.

Reset trigger

The Reset trigger polarity determines on which slope (Positive ↑ or Negative ↓) the integration process will begin and end.

Mean Subtraction

This option will subtract the mean from the data evaluated during the integration period. If this option is selected, the integration will only proceed after all the data in the integration period has been collected. When collected, the mean value of all the data is subtracted from each data point in the integration period. In this fashion, the integral of the corrected data points will result in the integral returning to exactly zero at the end of the integration interval. Although this option will result in õwell-behavedö integrations, the integrated data will be delayed by a fixed amount of time, as specified by the max cycle period.

Online	Enabling mean subtraction delays the signal by the mean cycle length. It waits for that period of time to pass so it can determine a mean value for the initial cycle, and it then tries to re-compute this mean for each cycle. If the resets are too short or too long, the window expires and the processing halts again until a new mean can be recomputed. Online processing may reset from threshold crossing in the control channel or window expiration when it loses mean tracking.
Offline	Since all the data is available, the mean is computed from the data in the channel and the signal is not delayed. Also, since it isnøt doing windowed means, there are no window expiration events that are inserted. Offline processing may reset from threshold crossing in the control channel.

Max cycle period

The Max cycle period should be longer than the maximum time expected from trigger event to trigger event in the Control Channel. Typically, the default scale settings for cyclic integrated data will be fine. However, the units may need to be changed (i.e., liters/sec to liters) via the Scaling option.

Output reset eventsô *not available for metachannels*

Add Events markers to show where Reset occurred and distinguish why the channel reached zero.

- Threshold crossing on the control channel

  For example: Calculation channel resetting on positive crossings of 0V on CH 1.
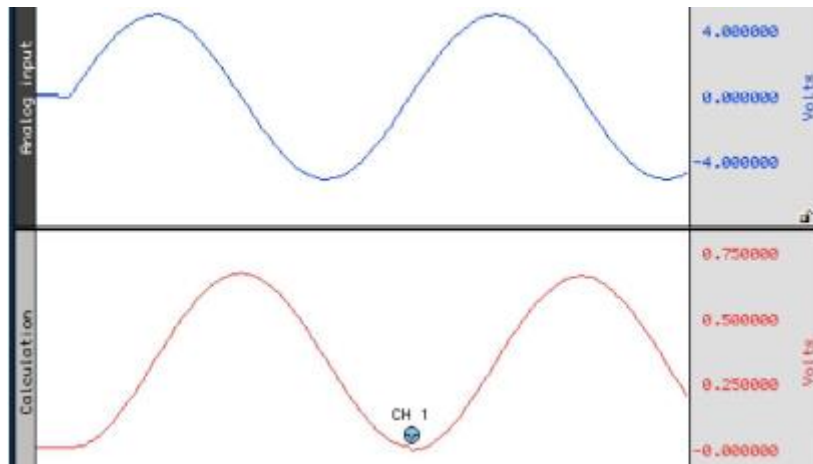
- Window expiry when mean removal is enabled

  For example: No threshold crossing within õmean cycle widthö as specified in calc channel setup. Settings of calc channel: threshold crossings positive, 3V, Mean cycle subtraction, 1 second period width. First reset is due to threshold crossing; second reset is due to window expiry.
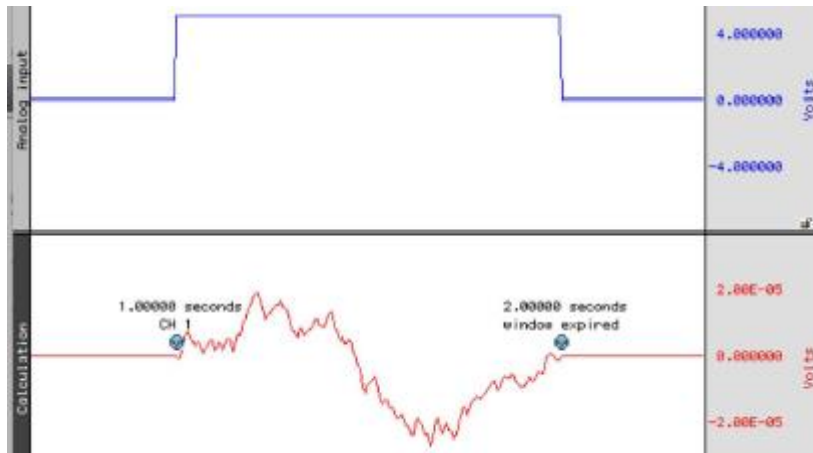
- Zero value due to õtrueö zero being achieved due to mathematical results

  For example: Mathematical Source is sine wave, integral is cosine. Input (10V) never crosses threshold levels. Signal reaches zero mathematically; no reset events appear on output.
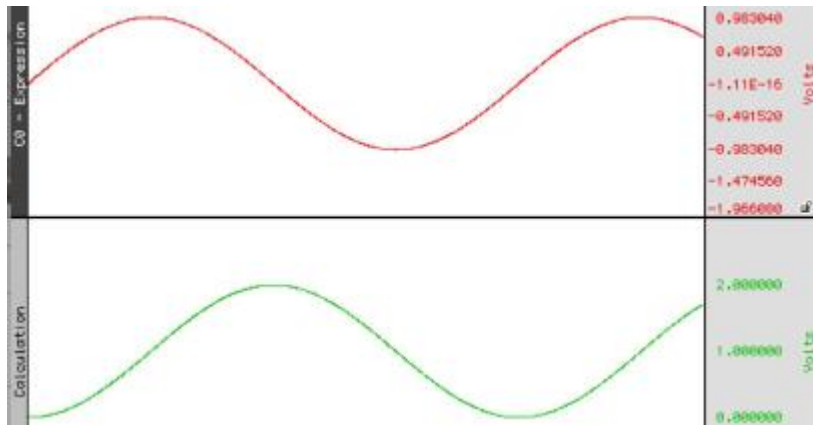
Average over samples (Integrate operation)

Online sample averaging can be useful when there is a high degree of noise present in the data. At least some of this noise can be õaveraged outö by pooling some number of adjacent data points together, taking the average of these points, and replacing the original values with the new averaged values. This process creates a õwindowö of moving averages that moves across the waveform smoothing the data.
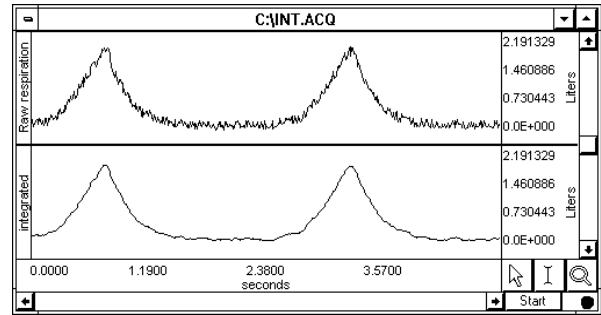
Integration used to smooth noisy data

Since an average represents the sum of a series of data points divided by the number of data points present, Use the Average over samples calculation to provide the information needed to create a moving average.

Samples

To specify the number of data points to average across, enter a value in the Samples box. The number selected will depend in large part on the selected sampling rate and the type of noise present. All things being equal, for slower sampling rates itøs recommended to mean average across a smaller number of samples. As the sampling rate is increased, itøs best to integrate across more samples. As the number of samples specified in the samples box increases, the amount of high frequency information contained in the data will decrease.

Parameters

Rectify ô The Average over samples calculation can also be used for producing an envelope of modulated data. For instance, EMG waveforms frequently contain high frequency information, which is often of little interest compared to the low frequency information also contained in the data. When the Rectify option is checked, BSL *PRO* will take the absolute value of the input data prior to summing and a plot of the waveformøs mean envelope over a specified number of samples will be obtained.
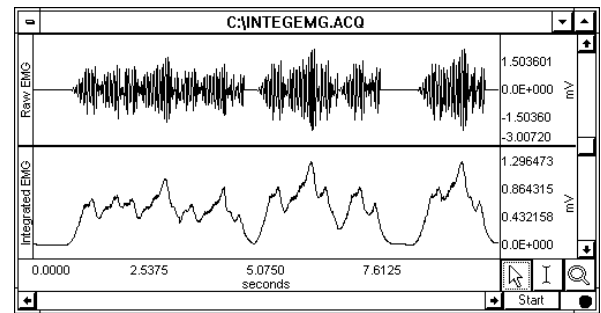
Online "Average over samples" feature used as an envelope detector

Typically, this option is only used for processing raw EMG and similar types of applications. The signal for Rectify is normalized by a factor of (# samples averaged)/(Channel sampling rate).

Root mean squareô provides the exact root mean square (RMS) of the input data (typically EMG) over the specified number of samples.

Remove baselineô provides the exact standard deviation of the input data (typically EMG) over the specified number of samples. When the mean of the input data equals 0-0, the standard deviation and the RMS will be equivalent.

Scalingí buttonô Since the integration values are going to be on a different scale than the original units, the scale of the integration channel needs to be changed to reflect the new units. Clicking the Scalingí button generates a scaling parameters dialog.

The rescaling involves multiplying the õInput unitsö values by a factor determined by the sampling rate and number of samples mean averaged across.

$$\text{Map or Scale value} = \text{Input units} \; x \; \frac{\text{Sampling rate}}{\text{Number of samples to be mean averaged}}$$

As an example, if data was being acquired at 75 samples per second, and itøs necessary to integrate across an interval of 10 samples, set the Integration Setup Scaling parameters so that +10 Volts corresponds to a Map (Scale) value of 75 and a Map (Scale) value entry of ó75 reflects an Input value of ó10 Volts.

➢   It is important to note that this rescaling should be performed independent of any rescaling performed on analog channels themselves. Even if an analog channel is being rescaled to some other units, the input values in the integration scaling should be set to +10 Volts (next to Cal 1) and ό10 Volts (next to Cal 2).
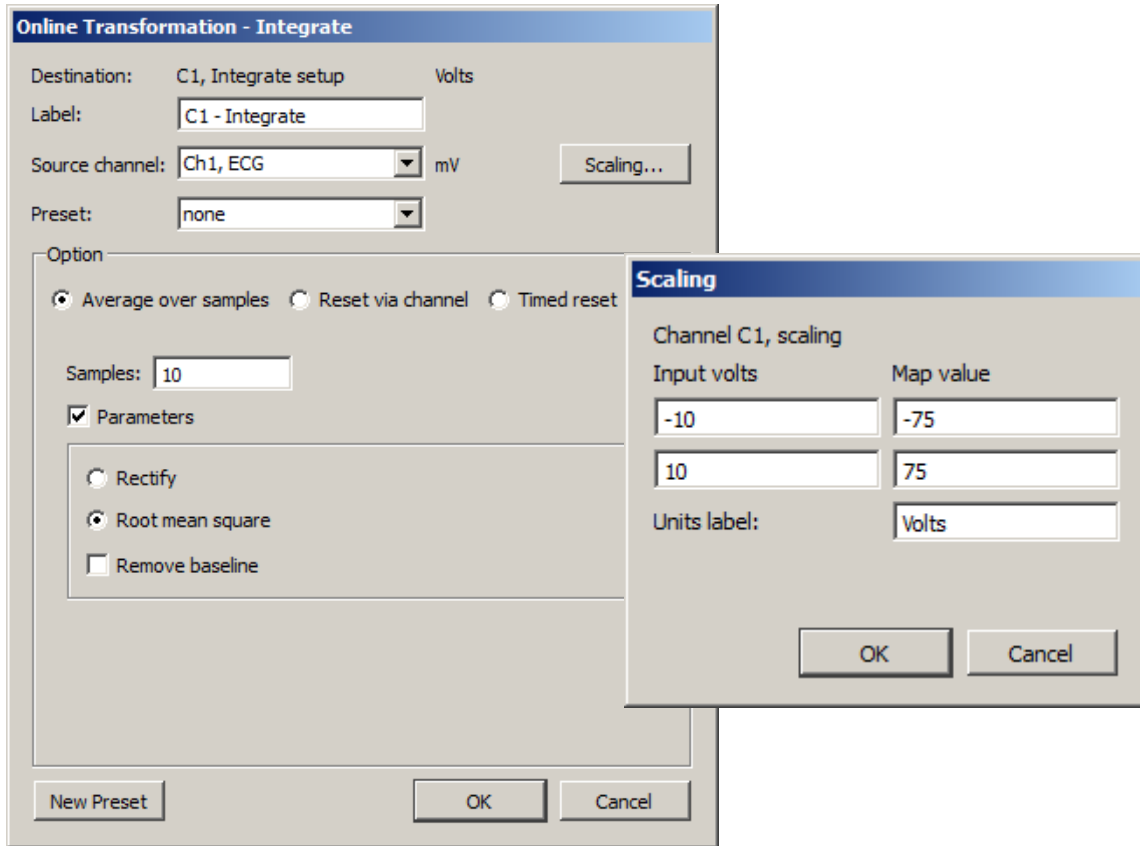
Integrate Calculation and Scaling dialogs for 10 point averaging

When data is averaged in this way, a portion of the data at the beginning of the record (equivalent to the number of samples being integrated) should be ignored, as they will reflect a number of zero values being averaged in with the first few samples of data.

Smoothing Calculation

The Smoothing Calculation functions online in real time and is very useful when trying to remove noise of varying types from a data set.

1. Choose MP > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. Check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Smoothing.
5. Click the Setup button in the Input Channels dialog to generate the Smoothing dialog.

(Off-line Smoothing is available under Transform > Smoothing.)

Source	Source is a pull-down menu of the available channels.
Smoothing factor	enter the number of samples to use as a smoothing factor.
Smoothing method	This calculation channel provides real-time Mean (default) or Median smoothing.
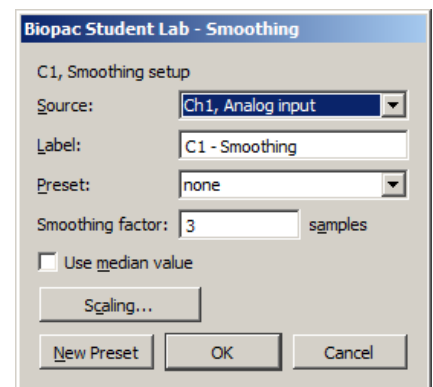
Mean value   The default is mean value smoothing. Use Mean value smoothing when noise appears in a Gaussian distribution around the mean of the signal.

Use Median value   Click in the box to activate Median value smoothing if some data points appear completely aberrant and seem to be õwild flyersö in the data set.

For a given sequence of wave data, $x = \{x_1, x_2,...,x_n\}$, Median value smoothing will sort the sequence and extract the median equivalent to the recommended NIST (National Institute of Standards and Technology) formula:

- n is odd: median is the center element of the sorted list of n items.

- n is even: median is the mean of the center pair of elements of the sorted list of n items.

The smoothing calculation channel is the primary method of computing real-time median values using the definition of median as given above. The smoothing output at a sample position is the median of the window of source channel samples including the current sample and the previous samples in the window.

The size of the window is 1 at the start of acquisition and increases incrementally until the final window size is reached. The median extraction method shifts between even and odd definitions as the window size is incremented.

Scaling   Click the Scaling button for access to options that modify the units or linearly scale the output.

Scaling

Channel C1, scaling

Input volts	Map value
-10	-10
10	10

Units label: Hertz

OK   Cancel
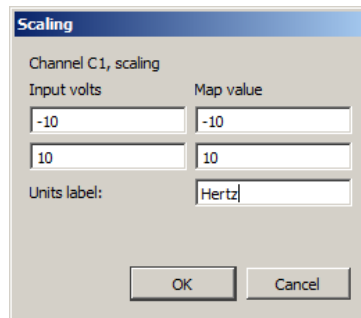
Difference Calculation

The Difference calculation returns the difference between two data samples over a specified number of intervals and divides the Difference by the time interval spanned by the data values. The Difference Calculation is useful for calculating an approximation of the derivative of a data set in real time.

To have BSL *PRO* perform a Difference calculation in real time:

1. Choose MP > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. Check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Difference.
5. Click the Setup button in the Input Channels dialog to generate the Difference dialog.

The Difference Calculation dialog is used to specify the source channel and the number of intervals between samples over which the difference is to be taken/ It also includes the option of rescaling the channel to reflect different units.

Click the Setup button in the Input Channels dialog to generate the Difference dialog:
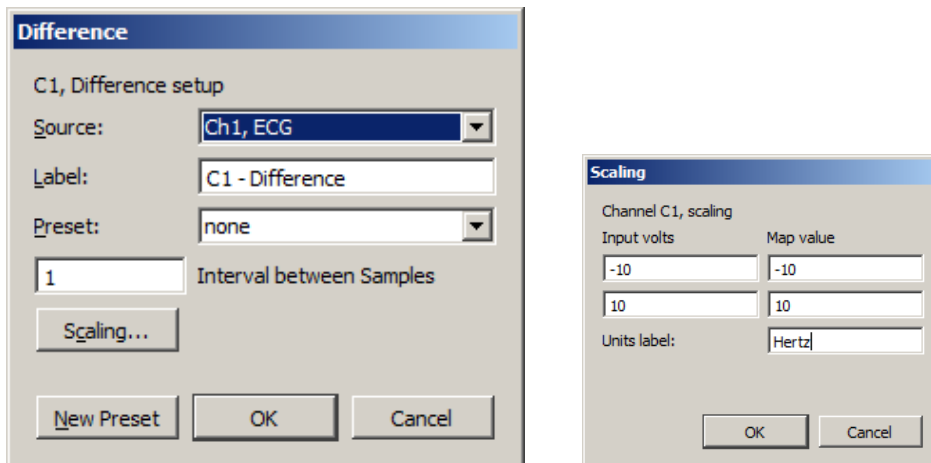
Source	When the Source channel contains relatively high frequency data, the Difference Calculation may result in a very noisy response, so it's best to use Difference on relatively smooth data.
Sample rate	This line provides the sample rate for the selected channel (may be different than the acquisition sample rate).
Intervals	Difference is calculated with respect to the number of intervals between points (rather than the number of sample points). For instance, two sample intervals span three sample points:

POINT<interval > POINT<interval > POINT

A 1-interval difference transformation applied to a blood pressure (or similar) waveform will result in the widely used õdP/dTö waveform.

✓ See page 270 for a complete description of the online Difference function.

Rate Calculation
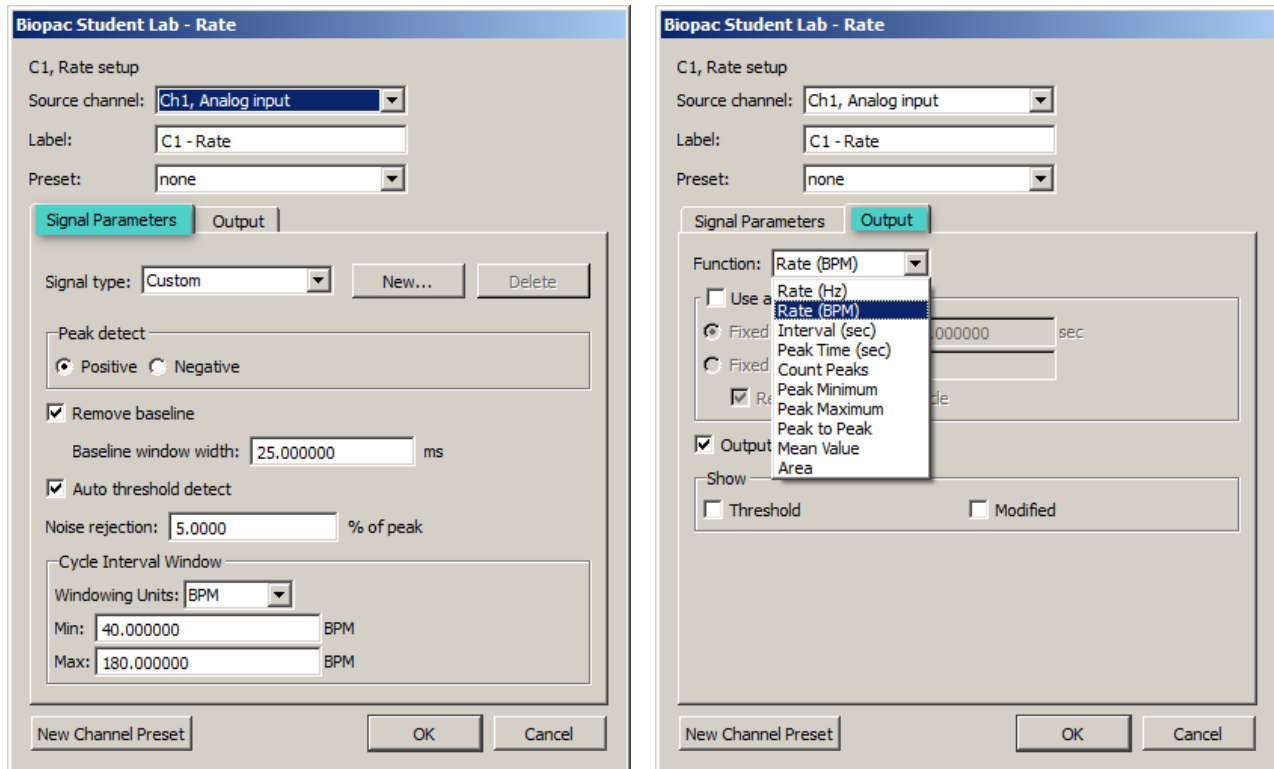
The Rate Calculation is used to extract information about the interval between a series of peaks in a waveform. This interval can be scaled in terms of BPM (the default), frequency (Hz), or time interval between peaks.

> ➢   The BPM (or beats-per-minute) Rate function is used as a measure of peaks or events that occur in a sixty-second period.

> ➢   The frequency rate function is commonly used to describe the periodicity of data, or the amount of time it takes for data to complete a full cycle (from one peak to the next peak).

> ➢   The Interval Rate function returns the raw time interval between each adjacent pair of peaks, which is essentially the inter-beat interval (IBI), frequently used in cardiology research.

These three functions essentially provide the same information in different formats, since a frequency of 2Hz is equal to an inter-peak interval of 0.5 seconds, both of which are equivalent to a BPM of 120. Other options allow recording of the maximum or minimum value of all peaks (the peak max/min option), or to count the aggregate number of peaks (the count peaks option).

In order to calculate Rate information, there are two options: Sspecifying the threshold manually or having BSL *PRO* automatically compute the default threshold value. This section describes the basic parameter settings for typical online Rate Calculations.

> NOTE: Parallel functions can be performed <u>after</u> data has been acquired. A detailed description of the Rate Calculation options can be found in the Find Rate section on page 294.

To perform a Rate Calculation in real time:

1.   Choose MP > Set Up Data Acquisition > Channels.
2.   Click the Calculation tab.
3.   Check an Acquire box for the Calculation channel to contain the filtered data. Check the Plot and Values boxes as appropriate for each channel.
4.   Click the Preset pull-down menu and select Rate.
5.   Click the Setup button in the Input Channels dialog to generate the Rate dialog.

Sourceô selected from the Source popup menu at the top of the dialog.

Labelô Use to create a label for the Rate channel

Presetô Use to select from 17 pre-defined calculation channel presets. New presets affecting source channel, label and output settings can be created and saved by clicking õNew Channel Preset.ö

Signal Parameters Tab

Signal Typeô Contains parameters for specific human and animal waveform morphologies. Choose from six pre-defined heart rate and respiration signal types, or click õNewö to create and save custom setups. Unlike channel presets, all pre-defined and custom signal types appear in both calculation channel Rate (online) and analysis Rate (offline) dialogs. Signal type modifications affect settings in the Signal Parameters tab only. For more details on Rate signal types, see page 297.

Peak Detectô Choose whether to look for positive or negative peaks in the signal.

Remove baselineô provides the exact standard deviation of the input data (typically EMG) over the specified number of samples. When the mean of the input data equals 0-0, the standard deviation and the RMS will be equivalent.

Baseline window widthô Width of the window for the difference operation applied prior to peak detection. (E.g. the value of the source x ms previously is subtracted from the current value to generate the signal that is analyzed with the peak detection.)

Auto Threshold detectô The most convenient way to calculate a Rate channel online is to have BSL *PRO* automatically compute the threshold value (the õcutoffö value used to discern peaks from the baseline). This is done by checking the Auto Threshold detect box.

Noise rejectionô BSL *PRO* constructs an interval around the threshold level when Noise rejection is checked. The size of the interval is equal to the value in the noise rejection text box, which by default is equal to 5% of the peak-to-peak range. Check this option to help prevent noise õspikesö from being counted as peaks.

Cycle Interval Windowô When õautomaticö Rate Calculations are set, specify a minimum rate and a maximum rate. These parameters define the range of expected values for the Rate Calculation. By default, these are set to 40 BPM on the low end and 180 BPM on the high end.

The Rate Calculation will use these values to find and track the signal of interest, assuming the input BPM range is reasonably well bracketed by these values. Depending on the shape of the input cycle waveform, the Rate window settings may be closer or further from the expected rates.

➢ For ECG-type data (where the waveform peak is narrow with respect to the waveform period), the Rate window values will closely bracket the expected values.

➢ For more sinusoidal data, with the waveform energy distributed over the waveform period (as with blood pressure or respiration), the Rate window will closely bracket the expected rate on the high-end, but can be up to twice the actual measured rate at the low-end.

Windowing Unitsô Use to select the unit type to be used in the rate detection. The options are Hz, BPM and seconds.

Output Tab

Function ô The popup menu includes options to scale the rate in terms of Hz, BPM, Interval, Peak Time, Count Peaks, Peak Minimum/Maximum, Peak-to-Peak, Mean Value, or Area.

➢ For more information on each of these functions, see the Calculation Channels section beginning on page 116.

➢ Calculate systolic using the peak maximum Function, diastolic using the peak minimum Function, and mean blood pressure using the mean value Function.

➢ NOTE: All of these Function options are available in the post-acquisition mode through the Analysis > Find Rate function

Use Averaging mode—Use to average to output of the selected function. Averages can be based upon a fixed time window or a fixed number of cycles. The ─Recompute on every cycleøoption will start the averaging output after *N* numbers of cycles are detected and then remain fixed until the next *N* cycles are detected.

Output reset events (not available for metachannels)ô When auto threshold detection is being used, the minimum and maximum rates of the signal are specified in the Windowing controls. If the input signal falls out of this range, the value of the rate function and automatic threshold level will be reset. By enabling õOutput reset eventsö a reset event will be placed on the output at the location of these window expirations. Rate detector is set to õPeak function, default window of 40 BPM to 180 BPM, auto threshold detect for positive peaks. The reset event occurs after the window expiration, approximately a full 40 BPM interval after the õpeakö transition from 0 to 5 volts in the source signal.
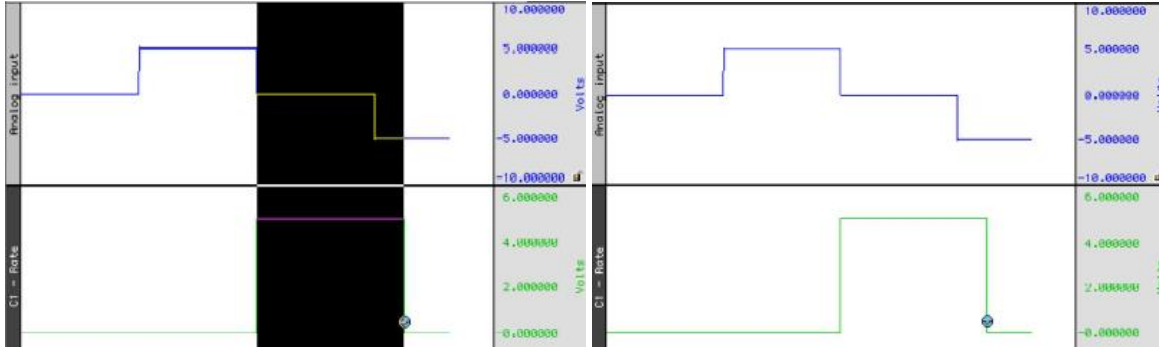
Show Thresholdô Plots the threshold used by the Rate calculation function. This feature is useful to help the rate detector performance on any given data.

Show Modifiedô Plots the modified data as processed by the Rate Detector. Typically, the modified data is a differential version of the original input data. The data will be modified if the õremove baselineö feature is checked in the Find Rate Setup dialog.

Math Calculation

The Math Calculation performs standard arithmetic calculations using two waveforms or one waveform and a constant. It is also possible to use other Calculation channels (such as a Rate Calculation channel) as an input channel for a Math Calculation channel, as long as the Calculation channel used as a source channel has a lower channel number than the Math Calculation channel.

1.   Choose MP > Set Up Data Acquisition > Channels.
2.   Click the Calculation tab.
3.   Check an Acquire box for the Calculation channel to contain the filtered data. Check the Plot and Values boxes as appropriate for each channel.
4.   Click the Preset pull-down menu and select Math.
5.   Click the Setup button in the Input Channels dialog to generate the Math dialog.

Use the pull-down Source menus to select the source channels (Source 1 and Source 2).

The Sample rate line provides the sample rate for the channel selected as Source; the channel sample rate may be different than the acquisition sample rate.

Use the pull-down Operand menu to select a function. In the example below, analog channel 1 (Source: A1) is added to analog channel 2 (Source: A2). To use this summed waveform as an input for another Math Calculation channel. One useful application would be to divide this waveform (C0) by K, where K=2, thus producing an arithmetic average of source channels A1 and A2.
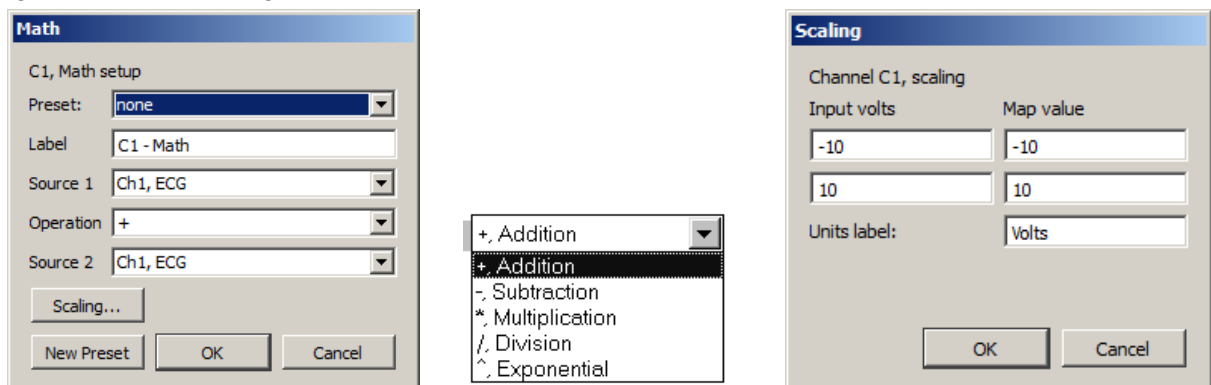
The õConstantö entry is activated when õKö is selected as a Source.

As an alternative to creating an additional Calculation channel for dividing the summed waveform, the scaling function can be used to perform the same task. To do this, click Scalingí button and then set the Map (Scale) value for the summed waveform equal to +5 and ó5 (to correspond to Input Volts values of +10 and ó10 respectively). This will effectively plot the sum of channels A1 and A2 as the arithmetic mean of the two waveforms.

> For additional libraries of online Calculation options, consult the sections on Function Calculation channels and the online Equation Generator (Expression, page 135). These types of Calculation channels can be used to perform more complex operations on waveforms. Although Calculation channels can be õchainedö together (so that the output from one serves as the input for another) to form more complex calculations, a separate channel must be used for each function. Since only sixteen Calculation channels are available, not all calculations can be performed. Additionally, chaining more than three or four channels together can require considerable system resources.
>
> For complex calculations (such as squaring a waveform then adding it to the average of two other waveforms) the Equation Generator (Expression) is a more efficient solution. All of the features available online in the Math Calculation channels can also be computed after an acquisition using the Waveform Math option (see page 273), which will eliminate the problem of system overload.

Function Calculation
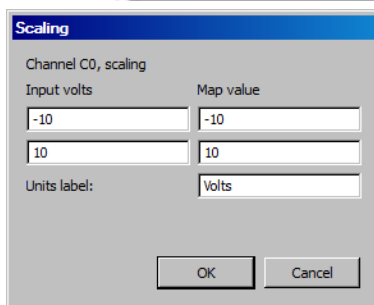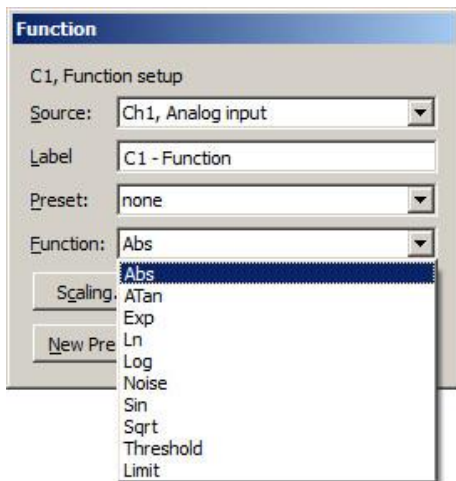
The Function calculation can be used to perform a variety of mathematical functions using two waveforms or a waveform and a constant. Function Calculation channels compute new waveforms in a manner similar to the math Calculation functions, but provide access to higher order functions. Like math Calculation channels, function Calculations can be chained together to produce complex functions (such as taking the absolute value of a waveform on one channel and Calculating the square root of the transformed waveform on another channel). These same functions are also available under the transform menu in BSL *PRO* for *post-hoc* operations. Many of these functions can also found in the online Equation Generator (see Expression on page 135 for details).

To have BSL *PRO* perform a Function Calculation in real time:

1. Choose MP > Set Up Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. Check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Filter.
5. Click the Setup button in the Input Channels dialog to generate the Function dialog.

Other Functions are available in the online Expression calculation channel (see Expression on page 135). Function Calculations can be chained together to produce more complex Calculations, although it is more efficient to program complex functions using the Equation Generator (Expression).

The Sample rate line provides the sample rate for the selected channel (may be different than the acquisition sample rate).

Function

Function	
Abs	Returns the absolute value of each data point
Atan	Computes the arc tangent of each data point
Exp	Takes the e^x power of each data point
Limit	Limits or "clips" data values that fall outside specified boundaries

Ln   Computes the base e logarithm for each data point
Log   Returns the base 10 logarithm of each value
Noise   Creates a channel of random noise with a range of ± 1 Volt
Sin   Calculates the sine (in radians) of each data point
Sqrt   Takes the square root of each data point.

Threshold   Converts above an upper threshold to +1 while converting data below a lower threshold to 0.

Thresholding Algorithm Assume a domain variable $t \in \{t_{start}, t_{start} + 1, t_{start} + 2, \mathrm{K}\ \}$

with t_{start} being an integer, a real-valued signal y(t) defined for all t, and two real valued levels y_{low} and y_{high} satisfying the relation $y_{low} \leq y_{high}$.

Define the Threshold function thresh(t) function such that:

$$thresh(t_{start}) = \begin{cases} 1 & y(t_{start}) \geq y_{low} \\ 0 & y(t_{start}) < y_{low} \end{cases} \qquad thresh(t) = \begin{cases} 0 & y(t) < y_{low} \\ 1 & y(t) > y_{high} \\ thresh(t-1) & y_{low} \leq y(t) \leq y_{high} \end{cases}$$

Filter Calculation

The Filter Calculation channel is used for performing real time digital filtering on analog, digital, or calculation channels. To apply a digital Filter Calculation in real time:

1. Choose MP > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. Check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Filter.
5. Click the Setup button in the Input Channels dialog to generate the Filter dialog.
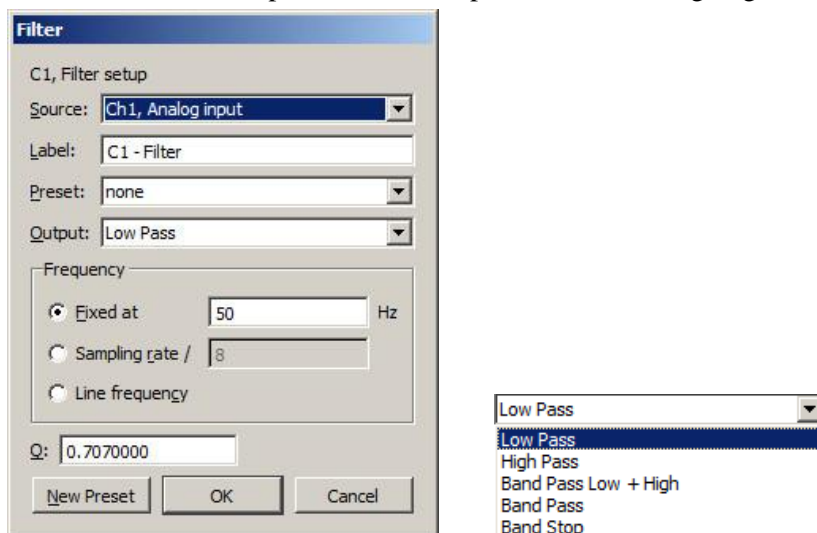
Filter Setup & Output Options

In the dialog above, the signal on analog channel one (A1) is run through a low-pass filter that attenuates data above 50 Hz. The õQö for this filter is 0.707, which is the default.

> One possible application of the online filtering option is in conjunction with the Show Input Values option (see page 206). Raw EEG data, for instance, can be filtered into distinct bandwidths (alpha, theta, and so forth) using one source channel and multiple filter Calculation channels. The filtered data can then be displayed in a bar chart format during the acquisition using the Show Input Values option.

Source   Set the source channel.
Sample rate   provides the sample rate for the selected channel (may be different than the acquisition sample rate).

Type (Output)	Lists the filter options: low pass, high pass, band pass, band pass (low + high), band stop, and comb band stop. See *About Filters* in this section for more details on filter types.
Frequency	Fixed valueô Type a value in the entry box.
	Sampling rateô Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.
	Line frequencyô Uses the line frequency at which the data was recorded.
Q coefficient	The online filters are implemented as IIR (Infinite Impulse Response) filters, which have a variable Q coefficient. The Q value entered in the filter setup box determines the frequency response patterns of the filter. This value ranges from zero to infinity, and the õoptimalö (critically damped) value is 0.707 for the Low pass and High pass filters, and 5.000 for the Band pass and Band stop filters. The Q can be changed if desired. A more detailed explanation of this parameter, and digital filters in general, can be found in Appendix B.

About Filters

While the technical aspects of digital filtering can be quite complex, the principle behind these types of filters is relatively simple. Each of these filters allows a cutoff point to be set for the low and high pass filters or a range of frequencies to be set (for the band pass and band stop filters).

➢ A Low Pass filter is used for specifying a frequency cutoff that will õpassö or retain all frequencies below this point, while attenuating data with frequencies above the cutoff point.

➢ High Pass filters perform the opposite function, by retaining only data with frequencies above the cutoff, and removing data that has a frequency below the specified cutoff.

➢ Each type of Band Pass filter is optimized for a slightly different type of task.

The Band Pass (low + high) filter is designed to allow a variable range of data to pass through the filter. For this filter, itøs necessary to specify a low frequency cutoff as well as a high frequency cutoff. This defines a range or õbandö of data that will pass through the filter. Frequencies outside this range are attenuated. The Band pass (low + high) is actually a combination of a low pass and a high pass filter, which emulate the behavior of a band pass filter. This type of filter is best suited for applications where a fairly broad range of data is to be passed through the filter. For example, this filter can be applied to EEG data in order to retain only a particular band of data, such as alpha wave activity.

The alternative Band Pass filter requires only a single frequency setting, which specifies the center frequency of the band to be passed through the filter. When this type of filter is selected, the õwidthö of the band is determined by the Q setting of the filter (discussed in detail below). Larger values for q result in narrower bandwidths, whereas smaller Q values are associated with a wider band of data that will be passed through the filter. This filter has a bandwidth equal to Fo/Q, so the bandwidth of this filter centered on 50 Hz (with the default Q=5) would be 10 Hz. This type of filter, although functionally equivalent to the band pass (low + high) filter, is most effective when passing a single frequency or narrow band of data, and to attenuate data around this center frequency.

➢ The Band Stop performs the opposite function of a band pass. A Band stop filter defines a range (or band) of data and attenuates data within that band. In this case, the Band stop filter is implemented in much the same way as the standard Band pass, whereby a center frequency is defined and the Q value determines the width of the band of frequencies that will be attenuated.

Off-line filtering

Apart from these online filter options, similar filters can be applied after an acquisition is terminated. Many of the biopotential amplifiers available from BIOPAC have selectable filters, which allows the filtering of certain frequencies (including 50 Hz or 60 Hz electrical noise) and can reduce the need for online filters.

Digital filtering can also be performed after an acquisition. Select various filter types by selecting Digital filters from the Transform menu. The filters available after the acquisition use a different algorithm but operate in essentially the same way.
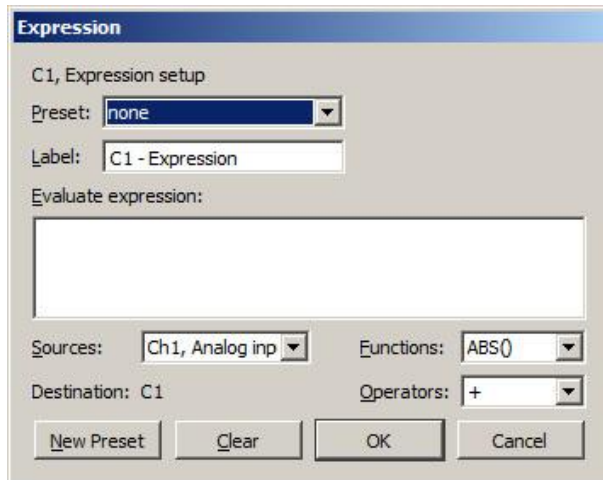
Expression

The online Expression calculation channel is available for performing computations more complex than possible in the Math and Function calculations. The Expression calculation will symbolically evaluate complex equations involving multiple channels and multiple operations. BSL *PRO* can perform conditional evaluation, data extraction, logical operations, expressions requiring a range of samples or the results of the previous expression, and evaluation of generic formulas that can be expressed in a closed, recursive form.

Unlike the Math and Function calculationsô which can only operate on one or two channels at a timeô the Expression calculation can combine data from multiple analog channels, and allows other Calculation channels to be specified as input channels for Equation channels. In addition, computations performed by the Expression calculation eliminate the need for õchainingö multiple channels together to produce a single output channel.

While the Expression calculation is more powerful than other Calculation channels, each Expression calculation requires more system resources than other Calculations. This essentially means that acquisitions that utilize Equation calculations are limited to a lower maximum sampling rate than acquisitions without online Expression functions. When an expression is evaluated, it is actually evaluated multiple times. The expression is computed starting at the first sample acquired, and is then evaluated once for each successive acquired sample.

BSL *PRO* can accept the notations SC, MC, and CHn to reference the sample at the current evaluation position or $SC(x)$, $MC(x)$, and $CHn(x)$ for values at locations prior to the present evaluation location using an offset expressed in sample intervals. For example, CH1(-1) will give the previous sample of Channel 1.

The same features that are available in online Calculation channels are also available under the Transform menu for evaluation of complex equations after acquisition. Thus, simple Calculations such as summing two channels or dividing one channel by another (and so forth) are best performed in either the Math calculation channels or the Function calculation channels.

On the other hand, for complex Calculation channels, such as squaring one channel, multiplying it by the sum of two other channels, and dividing the product by the absolute value of another waveform, a single Expression calculation channel is more efficient than chaining five Math and Function calculation channels.

Save to Calculation Channel

To evaluate an expression and save the result to a Calculation channel in real time:

1. Choose MP > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. Check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Expression.
5. Click the Setup button in the Input Channels dialog. This will produce a dialog for entering the expression to be evaluated.

The different components of each expression can be entered either by double-clicking buttons from the button rows (sources, functions, and operators) in the setup expression dialog, or by typing commands directly into the Equation box. The Expression uses standard mathematical notation.

For each expression, itøs necessary to specify at least one source, the function(s) to be performed, and any operators to be used. Sources are typically analog channels, although Time may also be selected from the source button row and BSL *PRO* will return the value of the horizontal axis for each sample point. When the horizontal axis is set to frequency (in the Display > Horizontal axis dialog), the õtimeö item in the source button row will switch to õfrequency.ö

When using the online Expression calculation channel, it is important to keep in mind that while different channels, functions, and operators can be referenced, the Calculation cannot reference future sample points. That is, data from waveform one can be transformed or combined in some way with data from waveform two at the same point in time, although data from one point in time (on any channel) cannot be combined with data from another point in time (on any channel). See the section on post-acquisition expression commands (beginning on page 272) for ways around this limitation.

Functions	The arguments to each function are represented in the Functions table in italics and may be replaced by any valid expression. Each argument is separated from its next argument by a comma. Expressions can only contain commas within balanced parenthesis pairs. An ellipsis (õ...ö) at the end of a function description indicates that any number of arguments may be present provided they are in a comma separated list. When a function is added to an Expression, the cursor is placed between the parentheses.
Conditionals	Change output based upon a condition test. All of the conditionals treat the value zero as false and any non-zero value as true. Expressions can only contain commas within balanced parenthesis pairs.
Offset Notation	Offset notations take integer offsets in terms of the number of samples using the formation CH#(P) *where* CH# is the channel number and P is the number of points. For example, an offset of -1 will return the data point immediately to the left of the selected point and an offset of +1 will return the data point immediately to the right of the selected point.
	To refer to previously acquired data, offsets must be negative. For notational convenience, offsets that result in an invalid negative sample position (e.g. no data is defined prior to the first sample in the graph) evaluate to zero. Any attempt to access a sample beyond the end of the data will result in an error. Any attempt to use a positive offset for an online Equation Generator (Expression calculation channel) will result in an error.
CH$n(x)$	Returns the value of channel with index n x samples away from the current evaluation position.
SC(x)	Returns the value of the selected channel x samples away from the current evaluation position. Only allowed for Transformations and Measurements; not allowed for Calculations.
MC(x)	When x is zero or positive, returns the value of the measurement channel x samples away from the current evaluation position. When x is negative, returns the result of the expression evaluation that occurred x steps previous to the current evaluation position. Only allowed for Measurement Expressions (see below); not allowed for Calculations or Transformations.
Recursive notation	Since transformations and calculation channels replace the source data of the channel with the result of the expression evaluation in sequence, negative offsets are equivalent to returning the final result of the expression that was evaluated a certain number of steps in the past. The channel where the expression results are stored can be thought of as a storage record of the previous evaluation steps. Negative sample offsets, therefore, can be used to compute any formula that can be expressed in closed recursive form. For example, the recursive definition of the Fibonacci sequence is:

$$F_n = F_{n-1} + F_{n-2}$$

To evaluate this as an expression transformation, use the expression:

$$SC(-1)+SC(-2)$$

Note that to actually get the Fibonacci sequence, the selected channel would need to have a constant value of one prior to the transformation.

Expression Measurement

Measurements are powerful tools for quick manual analysis and also for advanced automated analysis when combined with the Cycle/Peak detector. Expression measurements extend measurements to evaluate simple formulas or complex data reduction. Each Expression measurement has an expression associated with it and the measurement result is derived from computing the Expression(s) on the selected data.

Measurement expression dialog is generated the first time a measurement is set to Expression or when the measurement õinfoö button is clicked.

Preset menu allows access to pre-loaded commonly used expressions and displays user-defined custom presets, along with a list of recently-used expressions.

OK invokes a syntax check. If there is an error, the user will be prompted to correct the error and the error will be selected (highlighted) in the Expression edit field.

Cancel discards any changes to the Expression measurement and reverts back to the previous Expression.

Clear erases the current contents of the expression edit field.
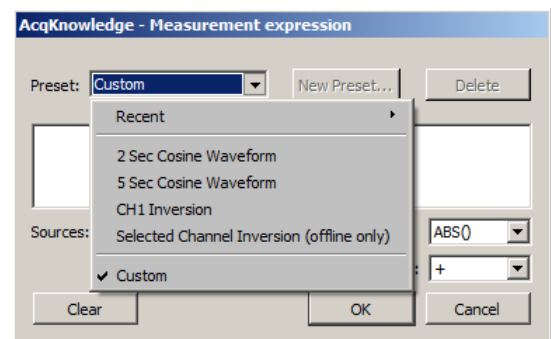
Measurement Channel

Expression measurements can reference the õmeasurement channelö (MC), which refers to either the selected channel or a specific channel as set in the measurement channel selection box within the graph window.

Negative sample offsets to MC are interpreted as returning the result of the Expression from a prior step. Transformations and calculation channels achieve this as they replace the contents of their destination channels sequentially. Measurements, however, do not actually replace the data of their source channels. Expression measurements are actually executed on a temporary copy of the channel data in memory. This implies that negative indicies to the measurement channel are interpreted exactly the same for measurements as for transformations and calculation channels even though the õtransformedö data of the measurement is not visible. Negative sample offsets to MC that refer to the sample position prior to the leftmost sample of the selected area will always return zero.

Evaluation Rules

When a new selection is made, the first step in evaluation searches through the Expression measurement for any MMT() invocations. Any measurement whose value is needed by MMT() is computed at this time prior to the Expression evaluation. This behavior is similar to calculation channels and successfully allows measurements to the right and bottom of the Expression measurement to be used in the expression.

The expression is subsequently evaluated from the leftmost sample in the selection to the rightmost sample. It is evaluated at the waveform sampling rate of its source channel, with one expression evaluation per sample contained within the selected area. Interpolation is not used at the boundaries to maintain a consistent sample interval for the expression. After each expression evaluation, the result is cached in memory for potential negative MC result references.

The value of the final expression, the rightmost sample, becomes the result of the measurement.

Circularity Detection

Expression measurements may reference other expression measurements or calculation measurements by using the MMT() function in the expression. This raises the possibility of circular dependencies being formed by the user if a measurement expression either directly or indirectly needs its own value to compute a MMT() invocation. Circular dependency checking will be in place at execution time and will result in an error.

To refer an Expression measurement to its own value, use the MC notation.

Error Reporting

The Expression measurement result will display the text õErrorö if there are syntax errors in the Expression measurement, errors computing measurements referenced by MMT(), or a circularity.

Validation Tip   To function correctly, BSL *PRO* requires real-valued data. Make sure that expression results are real-valued. To test if a floating point number x is a real-valued number, use the expression:

$$NOT(OR(ISINF(x), ISNAN(x)))$$

Note for variable sample rate processing:

The Expression and Waveform Math functions will constrain operations between waves of different rates as follows:

If an equation is operating on two or more waves of different sample rates, the result of the operation will always be output at the lowest sampling rate from the waves (F low). If the destination channel for the result has an assigned rate other than (F low), the operation will not be permitted. If the destination channel is set to a new channel, the operation will always be permitted.

In BSL *PRO* and higher, all sources for Expressions and Waveform Math operations must be sampled at the same waveform sampling rate.

VSR data padding· If the channels are of unequal length (as a result of variable sampling rate or waveform editing), they will be padded for Append acquisition. Digital and Analog channels are stored as short integers by default; a waveform paste into a digital or analog channel, however, will result in its underlying data being converted to floating point. This will generate the %Abort/Replace+warning for pastes to Digital or Analog channels since the data format has changed since the last acquisition.

Additionally, if an Analog or Digital channel is used as the source waveform for a Copy, it will also be converted to floating point and will result in the %Abort/Replace+warning being generated.

Since Calculation channels are already floating point, pasting into them or copying from them will not change their data format. The channels will be padded with their last value and the append will commence.

Waveform Cut operations do not change the underlying data format for Analog, Calculation, or Digital channels. If only Waveform Cut is used, no data format conversion will occur and channels will be padded with their last value and subsequent appends are allowed.

Source	Description
CH	Value of the designated channel (CH*n*) at the current evaluation step.
Primary Source Channel *metachannels only*	Appears as PSC in the dialog. Refers to the data of the primary source channel of a metachannel.
Time	Time (in sec) of current evaluation step
Sample	Sample index of evaluation step; the first sample in the graph will always be reported as a value of zero.
Pi	Value of pi (3.1415926540) to double-precision accuracy.
SC	*Transformation and measurement only* Value of the selected channel at the current evaluation step; can still back-reference samples points.
True	Evaluates to the value 1 (non-zero values are interpreted as True)
False	Evaluates to the value 0
Segment Timer	Used as a source for the onscreen Stopwatch gauge view.
Random	Generates random white noise.
Gaussian Random*	Generates Gaussian white noise for startle responses. Returns a random value from a Gaussian distribution.

Operator	Operation
+	Addition
-	Subtraction
*	Multiplication
/	Division
^	Power
(	Open parentheses
)	Close parentheses

*Standard Gaussian model; useful for peak fitting.

param(0)*EXP(-((TIME-param(1))/param(2))^2

FUNCTION	RESULT
ABS	Returns the absolute value of each data point.
ACOS	Computes the arc cosine of each data point in radians. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)

AND(*x, y, …*)	Computes a logical %and+operation for its arguments. Accepts up to eight (8) arguments and evaluates to
	    1 if all of its arguments are non-zero values.
	    0 if one of its arguments is zero.

ASIN	Calculates the arc sine of each value in radians. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
ATAN	Computes the arc tangent of each sample point in radians. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
CEIL(*x*)	Computes the ceiling function (the closest integer larger than the value x).

COND(T, A, B, C)	Three-way conditional takes four arguments:
	        COND(*test_expr*, *neg_test_value*, *zero_test_value*, *pos_test_value*)
	Evaluates test_expr and if
	    < 0, returns neg_test_value
	    = 0, returns zero_test_value
	    > 0, returns pos_test_value

COS	Returns the cosine of each data point in radians. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
COSH	Computes the hyperbolic cosine of each selected value

EQUAL(*x, y, …*)	Performs a Logical equal (numerical comparison) of its arguments. Accepts up to eight (8) arguments and evaluates to
	    1 if all of its arguments are equal.
	    0 if one of its arguments is not equal to the others.

EXP	Takes the e^x power of each data point..
FLOOR(*x*)	Computes the floor function (the closest integer less than the value x).

IF(T, A, B)	Two-way conditional takes three arguments:
	IF(*test_expr*, *true_value_expr*, *false_value_expr*)
	The conditional evaluates test_expr and if
	    non-zero, returns true_value_expr
	    0, returns false_value_expr

ISINF(*x*)	Filters out infinities and unrepresentable numbers from data; important because such values can cause erratic behavior in autoscaling and other operations. Use to test whether any expressions have resulted in floating point overflow and have generated numbers too large to be represented in the computer. Evaluates to
	    1 if x is inf, the floating point representation of infinity.
	    0 if x is NaN or a real-valued floating point number.

ISNAN(*x*)	%is not a number+can be used to test whether any expressions have resulted in floating point errors such as division by zero. Use to ensure that the output of transformations and equations does not produce numbers that BSL *PRO* cannot display. Evaluates to
	    1 if x is NaN, the invalid floating point number.
	    0 if x is inf or a real-valued floating point number.

LESS(*x, y*)	Performs a numerical comparison of its arguments and evaluates to
	    1 if x is less than y.
	    0 if x is greater than or equal to y.

FUNCTION	RESULT
LOG	Computes the natural logarithm of each value
LOG10	Returns the base 10 logarithm of each value
MAXIMUM	Returns the maximum value of all input arguments.
MiINIMUM	Returns the minimum value of all input arguments.
MMT(*row,col*)	*Transformation and measurement only* Evaluates to the result of a measurement being displayed in the graph, as specified by row and column. Use to scale by a result without having to manually enter the result. Row and Column for a measurement start as 0,0 for the top left measurement box; the fourth argument on the first row is accessed by MMT(0,3). For this function, the required measurement box must be displayed in the graph. Since the values of measurements may change during the course of an acquisition, calculation channel expressions cannot use this function.
MOD(*x,y*)	Computes the floating point modulus; returns integer portion of modulus. Example: MOD(5,2) evaluates to %1+

NOT(*x*)	Computes a logical negation of its argument. Evaluates to
	    1 if x is zero.
	    0 if x is non-zero.

OR(*x, y, …*)	Evaluates multiple variables; true if any are true. Computes a logical %or+operation for its arguments. Accepts up to eight (8) arguments and evaluates to
	    1 if any one of its arguments is non-zero.
	    0 if all of its arguments are zero.

ROUND(*x*)	Returns an integer closest in value to the argument. For example: round (2.4) = 2 round(2.5) = 3 round(-1.5) = -1 round(-1.6) = -2
SIN	Calculates the sine (in radians) of each data point in radians. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
SINH	Computes the hyperbolic sine for each sample point.
SQR	Performs the %sgn+sign extraction function. Evaluates 1 if x > 0, -1 if x = 0, and 0 if x = 0.
SQR	Squares each data point.
SQRT	Takes the square root of each data point.
TAN	Computes the tangent of each sample point in radians. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
TANH	Calculates the hyperbolic tangent of each sample point.
TRUNC(*x*)	Removes the fractional part of the number and returns an integer. For example: TRUNC(2.4)= 2 TRUNC(2.5)= 2 TRUNC(-1.5)= -1 TRUNC(-1.6)= -1 *Note* When used with scientific notation, TRUNC(x) applies only to the fractional portion after the exponential factor is taken into account: TRUNC(2.93E+4) = TRUNC(29300) = %29300+ Since 2.93e+4 (29,300) has no fractional portion, the number is returned unchanged. Similarly, TRUNC(2.931245E+4) = TRUNC(29312.45) = %29312+

XOR(*x, y, …*)	Logical exclusive OR; true if an odd number is true. Computes a logical %exclusive or+for its arguments (e.g. %one or the other, but not both+). Accepts up to eight (8) arguments and evaluates to
	    1 if an odd number of its arguments are non-zero.
	    0 if an even number of its arguments are non-zero or
	      if none of its arguments are non-zero.

Delay Calculation
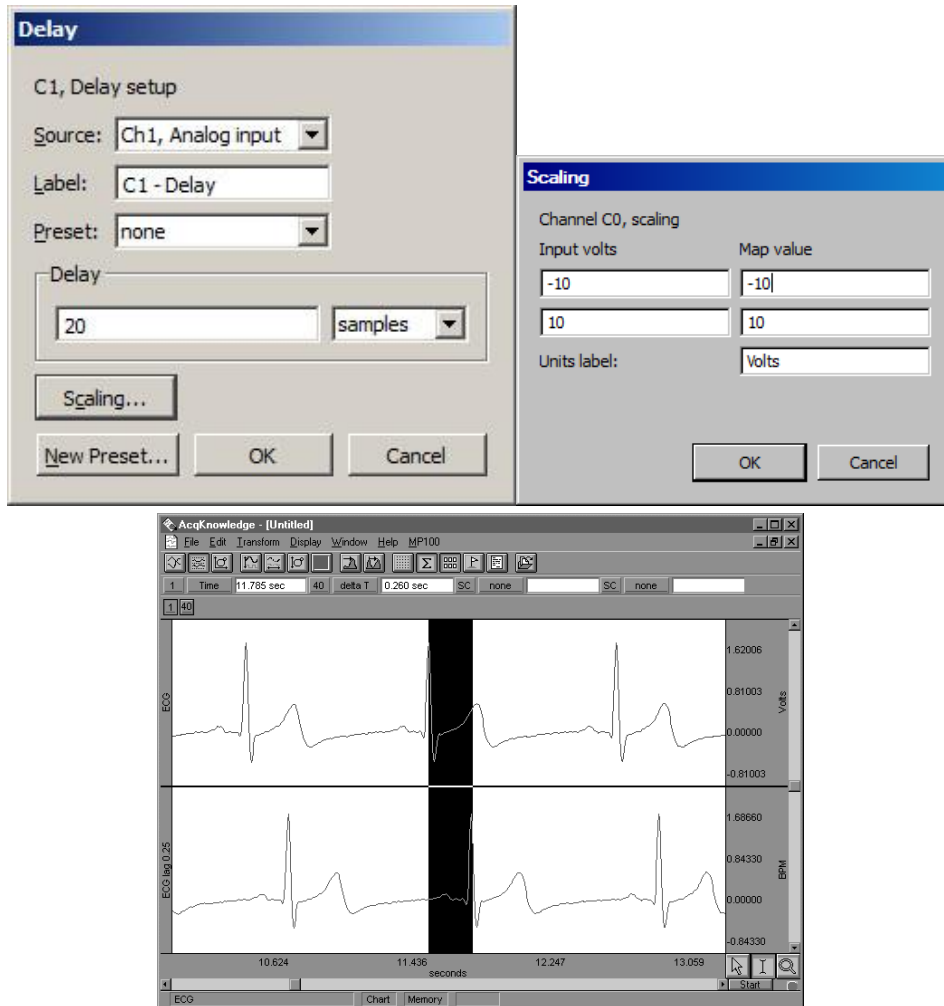
Delay setup dialog and resulting graph showing 20 sample delay

This option allows a Calculation channel to be used to plot another channel lagged (delayed) by an arbitrary interval. To apply a Delay Calculation in real time:

1. Choose MP > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. Check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Delay.
5. Click the Setup button in the Input Channels dialog to generate the Delay dialog.

The delay interval can be specified either in terms of samples or seconds. These types of plots are useful for producing non-linear (õchaosö) plots in BSL *PRO*øs X/Y display mode (see page 32 for a description).

When a delay channel is recorded, there is a segment at the beginning of the Calculation channel (equal to the value of the delay) that will read as 0 Volts. This is normal and occurs because the delay channel is waiting to õcatch upö with the original signal. BSL *PRO* fills this buffer with zeros until the delay channel begins to plot actual data. In the example below, the delay channel contains a 0.25-second interval of zeros at the beginning of data file.

Control Calculation
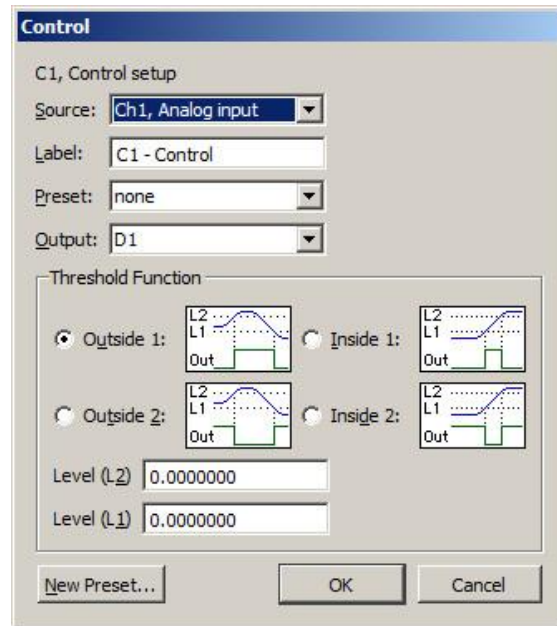
The Control function is used to output a digital pulse when the value for a specified input channel exceeds a certain level, falls inside a given range, or falls outside a given range. This feature is unique in that the output is on a digital channel (which ranges from I/O 1 through I/O 8) rather than a Calculation channel. Also, unlike other Calculation channels, this Control Calculation can only be performed in real time (i.e., while data is being acquired) and cannot be performed in post acquisition mode.

In addition to outputting a signal on a digital channel, the Control Calculation will also plot an analog version of the digital signal on the specified Calculation channel. For instance, in the example below, Calculation channel C1 is used to perform a control function using analog channel 1 (Ch1) as an input and digital channel 0 (D1) as an output. In addition to outputting a pulse on D1, the setup below will also produce a plot on channel 40 (the first Calculation channel) that emulates the signal being output on digital channel 1. Since Calculations are analog channels, the Calculation channel does not contain a õtrueö digital signal, but is a reasonably good approximation. To retain the physical output generated by a Control channel, the output digital channel should be looped back to another digital input channel of the MP unit and acquired as well as being connected to any external devices. The calculation channel values are not guaranteed to precisely match the actual digital output.

To have BSL *PRO* apply a Control Calculation in real time:
1. Choose MP > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. Check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Control.
5. Click the Setup button in the Input Channels dialog to generate the Control dialog.

There are four parameters that need to be specified for each Control channel:
a) Source channel   c) Type of threshold function
b) Output channel   d) Threshold level values

õSourceö refers to the input channel to be used for the Control function. As with other Calculation channels, the Control function can use either an analog channel or another (lower) Calculation channel as an input. In the previous example, analog channel 1 (Ch1) is used as the input channel. It is not possible to use a digital channel as an input channel for a Control Calculation.

Auto-plotting affects control channel timing accuracy.

The timing accuracy of control channels is dependent on the CPU load of your machine and MP unit communications latencies.

If you require timing accuracies less then 0.2 seconds, you should disable auto-plotting to reduce the CPU load. Turn off now?

[Turn Off]   [Leave On]

The channel selected in the Output Channel section determines which digital channel the pulse will be sent to. The digital channels range from 1 to 8 (D1 through D8. In the sample dialog shown, the digital pulse is sent over I/O line D1.

Digital channels have two levels, 0 Volts and +5 Volts. When the signal transits from 0 Volts to 5 Volts, an õedgeö is created and since the signal is going from low to high, this is referred to as a positive edge. Similarly, as the signal transits back from 5 Volts to 0, a negative edge is created. These transitions or edges can be used to trigger external devices when an analog signal level meets certain threshold criteria.

The Threshold Function option sets the criteria for the Control channel. Threshold conditions can be set so that the digital I/O line goes to +5 Volts when the conditions are met, or program the digital line to go to 0 Volts when the threshold conditions are met. Threshold conditions can be set so that either (a) the digital line is switched when the value of an analog channel exceeds a specified value or (b) the digital line is switched when an analog channel falls within a given range. BSL *PRO* also supports creation of a single level threshold or a õwideö threshold.

Tip   To use test conditions more complicated than simple thresholding, combine the conditional tests of Expression calculations with the Control channel to change digital output based on the Expression result.

For example, suppose itøs necessary to set a Control channel to switch digital line 5 from low to high whenever the signal for Calculation channel one (C1) exceeds 85 BPM. Set the source channel to C1 and the output to D5. Select the upper left graph in the control dialog and set L2 and L1 to 85, as shown:
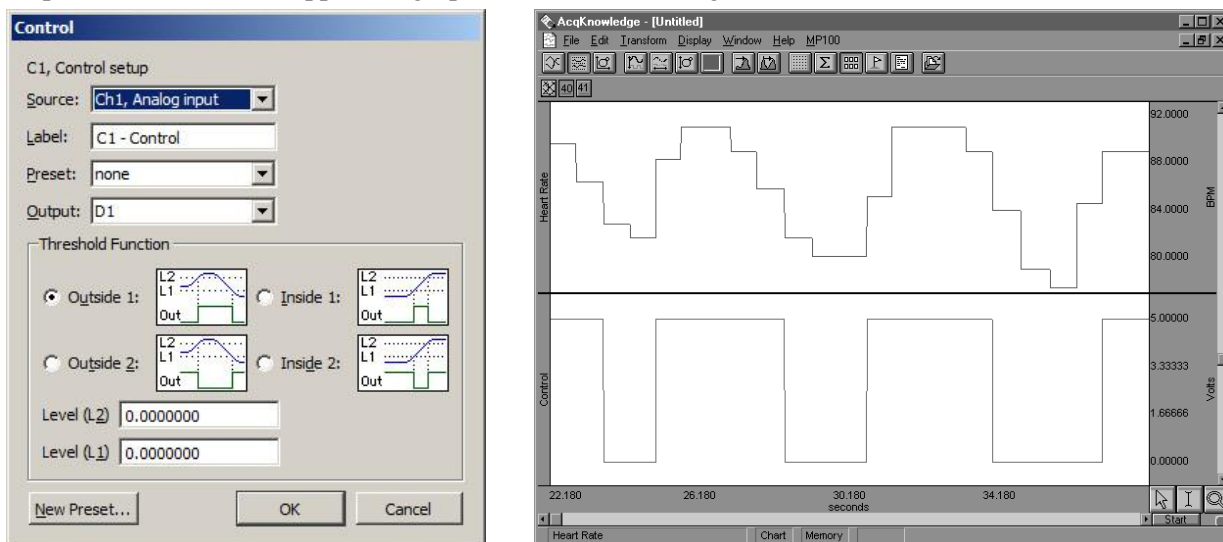
Control dialog and graph showing result of BPM control example

As shown in the preceding graph, there are a number of instances where C1 (heart rate) exceeds 85, usually for a short period of time. When it does drop below 85, it appears to return to a value greater than 85 within a second or two. In instances such as this, it might be useful to õwidenö the threshold so that the digital line is triggered whenever the input value is greater than 85, but the signal must drop significantly below the threshold value before the threshold is reset.

As another example, the upper threshold value (L2) is set to 85 and the lower threshold (L1) is set to 83, which means that the threshold will not reset until the signal from the source channel drops below 83. In the following example, the digital line is switched from low to high (from zero to +5 Volts) when the heart rate channel exceeds 85, and stays at +5 Volts for several seconds even though the source channel drops below 85 (but above 83). The digital line does not switch back to zero until the heart rate channel drops below 83 (toward the end of the record). Once this occurs, the threshold is reset and the digital line will switch again the next time the source channel exceeds 85 BPM.
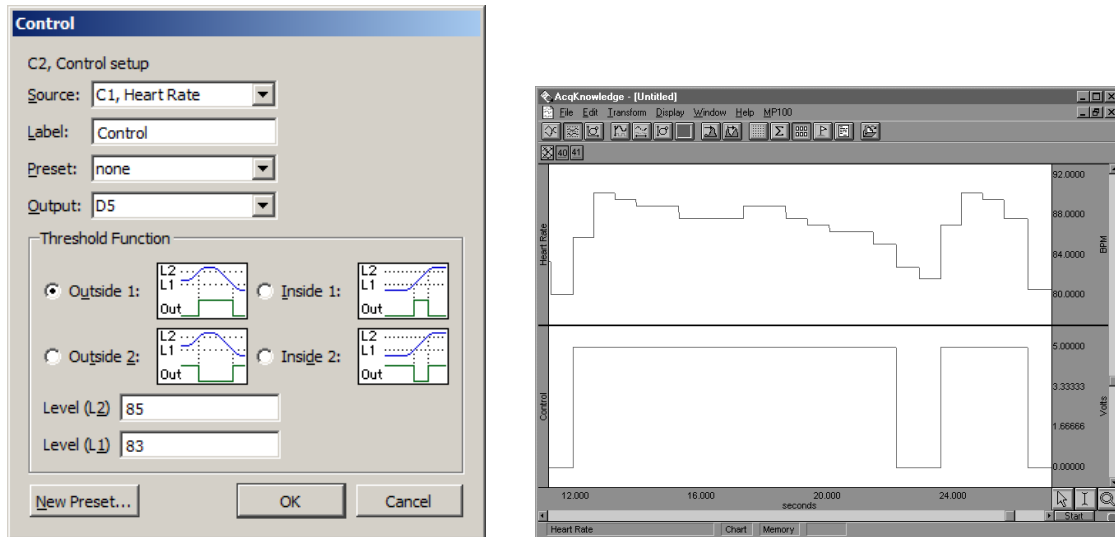
Control dialog and graph showing control channel with "wide" threshold

It is also possible to have the digital line switch when the source channel drops below a certain value. In the example below, a simple threshold is used to switch the digital line high each time the source channel drops below 50 BPM. Since L2 and L1 are set to the same value, this is not a õwideö threshold (as above) and the threshold resets each time the source channel goes above 50 BPM.
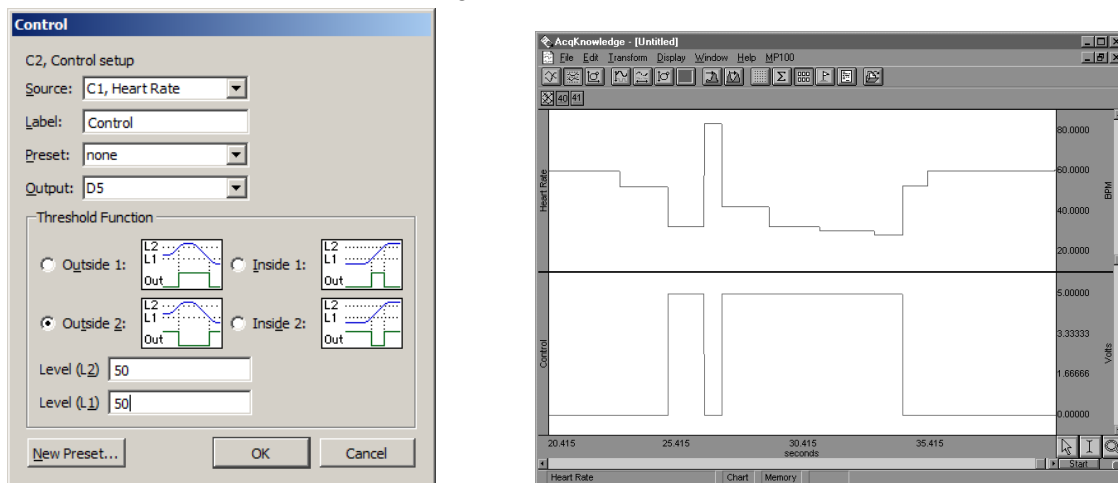
Control dialog and graph showing control channel detecting source channel levels less than 50 BPM

These examples are only a few of the possible applications of the control channel using the two threshold icons on the left-hand side of the Control Setup dialog. Variations of these examples not discussed above can be configured (i.e., switching the digital line from low to high using a wide threshold whenever the source channel drops below a given channel). Moreover, each of the options can be construed somewhat differently than presented here. For example, the previous example switches the digital line from low to high each time the signal on the source channel drops below 50 BPM. Conversely, it also switches from high to low each time the source channel value is greater than 50 BPM. This allows varying the default setting for the digital channels (whether the default is zero or +5 Volts) depending on what types of devices are connected.

In addition to setting õabove and belowö type thresholds, the Control channel can be programmed such that the digital line is switched whenever the source channel falls within a given range or outside a specified range. In the example that follows, digital line 15 is set to switch from zero to +5 Volts whenever the source channel signal falls between the values entered in the L1 and L2 boxes. In this case, I/O is switched to +5 Volts whenever the heart rate is greater than 60 BPM but less than 80 BPM.
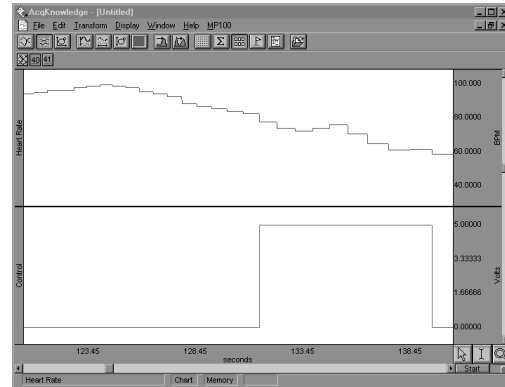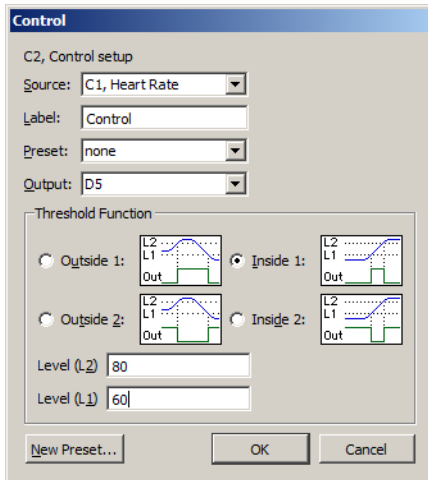
Control dialog and graph showing control channel switching from
low to high when source channel is between 60 BPM and 80 BPM

The digital line can also be configured to switch from high to low when the signal on the source channel falls *within* a given range. This is equivalent to setting the digital line to shift from low to high when the source channel values fall outside a given range (as shown below).
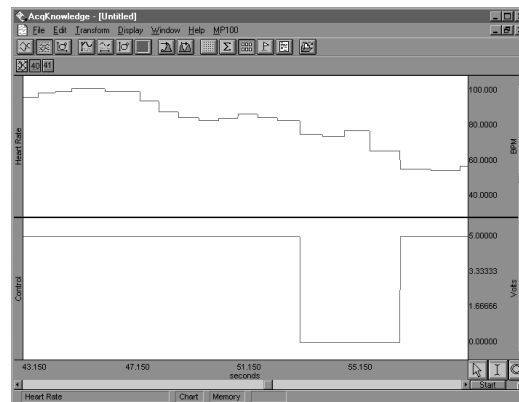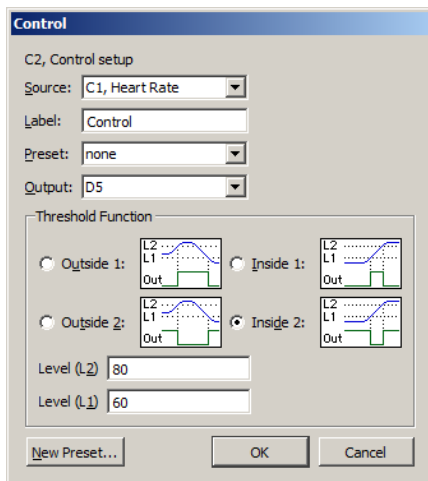
Control dialog and graph showing control channel switching from
high to low when source channel is between 60 BPM and 80 BPM

Adaptive Filtering Calculation
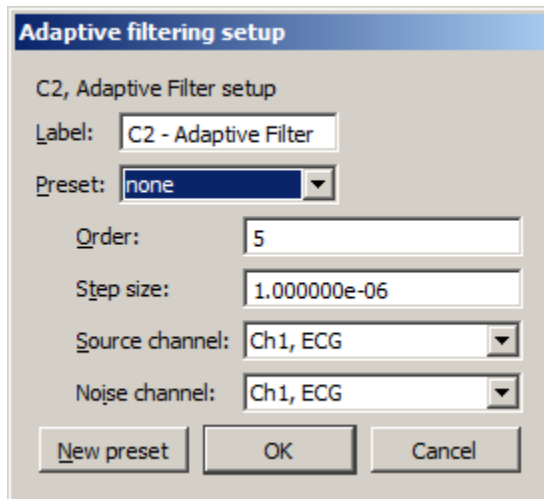
Adaptive filtering setup

C2, Adaptive Filter setup

Label: C2 - Adaptive Filter

Preset: none

Order: 5

Step size: 1.000000e-06

Source channel: Ch1, ECG

Noise channel: Ch1, ECG

New preset   OK   Cancel

Adaptive filtering is a signal processing technique that processes two different signals in relation to one another and can be used for noise estimation, noise reduction, general-purpose filtering, and signal separation. Adaptive filtering creates efficient high-quality filters with a minimal number of terms, which can be very useful in blocking mains interferences or other known periodic disturbances.

▪ Useful for noise filtering where it is possible to acquire a signal that is correlated to the noise (similar to the way noise-cancelling headphones detect and remove outside noise). Applications include removing EMG from ECG or EOG from EEG.

⮑ See the Adaptive Filtering transform on page 257.

To have BSL *PRO* apply an Adaptive Filtering Calculation in real time:
1. Choose MP > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. Check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Adaptive Filtering.
5. Click the Setup button in the Input Channels dialog to generate the Adaptive Filtering dialog.

The weights within an adaptive filter are modified on a step-by-step basis. BSL *PRO* uses the N-tap FIR adaptive filter, with coefficients updated using least means squares (gradient) feedback.

Order	Specify a positive integer for the number of terms to be used in the internal FIR filter.
Step size	Provides *mu*, the rate of adaptation of the coefficients within the FIR filter.
Source channel	The source channel will be replaced by the adaptive filter results.
Noise channel	The noise channel is the signal that is correlated with the noise to be eliminated from the Source; it is not modified by adaptive filtering.

Source and Noise channels must have the same channel sampling rate (under Channel Set Up).

Comb Band Stop Filter Calculation

To have BSL *PRO* apply a Control Calculation in real time:
1. Choose MP > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. Check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Comb Band Stop.
5. Click the Setup button in the Input Channels dialog to generate the Comb Band Stop dialog.

See page 133 for details.

Metachannel

See Metachannel details on page 117.

Rescale Calculation

Rescale applies two-point linear mapping and allows users to change the measurement units (for example, to change temperature from Celsius to Farenheit). The text corresponding to the new units can be manually entered.

To have BSL *PRO* apply a Rescale Calculation in real time:

1. Choose MP > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. Check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Rescale.
5. Click the Setup button in the Input Channels dialog to generate the Rescale dialog.

- Use the Rescale transformation (after acquisition) to adjust forgotten calibration of analog channels or reverse incorrect calibrations.
- A "Rescale" Automator action has been added to allow rescaling to be performed in workflows.

The rescale formula is:

$$v_{new} = \frac{y_{new} - y_{old}}{x_{new} - x_{old}} v_{old} + \left(y_{new} - \frac{y_{new} - y_{old}}{x_{new} - x_{old}} x_{new} \right)$$

Rescale Source   Displays the label and number of the selected channel.
Old Units   Displays the values of the current vertical units of the channel
New Units   Allows for manual entry of the new units to be used. The new units will be displayed in the vertical units of the channel
    Note   When rescaling only a selected area of the waveform, the manual entry of new units is not available unless õTransform entire waveö is checked since it is not possible to display different units for different time ranges in the same channel.

Slew Rate Limiter
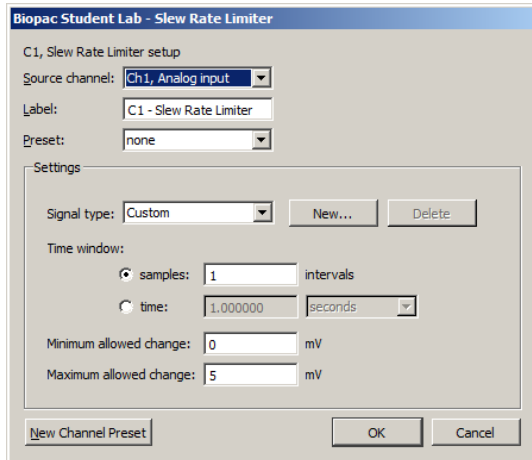
Slew Rate Limiter is an effective tool for signal separating, denoising and removing motion artifact during and after recording. The algorithm restricts the rate of change of a signal to a specific time window or sample width window. The allowable amount of motion artifact over a given time/sample window can be precisely adjusted from a minimum allowable change to a maximum allowable change, thereby eliminating artifacts that exceed the selected amplitude range within a given time period.

The Slew Rate Limiter algorithm restricts the rate of change of a signal to a specific window. If two different types of signals with significantly differing rates of change are mixed together, limiting the allowable rate of change of the mixed signal allows for signal separation by reducing the impact of a fast moving signal on a slow one (and vice versa).

Assume a mixed signal *y*. Define a time window width *w*. Define the minimum allowable change in amplitude over the time window *w* as and a maximum allowable change in amplitude as where.

The Slew Rate Limiter may be applied in real time as an online calculation channel, or in post-processing via the Transform menu (see page 275). As with all online and offline transformations, signal type settings can be saved as custom presets by clicking the õNewí   ö button and naming the new preset.

To have BSL *PRO* apply the Slew Rate Limiter in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. Check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull down menu and select Slew Rate Limiter.
5. Click the Setup button in the Input Channels dialog to generate the Slew Rate Limiter setup dialog.
6. Set the desired time window to apply the slew rate limiter algorithm based on seconds or samples.
7. Set the minimum and maximum allowed change to adjust the sensitivity to motion artifact.
8. Click OK and run the acquisition. Any artifact that falls outside the boundaries of the maximum/minimum allowed change setting will be eliminated from the recorded data.

▶   Watch the BIOPAC Slew Rate Limiter video for a detailed demonstration of this feature.

Filter – FIR (BSL 4.1 and higher)

```
Biopac Student Lab - Filter - FIR

C1, Filter - FIR

Source:  Ch1, Analog input          ▼

Label:   C1 - Filter - FIR

Preset:  none                       ▼

Type:    Low pass        ▼

Window:  Blackman -61dB  ▼

┌─Frequency cutoff──────────────────┐
│  ○ Fixed at        50          Hz │
│  ◉ Sampling rate / 8              │
│  ○ Line frequency  (60Hz)         │
└───────────────────────────────────┘

┌─Number of Coefficients────────────┐
│  ○ Fixed at   39                  │
│  ◉ Optimize for sample rate and cutoff │
└───────────────────────────────────┘

Delay at current settings: 32 samples

New Preset ...     OK        Cancel
```
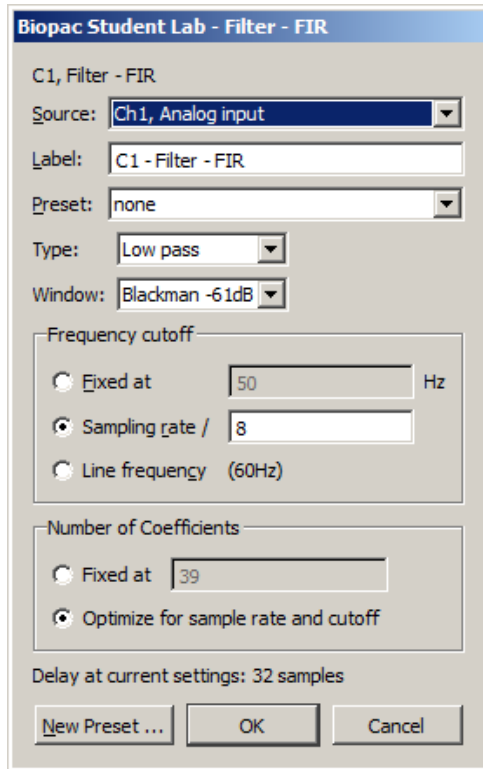
In BSL 4.1 and higher, FIR Filters are available as an online calculation channel. Until recently, real-time FIR filtering during acquisition wasn¢t feasible due to processing power limitations, but these constraints are no longer an issue for modern dual-core and quad-core processors.

Online FIR filters are similar to their offline transformation menu counterparts with the exception of the following convention.

Delay at current settings: For FIR filtering in general, a delay is imposed on the output signal, and this parameter shows the number of delay samples the current settings will introduce. If the number of coefficients is fixed, the delay value will equal the number in the õFixedö editable field. If the number of coefficients is set to be optimized for sample rate and cutoff, the delay value will vary. The filter algorithm compensates for this delay in order to assure proper alignment of filter output with the acquired signal.

When modifying the fixed number of coefficients or the frequency, the delay value is updated accordingly. However, it should be noted that a close comparison between online and offline FIR filters will reveal that they are not perfectly in phase, but out of phase by half of the imposed FIR calculation channel delay.

As in other BSL *PRO* calculation channel presets, modified Filter ó FIR setups can be saved as a custom preset by selecting õNew Preset.ö

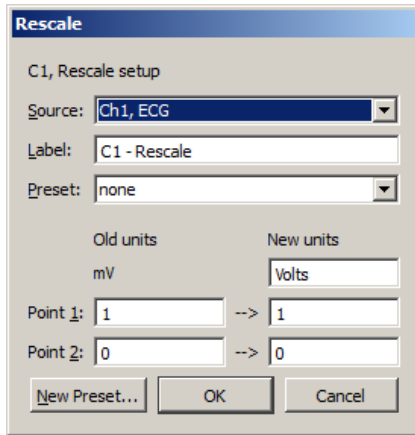To have Acq*Knowledge* apply the Filter ó FIR in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check the Acquire, Plot, and Values box for the Calculation channel to contain the filtered data.
4. Click the Preset pull down menu and select Filter ó FIR.
5. Click the Setup button to generate the Filter ó FIR settings dialog.
6. After starting acquisition, real time FIR filtering will appear in a dedicated calculation channel for the duration of the recording.

For specific details on the various FIR filter types, windowing, and recommended settings, see the offline Filter ó FIR Transform option on page 254.

Chapter 7   Set Up Acquisition
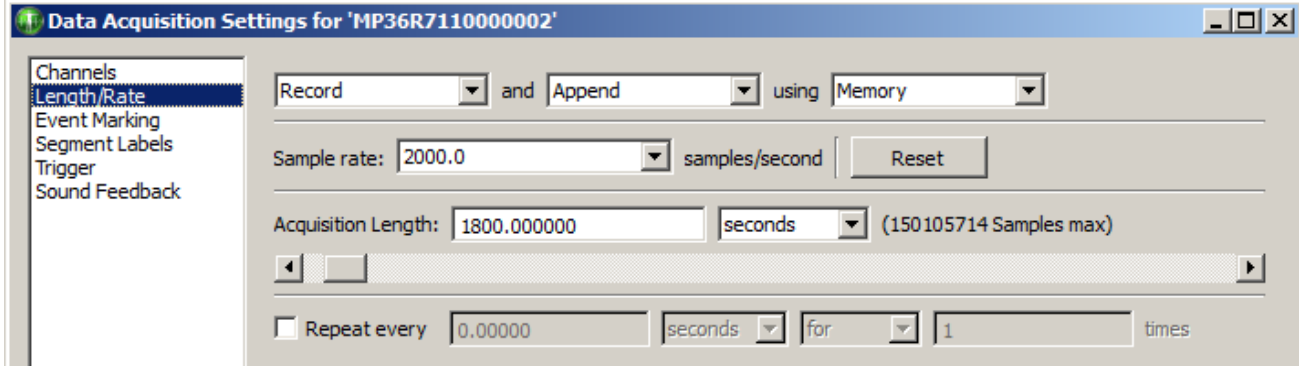
Data Acquisition Basics

Once the channels to be acquired have been selected, the next step is to set up the acquisition parameters. These options control the data collection rate, where data will be stored during an acquisition, and the duration of each acquisition. Choose MP > Set Up Data Acquisition > Length Rate to generate the dialog to set the following options.

Storage Mode

At the top of the dialog are three popup menus for configuring various aspects for storing data from each acquisition.

Record/Record last allows control over whether the software saves all data or only the most recent segment of the data.

- **Record**ô the MP hardware will store data for the amount of time specified in the acquisition length box. This is the default and is appropriate for almost all types of acquisitions.

- **Record last**ô only available when acquisitions are set to 'Save Once' or 'Memory'ô the MP hardware will acquire data continuously, but will only store the most recent segment of data equivalent to the duration in the acquisition length dialog. That is, if the value in the acquisition length box is 30 seconds and record last is selected, the MP System will acquire data continuously, but will only store the most recent 30 seconds of the data.

Save once/Autosave file/Append configures how the data is saved to a file. By default, BSL *PRO* will save the data to a single continuous file.

- **Save once**—BSL *PRO* will begin an acquisition when the mouse is clicked on the start button, and will stop either when the acquisition length has been reached or when the stop button is clicked with the mouse.

- **Autosave file** ô use this option to perform several acquisitions one after another, and save the data from each acquisition in a separate file. When the Autosave option is selected, a File button will appear to the left of the sample rate dialog. Click File to generate a standard Save dialog to enter the root file name for the data from each acquisition. After clicking Save in, another dialog is generated with options to append an incrementing number, time (system clock), or date (system clock) to the filename: Media functionality does not support the *Autosave file* acquisition mode.

- **Append** ô similar to ‑Save Once‗ except that Append allows stopping and restarting acquisitions at arbitrary intervals. Append mode is unique in that clicking on the Stop button only pauses the acquisition, which can then be restarted by clicking on the Start button.

In Append mode, each time an
acquisition is restarted, an append
event is inserted with the default label
õSegment 1, Segment 2ö, etc. Although
itøs possible to pause for any period of
time, the application will only acquire
data for the amount of time indicated in
the Acquisition Length box. Data can
be acquired in Append mode while
being saved to memory or disk. (For
information on customizing append
marker labels prior to acquisition, see
Set Up Segment Labels on page 207.

Sample data Acquired in "Append" mode.
Event markers indicate where Acquisition was paused.

Appended segments can be stored to disk or memory.

➢ **Append to Disk**: In this mode, it is usually best to record all channels at the same rate. If the user
stops the acquisition, the length will be the same for all channelsô so the next segment of appended
data will neatly link onto the end of the existing record. If channels are sampled at different rates,
append to disk operation will cause the software to rewrite all data files in the graph and add
õextraö data to the õunevenö waves. This extra data will be a continuation of the same data point at
the end of each uneven wave. This operation may take some time to complete for very long data
files.

▪ Append to existing filesô just open them, change the storage mode to õAppend to Diskö and
Start the acquisition.

▪ Append to disk requires BSL *PRO* format files. When opening any other file format, a prompt
will appear for translating the file.

➢ **Append to Memory**: In this mode, data is appended to the õunevenö waves in the same manner as
described for Append to Disk. When channels are sampled at different rates, this mode will respond
faster than Append to Disk because the data files are already in memory so the software does not
have to rewrite all the data files in the graph. This is the default mode for acquiring data in BSL.

A **Reset** button is generated in the Set Up Acquisition dialog when Append is selected. Click
the Reset button to erase the acquired data file and start a fresh acquisition file (this is
essentially the same as saying yes to an õOverwrite existing data?ö prompt).
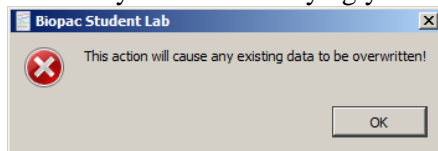
The Rewind button on the toolbar will delete the last recorded segment. Ctrl-Rewind (Windows)
or Option-Rewind (Mac OS) will delete all recorded segments (similar to the Reset button).

Append plus **external trigger**

An acquisition that takes place over a long period of time with brief events which are few and far between
can be Set Up in the following manner: the researcher watches for these event, triggers the acquisition to
start, and then lets the pre-defined acquisition length run out. When another event of interest occurs, the
researcher triggers the next acquisition. This acquisition will be õappendedö onto the end of the first
acquisition. Memory is the only limit as to how many õappendagesö can be added.

Append plus **Variable Sampling Rates**

If the mode is started and stopped manually, it is statistically possible that, prior to the next pass of the Append, extra data points may be inserted in various data channels to õline upö the data (see sample on page 103). These extra data points simply replicate the last sample in any affected channel. To minimize the impact of the extra data points, make sure the lowest sampling rate is on the order of 10 Hz or higher, or donøt use VSR.

Disk/Memory determines where to store data during an acquisition. Once data has been acquired and is stored in a file, it is stored on a hard disk or other similar device. There are a number of options for storing data *during* an acquisition. The best choice as to where data should be stored during an acquisition depends in large part on the nature of the acquisition itself, and the type of computer being used.

▪ Memory stores data in computer memory during an acquisition. After the acquisition is completed the file can be saved using õFile > Save As.ö This usually allows for faster acquisition rates, although most computers have less available RAM than disk space.

▪ Disk saves data directly to the computerøs hard disk during an acquisition. Disk mode is fast enough (in terms of maximum sampling rate) for many applications, especially when only a few channels are being acquired. Saving data to Disk also allows for longer acquisitions, since most computers have more hard disk space free than free RAM. A final advantage of saving data directly to Disk is that if there is a system failure (including power outage), all the data collected up to that point is saved on disk and can be recovered, whereas the data is deleted if it is being saved to computer memory.

> **IMPORTANT**ô When saving files to Disk, always be sure to save files under a different name BEFORE starting each acquisition. Otherwise, any previous data in that file will be overwritten. In Memory mode, simply save the file after the acquisition.

Acquisition Sample Rate

The value in the box labeled õSample rateö indicates how many samples the MP System should take per channel during each second of data acquisition. The sample rate can be changed by clicking on the pull-down menu. To allow for variable sample rates, the rate options are constrained so that channel sample rates are equal to or a specific power of 2 less than the acquisition rate. Sample rates can be chosen at the selected increments only; custom rates are not accepted.

Depending on the nature of the data being acquired, the õbestö choice in terms of sampling rate will vary. Technically speaking, the minimum sampling rate should be at least twice the highest frequency component of interest. This means that if the area of interest has frequency components of 100 Hz, itøs recommended to sample at least 200 times per second. Fourier analysis (FFT) can be used to determine what frequency components are present in the data (see page 277 for a more detailed description of the FFT function).

> TIP: A good rule of thumb is to set the sampling rate to at least three to four times the highest frequency component of interest.

In less technical terms, lower sampling rates can be used for data with slowly changing values (e.g. respiration, EDA), whereas higher sampling rates should be set for data where values change markedly in magnitude or direction (e.g. ECG, EEG, evoked response).

The maximum allowable sampling rate will automatically adjust itself according to the storage mode, how many channels are being acquired in the channel setup window and the type of computer being used. This can be demonstrated by entering a large value (say 99, 999) in the sample rate box. Now, click the mouse button or press return and BSL *PRO* will automatically return the maximum allowable sample rate given the computerøs throughput and the acquisition parameters.

If data is being stored to disk or computer memory (RAM) during an acquisition, To set a sample rate that is too high. The acquisition will begin normally, but BSL *PRO* will stop the acquisition and display a message indicating that the acquisition buffer has overflowed. The data up to this point has been saved, and the sample rate must be decreased in order to complete an entire acquisition.

The sample ECG waveforms below illustrate the effect of different sampling rates on obtaining varying levels of fidelity when reproducing the data.

▪ Top waveform: data is sampled relatively slowly; difficult to make out the shape of the waveform.

- Middle waveform: sampled at the faster rate; more samples are taken in the same period of time, which results in higher resolution for some components of the waveform.

- Bottom waveform: sampled at a relatively high rate; increased resolution of the waveform. Waveform components that were obscured at slow sampling rates are now well defined, and measurements taken on this waveform would be able to better establish the maximum amplitude, time between different ECG complexes, etc.
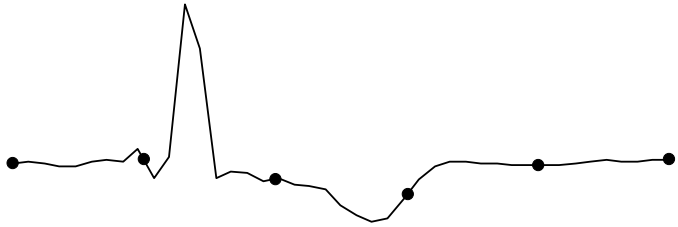
Representation of ECG waveform sampled with relatively few samples per second "True" ECG wave is superimposed over dots that indicate sample points.

Preceding waveform as it would look if plotted in BSL *PRO* (with data points superimposed).
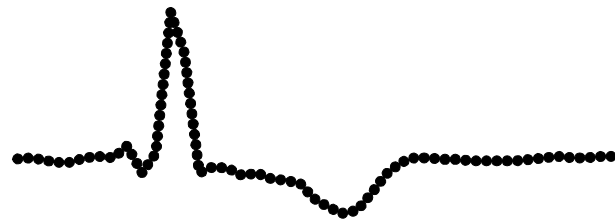
Representation of same ECG waveform sampled at a relatively higher sampling rate.

As shown, under-sampling completely misses the QRS complex of this waveform, although it might detect components of the QRS in subsequent beats. Although this is an extreme example of how under-sampling can affect digitally processed data, it is important to note that the rate at which data is sampled has important implications for the interpretation and analysis of data.

The disadvantage of acquiring data at high sampling rates is that each sample point takes up memory, whether it is RAM , disk space or memory. Moreover, once the file is saved, it will require more disk space than a file of similar duration sampled at a slower rate.

Note for variable sample rate processing:

The Expression and Waveform Math functions will constrain operations between waves of different rates as follows:

If an equation is operating on two or more waves of different sample rates, the result of the operation will always be output at the lowest sampling rate from the waves (F low). If the destination channel for the result has an assigned rate other than (F low), the operation will not be permitted. If the destination channel is set to a new channel, the operation will always be permitted.

VSR data padding· If the channels are of unequal length (as a result of variable sampling rate or waveform editing), they will be padded for Append acquisition. Digital and Analog channels are stored as short integers by default; a waveform paste into a digital or analog channel, however, will result in its underlying data being converted to floating point. This will generate the "Abort/Replace" warning for pastes to Digital or Analog channels since the data format has changed since the last acquisition.

Additionally, if an Analog or Digital channel is used as the source waveform for a Copy, it will also be converted to floating point and will result in the "Abort/Replace" warning being generated.

Since Calculation channels are already floating point, pasting into them or copying from them will not change their data format. The channels will be padded with their last value and the append will commence.

Waveform Cut operations do not change the underlying data format for Analog, Calculation, or Digital channels. If only Waveform Cut is used, no data format conversion will occur and channels will be padded with their last value and subsequent appends are allowed.
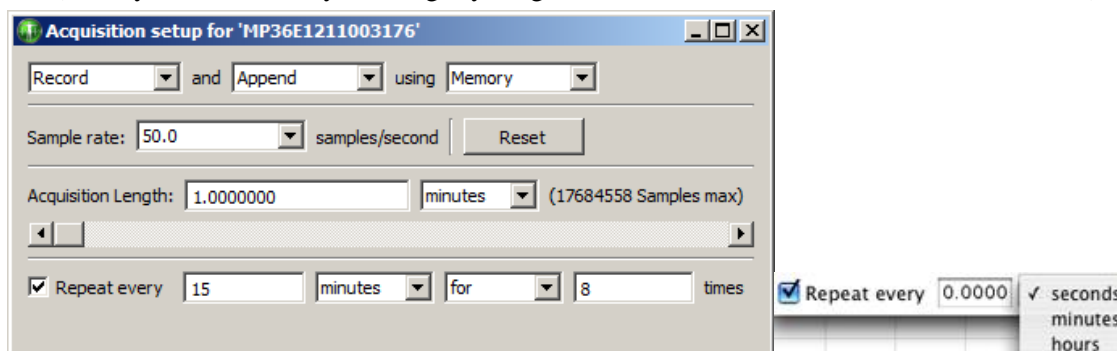

Acquisition length

To set the duration of an acquisition, enter a number in the acquisition length box. By default, 3600 seconds of data will be recorded. The popup menu right of the length box allows scaling the acquisition duration in terms of milliseconds, seconds, minutes, hours, or samples. Changing this option will not change the length of the acquisition, only the units used to describe it. Thus, the same acquisition can be described as lasting 3600 seconds, or 60 minutes, or 3,600,000 milliseconds. Scaling the duration of an acquisition in terms of samples is essentially the same as the time scaling options, except the length of the acquisition will be expressed in the total number of samples to be collected on one channel.

Regardless of the scale used to determine the length of acquisition, the acquisition will end when the value in the total length box is reached. The acquisition can also be interrupted or ended at any time by clicking the graph winodwøs õStopö button.

The application will automatically limit the maximum recording length to the amount of available memory (memory or disk modes). The default is to record one acquisition of the duration specified in the acquisition length box. The acquisition length parameter has a somewhat different interpretation in the *Record Last* mode. For more information on these features, see page 151.

Repeating

The Repeat mode allows data to be acquired from repeated trials using the same parameters for each trial. Checking the Repeat every box at the bottom of the acquisition setup dialog enables a series of dialogs and popup menus at the bottom of the dialog. These allows control over how the number of times an acquisition will repeat as well as the interval between trials. When this is unchecked, the acquisitions will repeat as soon as possible (usually instantaneously, but slightly longer if data must be saved to a file between trials).

Interval	The entry to the right of the õRepeat everyö checkbox tells BSL *PRO* how long to pause between the start of one acquisition and the beginning of the next acquisition. This can be scaled in terms of seconds, minutes, or hours using the second popup menu.
	It is important to note that this value measures the interval between the start of two adjacent trials, rather than the interval between the end of one trial and the start of the subsequent trial. If the repeat interval is set for 15 minutes and the acquisition length is set to 1 minute, then there will be a 14-minute pause between the end of the one trial and the beginning of the next.
Trials	Set how many trials to acquire:
	for perform a finite number of trials; enter the number of trials to acquire
	forever perform an infinite number of trials. Trials will be repeated at the specified interval until the acquisition is stopped either by clicking on the stop button in the graph window or if there is not enough free memory on the target storage device.

Regardless of which options are checked, data for each trial is acquired according to the acquisition parameters specified in the dialog. In the above example, each trial of data will be sampled at 50 Hz and will last 1 minute; the trials will be repeated every 15 minutes for a total of 8 trials.

Setup Channel Options
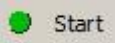
Channel	The **Channel** column contains the alpha-numeric channel numbers. õ**Analog**ö (or continuous) input channels begin with õ**CH**ö and run from CH1-CH4. õ**Digital**ö input channels begin with õ**D**ö and run from D1-D8. õ**Calculation**ö channels begin with õ**C"** and run from C1-C16.
Acquire	When the **Acquire Data** box is checked for a given channel, data will be collected on that channel.
Plot	If **Plot** is also checked, data will be plotted on screen in real-time during the acquisition. If the plot box is unchecked, data will still be recorded for that channel, but the waveform display will be disabled. To display the waveform plot after the acquisition is over, show the channel.
Value	Checking the **Value** box enables the display of numeric and/or graphic values for each channel in real time. To display the values, select **Show Input Values** (via the MP36 menu). Input values are displayed in a separate window from the main graph window.
Default	The default is to collect one channel of data on analog channel 1 (CH1), and to plot and enable value display for this channel
TIP	Usually, itøs recommended to check all three boxes for all channels acquiring data.
Label	The **Label** entry for each channel supports entry of up to 58 characters to identify the channel.
Preset ▼	Clicking on the **Preset** button will generate a menu of available presets for the channel. Presets for common applications configure the hardware gain, filters, etc.
	➢ For a detailed summary of **Analog Input channel, Digital Input channel,** and **Calculation channel** options see the **Presets** section beginning on page 116.

If a preset is modified prior to starting a recording in Append mode, the following prompt will be displayed. Choose Abort, save the data, and then change the presets to acquire as a new data file.
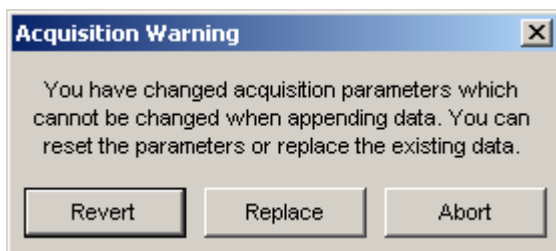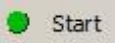
Starting an acquisition
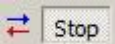
After setting up the channels and defining the channel parameters, the acquisition can be started. If a file window is not already open, choose **File** > **New** to generate a graph window.

Note the circle to the left of the 🟢 Start button. This circle indicates the communication status between the computer and the MP data acquisition unit.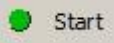 The circle will be solid green wmen the MP unit is properly connected to the computer and powered on. If the MP unit is not properly connected, thie circle will be solid gray.

Start the acquisition by positioning the cursor over the 🟢 Start button and clicking the mouse button or by selecting õ**Alt + Spacebar**.ö If no input devices (e.g., electrodes or transducers) are connected to the MP unit, the system will collect a small value of random signal õnoiseö with a mean of about 0.0 Volts.

- ➢ For information on how to connect measurement devices to the MP36, see the BSL Hardware Guide.
- ➢ Acquisitions can also be started using a variety of õtriggers,ö which are discussed on page 207.
- ➢ Once acquisition starts, the 🟢 Start button in the acquisition window changes to ⇄ Stop . The two opposing arrows to the right of the button indicate that data is being collected. Also, the õBusyö status indicator light on the front of the MP unit will illuminate, showing that data is being collected.

Stopping an Acquisition

To stop an acquisition at any time, click the ⇄ Stop button in the lower right corner of the screen or select õ**Alt + Spacebar**.ö An acquisition will stop automatically when it has recorded an amount of data equal to the **Acquisition Length** entry.

Rewind

⏪ The Rewind button to the right of the Start/Stop button allows the last recorded data segment to be erased and subsequent appended data to be added to the existing data file. This function will erase the last segment along with the Append Event 🔶 for that segment; the application will keep track of Append Event labels, so that the label always matches the segment number
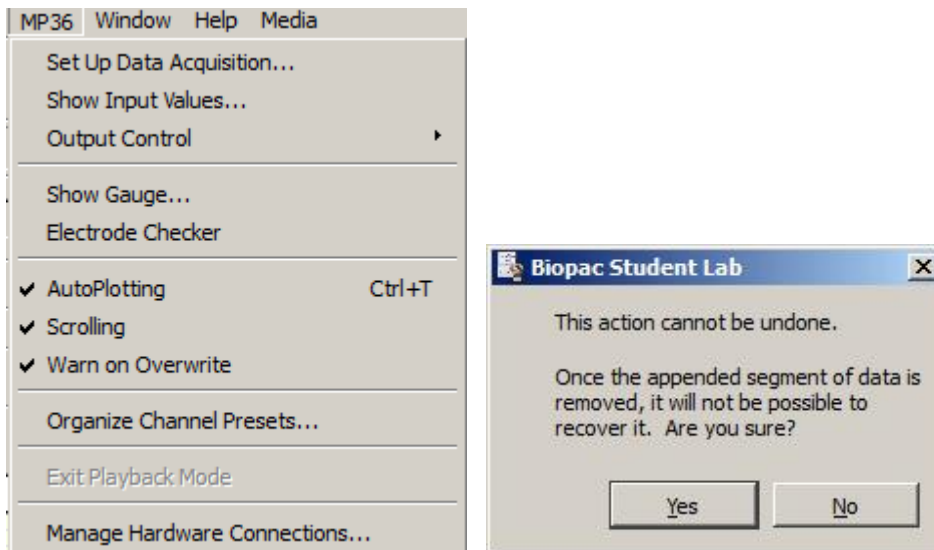
If the õWarn on Overwriteö option is active, a warning dialog will be generated before the segment is deleted.

Saving acquisition data

To save a data file, pull-down the File menu and choose the Save command.

Electrode Checker
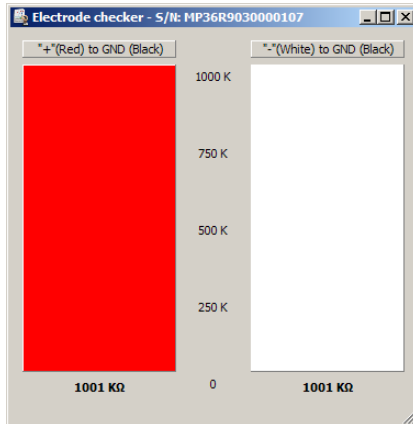
The **Electrode Checker**, in conjunction with the MP36 unit, measures how well electrodes are making contact with the surface of the skin. To use this feature:

1) Attach the electrodes to subject.

2) Connect the electrodes to an electrode lead set (such as the SS2LB).

3) Instead of connecting the electrodes to one of the four analog inputs, connect the Simple Sensor end of the electrode lead to the **Electrode Check** port on the front of the MP36 acquisition unit.

4) Click the **MP3X** menu and scroll down to select **Electrode Checker**.

This will generate a small õthermometer-likeö display. At the bottom of the display, a number with a kΩ (Kohms) symbol should be visible. This value describes the impedance of the electrode/skin contact, with lower numbers being associated with better conductivity. The better the conductivity, the õcleanerö the signal displayed on the screen. If the MP36 is off or no nothing is connected to the õElectrode Checkerö on the MP36 unit, the Electrode Checker display will remain õOFF.ö

Poor contact   Good contact   Off
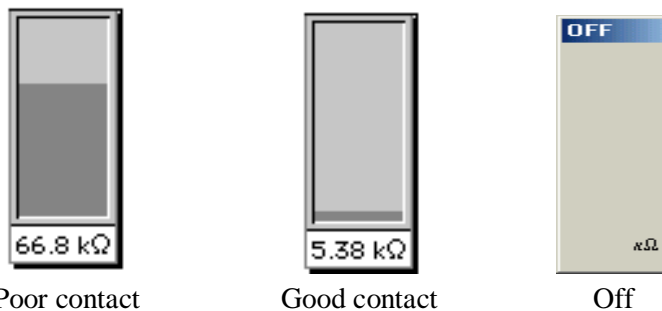
TIP While there are few absolutes as to what constitutes ％good＋contact, one rule of thumb is that this number should be below 10 kΩ, and the lower the better.

TIP To decrease the impedance of an electrode connection, itøs recommended to ％abrade＋the surface of the skin with an abrasive pad (such as ELPAD). This removes a thin layer of dead skin cells and should result in a signal that has relatively little noise.

Timers (Stop watches and Elapsed timers)

The Timers function allows for easy visualization and measurement of elapsed time within the Acq*Knowledge* user interface, and consists of a simple toolbar display. Timers can be helpful when actions need to be performed at specific intervals prior to and during an experiment. The Timers function provides an easy-to-read digital display in the toolbar region above the graph window, and supports the creation of multiple timers, which can be added or removed as needed.

Timer Types

There are two main types of timers, acquisition controlled (õelapsedö timersö) and independent timers (õstop watchesö). Manual õstop watchö timers can be used at any point for tracking time independently of acquisition, while elapsed timers are tied to a recording in progress and unavailable unless an acquisition is running.

Independent Timers (Stop watches)

Independent timers are manually started and stopped, and have a countdown feature with an audible alarm and flasher. Multiple timers can be added to the toolbar region, and can be started and stopped independently. Pause mode is not supported. Although the timer can be stopped at any time, restarting it resets the timer back to 0:00:00.

Elapsed Timers (Acquisition controlled)

Elapsed timers start when the acquisition õStartö button is clicked and continue counting for the set duration of the recording, or until the acquisition õStopö button is clicked. When acquiring in Append mode, the elapsed timer is reset at the beginning of each new segment. Any trigger or delay time applied between segments is not included in the elapsed time. Multiple elapsed timers can be added to the toolbar region. This mode does not support the countdown or alarm feature.

To set up a timer:

o   Display > Show > Timers.

o   The timer toolbar will appear as shown below:
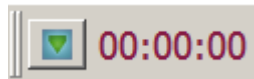
o   The **elapsed timer** option is enabled by default. If only a single elapsed timer (acquisition controlled) is desired, simply start the acquisition and the timer will start automatically.

o   If an **independent timer** (stop watch) is desired, right click on the numbers portion of the timer toolbar and choose õSettings.ö In the Timer Settings, choose õIndependent startö and click OK.

To start/stop independent timers: Click on the toolbar number display to toggle start/stop, or right click on the toolbar number display and choose õStart timerö or õStop timerö (see figure below).

To set up multiple timers:

1.   Click the Timers toolbar icon and choose the desired timer type. Repeated clicking on a timer option will create additional timers of that type, which will appear in the timer toolbar region.
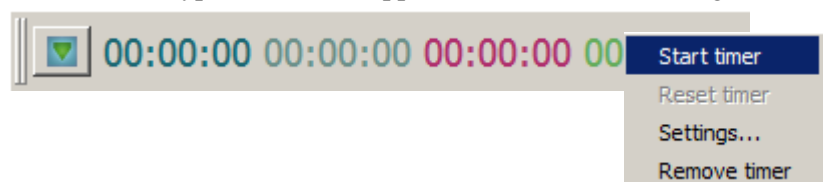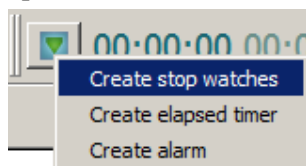
To set an alarm:

1.   Click on the Timers toolbar icon and choose õCreate alarm.ö

2.   Right click on the numbers display portion of the new alarm and choose õSettings.ö

3.   Set the desired time in the õCountdown timerö field.

4.   Check õSound alarmö and õBlink upon alarm.ö
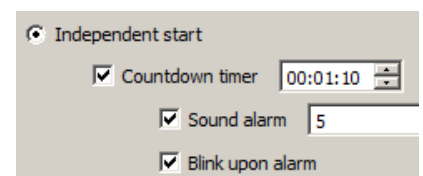
NOTE: These settings will remain the default for subsequent alarms until the settings are changed.

Overview of Timer Settings

CONTROL	DESCRIPTION
Timer name:	Field for assigning name to timer.
Start timer with acquisition:	Timer will start and stop with data recording only.
Independent start	Timer is started and stopped manually, independent of acquisition status.
Countdown timer	Sets the countdown time duration.
Sound alarm	Selects the audible alarm option and specifies the number of times the alarm will sound.
Blink upon alarm	Enables the timer numbers to flash on and off when the countdown is complete.
Display > Font family: > Font size > change color	Selects timer font style, size and color.
Include fractional seconds	Sets option to display 1/100ths of a second in timer display.

All parameters established in the Timer Settings are retained in saved graphs and graph templates.

Chapter 8   Output Control MP Menu

```
CH to Output
Digital Outputs
Pulses
Stimulator - BSLSTM
Low Voltage Stimulator
Pulse Sequence
Human Stimulator - STMHUM
Visual Stim Controllable LED - OUT4
Arbitrary Wave Output
Sound Sequence
```

```
CH3 to Output
Digital Outputs
Voltage
Pulses
Stimulator - BSLSTM
Stimulator - SS58L
Pulse Sequence
Sound Sequence
```

MP36 hardware   MP 35 hardware

The MP UNIT can output pulses or analog voltages via the **Analog Out** port; this port is also used to connect to BIOPAC's external stimulators. The MP35 has an additional **I/O Port** which is used to output digital (TTL Level) signals.

Parameters for output signals are set via **Output Control**. Access to a specific Output Control is via the **MP > Output Control** submenu.

There are nine Output Controls for the MP36, ten for the MP35A, nine for the MP35, and two for the MP45:

Output Control	See→	**MP36/35** Functionality	**MP45** Functionality
CH# to Output	page 163	Direct analog CH1-4 to output listen to signals	Direct analog CH1-2 to output listen to signals
Digital Outputs	page 165	Control 8 digital outputs	Not available
Voltage	page 167	Output Voltage Level (0 . 4 V DC) Not available in MP36	Not available
Pulses	page 168	Use with third-party devices; software can control pulse width and repetition.	Not available
Stimulator - BSLSTM	page 168	Use with BSL Stimulator	Not available
Low Voltage Stimulator Stimulator . SS58L	page 168	Use with MP36 Analog Out port or MP35 with SS58L Low Voltage Stimulator; software can control pulse amplitude, width and repetition (-10 to +10 V)	Not available
Pulse Sequence	Page 169	Available in MP35A & MP36 only. Direct analog CH1-4 output. Allows for output of customized pulse trains.	Not available
Human Stimulator - STMHUM	Page 169	Handheld user-controllable stimulator that plugs directly into the Analog Out port.	Not available
Visual Stim Controllable LED . OUT4	Page 173	Use with MP36/MP35 Analog Out port. Used to present a visual stimulus to subject in the form of a flashing LED.	Not available

Arbitrary Wave Output	Page 174	Output stimulus waveforms, Square, Tone, Ramp, or Arbitrary waves.	Not available
Sound Sequence	Page 173	Outputs customized sounds assignable to a user configurable pulse train.	Available

To open an Output Control, select it from the **MP UNIT > Output Control** submenu. A checkmark appears next to the submenu selection and an **Output Control** panel is displayed, bordered in red beneath the BSL *PRO* Toolbar in the active data window. To close an Output Control, select from the menu again (toggles between display and hide) or right-click in the open control panel and choose **Close**.

Only one Output Control panel may be open at any time. Switching between different data files can change the display and operation of the control panel.

Because some output devices can be used for stimulation on humans and can achieve voltages up to 100 Volts, built-in software logic makes output control as safe as possible.
See page 189 for safety notes regarding human subjects.

The following applies to all Output Controls.

The output will not operate unless its software control panel is open.

When an Output Control panel is closed, or the BSL *PRO* application is closed, MP36/35 output goes to 0 Volts, preventing the output device from sending pulses.

When an Output Control panel is opened, output is always OFF until activated by a click of the ON/OFF switch in the control panel or, if parameters allow, a click of the Start button in the data acquisition window. (Exceptions are the Voltage Output Control, which outputs immediately, and the Digital Outputs Control when set to the preference õSet each output immediately.ö)

Output preference parameters are <u>local</u> and are saved with the data file or a graph template file. The data or template file holds the output parameters as established when the file was saved. (See õSave as Graph Template,ö page 224.) Switching between other open graphs can change the display and operation of the control panel since the settings in each graph are independent entities.

If desired, custom Output preference parameters can be saved as a preset for a current graph (file preset) or for all graphs (global preset) by using the õSave Settingsö button in the Output Preferences window. A saved Output preference can be recalled by choosing õOrganize Listö and selecting the desired custom preset.

Controlling Output Signals

Use both the Output Control panel and its respective Preferences dialog to control the output signal. Output Control **Preferences** dialogs establish the parameters for output. Preferences dialogs are only available when the corresponding Output Control panel is open and active. Voltage does not have Preferences.

To generate the **Preferences** dialog, either:
Open an Output Control panel and then right-click anywhere in it to generate a pop-up menu. Choose **Preferences** to open the dialog (**Close** will close the control panel).
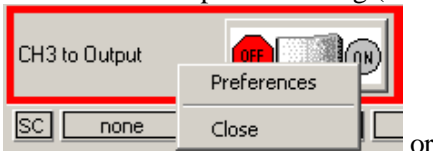
 or

If a control panel entry box is grayed or disabled, its values may be established, or limited, by settings in the Preferences dialog. If **Preferences** parameters allow, enter values directly in the **Output Control** panel.

Key into the entry boxes and then enter the value by pressing the **Enter** key.

Use the **Tab** key or mouse to move to another entry box.

Click the **OK** button if in the preference dialog.

Values entered into a control panel or its Preferences dialog that are outside the specifications of the output device, or outside the limits defined by the Preferences dialog, may change automatically to reflect either the closest value to that requested that the hardware can achieve, or the closest increment defined by the limits in Preferences. (The software does not correct inputs as they are being typed, it but may make changes after the value is entered.)

For example, if a Pulse width of 5 ms is entered into the Pulses Output Control panel entry box, but Preferences defines a range limit of .5 to 2 ms for Pulse width, the system will automatically change the new entry to 2 ms.

Saving Panel settings:

Output Control panel settings will be retained until a file is closed or saved. If a file is closed but not saved, settings will be lost (defaults established); if a file is saved, panel settings will be saved.

CH# to Output Output Control – MP36/35

The CH# to Output Output Control redirects an analog input signal to the **Analog Out** port on the back of the MP UNIT. The signal from the assigned channel will continue to be record and plot data.

This Output Control is used commonly when attaching headphones to the MP unit to listen to signals coming in on an analog input channel; for example listing to the Electromyogram.

To display this control panel:

Choose MP UNIT > Output Control> CH# to Output to open the control panel.

MP36/35 users may use analog input CH1-CH4. Channel 3 is the default setting. If another channel N has been designated, the menu will read õCH<N>.ö

Use the control panel **ON/OFF Switch** to start and stop output. OFF grounds the output so no signal (or sound) should be present.

Preferences

Use the **Preferences** to select the channel to redirect to output. Open the Preferences dialog by right-clicking the CH# to Output control panel region.
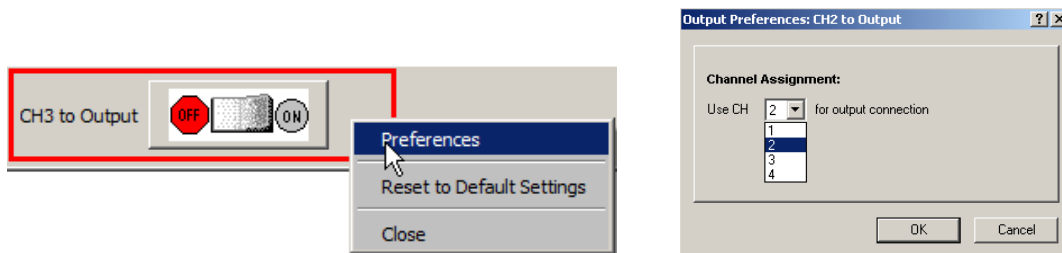
Use the pull-down menu to select the desired channel CH 1-4 to use for the output.

Click OK to set the output channel and return to the control panel.

Note   Only the Hardware settings (Gain, Offset, Input Coupling) from the Input Channel Parameters dialog (MP UNIT > Set up Channels) will be applied since output is established prior to the processing of Digital Filters.

MP36 Input > Output Scaling

The MP36 hardware can pipe signals from any channel input to the output using the õCHX to Outputö control panel in the BSL softwareô due to the difference between the input and output range, there will be a change in signal level (scaling). The output range depends on the output pin used as shown in the following table.

Output Pin (Analog Out port)	Pin Description	Output Range (Volts)
Pin 1	Headphones, A.C. Coupled	-2.048 to +2.048
Pin 2	Low Voltage Stimulator, D.C. Coupled	-10 to +10

The input range is gain-dependent. The table below shows the scaling (multiplying) factors to use for each gain setting.

| Gain	Input Range +- millivolts	Output Scale**—*accurate to ±10%* *Factor 1*	*Factor 2*
		Pin 1 (Headphone out)	**Pin 2** (Low Voltage Stimulator)
x5	± 2 V	1.024	5
x10	± 1 V	2.048	10
x20	± 500 mV	4.095	20
x50	± 200 mV	10.238	50
x100	± 100 mV	20.475	100
x200	± 50 mV	40.950	200
x500	± 20 mV	102.375	500
x1,000	± 10 mV	204.750	1,000
x2,000	± 5 mV	409.500	2,000
x5,000	± 2 mV	1023.750	5,000
x10.000	± 1 mV	2047.500	10,000
x20,000	± 0.5 mV	4095.000	20,000
x50,000	± 0.2 mV	10238.000	50,000

Notes

* 1: To properly measure the output signal, at least a 2K Ohm load is required.

** 2. Input to Output scaling is accurate to within 10%.

CH# to Output Control – MP45

The CH# to Output Control operates similarly to the MP36/35 functionality, but since the MP45 hardware's interfaces with the computer's sound card, the computer audio properties may need to be adjusted properly in order to optimize the signal output. Prior to using the CH# to Output Output Control with MP45, the following steps are recommended.

1. Open the computer's audio properties control panel (Control Panel > Sound).

2. Select the MP45 System as the Playback device and click the õPropertiesö button.

3. Select the õLevelsö tab and adjust the õSpeakersö slider to 100 (maximum volume).
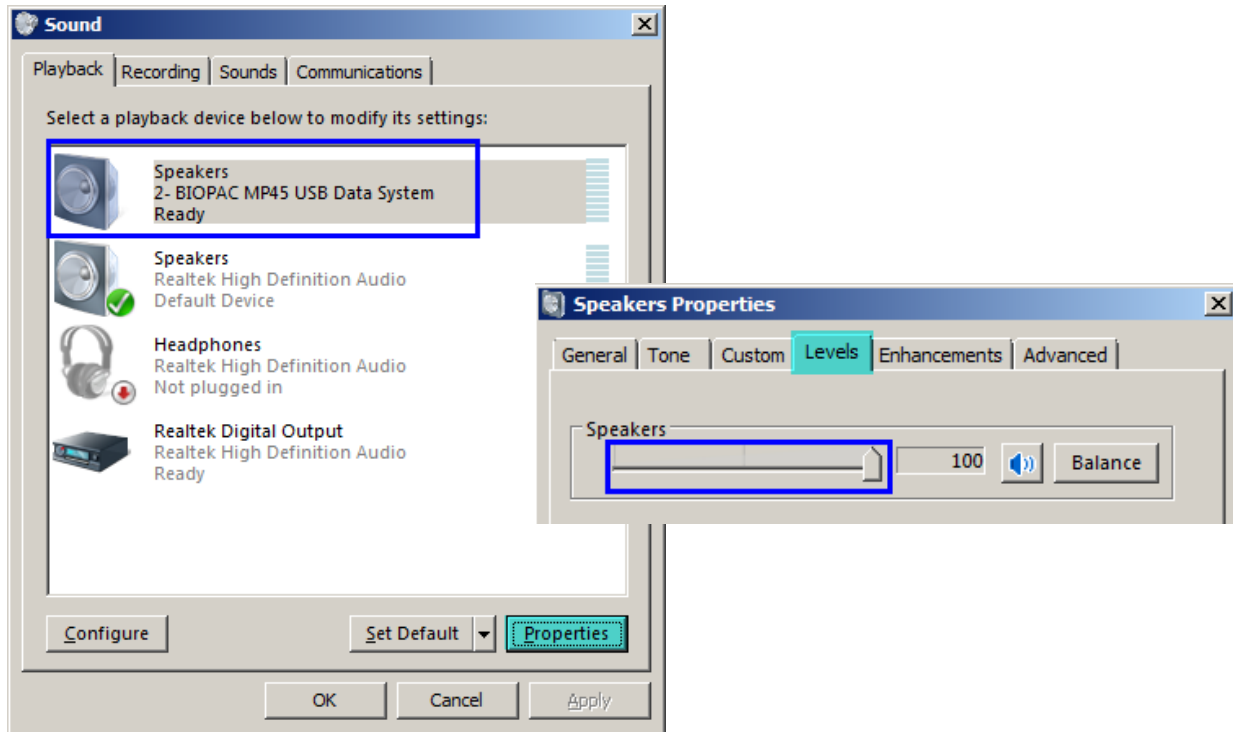
For more information on MP45 audio properties, see page 22, or see the õTroubleshooting MP45 Communicationsö guide in the Biopac Student Lab User Support folder. (Drive:\Program Files\BIOPAC Systems, Inc\Biopac Student Lab 4.x\User Support System\English ó en).

Additional MP45 Considerations for CH# to Output Control

- Unlike the 4-channel MP36/35 hardware, MP45 supports analog input CH1 or CH2 only. Channel 1 is the default setting.
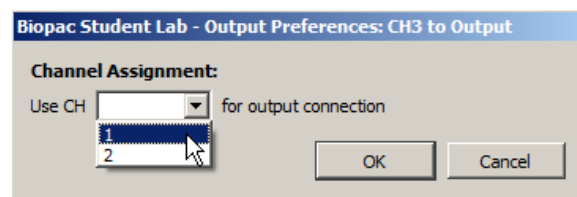
- For MP45, the ON button can be pressed at any time, however sound will only be heard during acquisitions. The button will remain ON until manually turned OFF or until the control panel (or file) is closed.

See page 382 for **MP UNIT Input > Output Scaling** values.

Digital Outputs Control — MP36/35 only

MP45 Users: The Digital Outputs Control panel is not available when using an MP45.

The Digital Outputs Control allows control of signal output on each of eight digital lines via the **I/O Port** connector on the back of the MP36/35. Use it to control external devices. The digital output uses standard TTL levels which correspond to the control panel setting as follows:
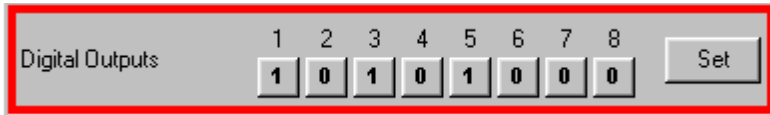
Control Panel setting	Output Voltage level (Volts)
0	0
1	+5

To display this control panel:

Choose **MP36/35>Output Control>Digital Outputs** to open the Digital Outputs Control panel

Click each digital output line to set its digital state to 0 (off) or 1 (on).

To set **Preferences** for Digital Outputs, open the Preferences dialog by right-clicking the control panel).

Select from the following two options:

Set each output immediately (default) allows the state of each digital output line to be toggled between 0 and 1, and changes the state **immediately**. In this mode, no **Set** button is available in the control panel. Output for each line is set upon clicking its toggle button.
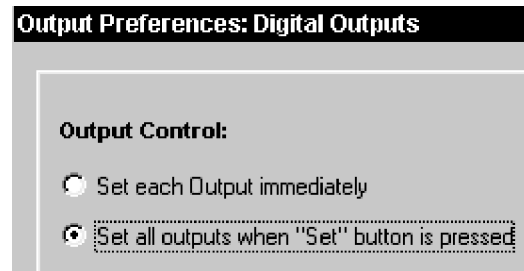
Set all outputs when Set button is pressed allows the state of each digital output line to be toggled, but the states will not physically be changed until the **Set** button is clicked on the control panel. In this mode, a **Set** button is available in the control panel. When the **Set** button is clicked, all eight digital lines will update simultaneously.

Click OK to set Preferences and return to the control panel.

Voltage Output Control

The Voltage Output Control is used to output a voltage level (DC voltage) via the Analog Out port on the back of the MP35 to control another piece of equipment.

Note: This option is not available in MP36 or MP45 hardware.

To use this control panel:

Choose **MP35>Output Control>Voltage** to open the Voltage Output Control panel.
Enter a value manually, or use the scroll or arrow buttons to increase or decrease values.

When using the scroll box, a change will not occur on the output until the mouse button is released.

The display shows the value that is to be output. If an entry exceeds the voltage range limits of the MP Acquisition Unit, the value automatically rounds to the nearest obtainable value.

MP35 Voltage Output	
Range	0 - 4.096 Volts
Resolution	1 mVolt

There are no Preferences for the Voltage Output Control.

When multiple graph windows are open, Voltage Output stops (goes to 0 Volts) if the graphs are switched and the new active graph contains its own Output Control panel. When the graph containing the Voltage Output Control panel is made active again, Voltage Output goes back to the previously set level.

Pulses Output Control

Stimulator – BSLSTM Output Control

Stimulator – Low Voltage Output Control

Stimulator – Human Stimulator – STMHUM Output Control

Control panel options for Pulses, Stimulator ó BSLSTM and Stimulator ó Low Voltage

Additional control panel options for **Low Voltage Stimulator**

The BSL *PRO* System offers a variety of pulse output options. Exercise caution when using any of the options with human subjectsô see the **Safety Note** on page 189.

Pulses Output Control

Select this Output Control for general pulse output, or when synchronizing to 3rd-party devices.

Use for reaction time measurements, where a subject listens with headphones for a series of õclicksö (pulses) and responds as quickly as possible with a button press. Determine reaction times by calculating the time between the start of the pulses and the responses.

Use to trigger another device (automatically send a pulse from the MP UNIT when acquisition starts).

Use to control a 3rd-party stimulator. BIOPAC recommends use of the BIOPAC BSLSTM Stimulator with the MP UNIT and BSL *PRO* software. If using the BSLSTM Stimulator, use the **Stimulator - BSLSTM Output Control** instead of this Pulses Output Control.

Stimulator – BSLSTM

Select this Output Control when using the BSL *PRO* stimulator (BSLSTM)

Use with stimulation electrode HSTM01 for safe stimulation of human subjects (0 ó 100 Volts), as well as lower voltage (0 - +10 Volt) general-purpose stimulation, such is used with amphibian muscle or nerve preparations.

Set up note   Placing the BSLSTMA/B unit too close to MP UNIT hardware can result in data distortion of the BSLSTMA/B pulse width signal; distortion is more apparent at higher sampling rates.

- NEVER set the BSLSTMA/B atop an MP UNIT
- Position the BSLSTMA/B away from the MP UNIT to reduce the signal distortion

Stimulator SS58L Low Voltage Stimulator

Select this Output Control for low-voltage (-10 - +10 Volt), direct drive stimulation via MP36 Analog Out port (with or without OUT3 BNC adapter) or an MP35 with SS58L connector.

Use with stimulator electrode HSTM01for safe, stimulation of human subjects (0 ó 100 Volts), as well as lower voltage (0 - +10 Volt) general-purpose stimulation, such is used with amphibian muscle or nerve preparations.

Outputs through a BNC connector so it can be used with most stimulation cables (such as those that terminate in a needle probe).

Stimulator Human Stimulator – STMHUM

Select this Output Control to conduct stimulation studies that enable subjects to control the stimulus delivery. This hand-held stimulator connects directly to the MP36 Analog Out port and has a red button for delivering the stimulus signal. The electrodes on the bottom of the unit are placed directly onto the subject. The STMHUM functions much like the BSLSTM but with no additional hardware required. The voltage range is 0 ó 100 volts and can be limited or locked to a user defined level in the STMHUM Output Control panel, which resembles that of the Low Voltage Stimulator.

To use one of these control panels:

Choose MP UNIT > Output Control and then select Pulses, Stimulator ó BSLSTM, Low Voltage Stimulator, or Human Stimulator ó STMHUM.
Right-click the Output Control panel (or choose **File>Preferences** and select from the sub-menu) to generate the Output Preferences dialog.
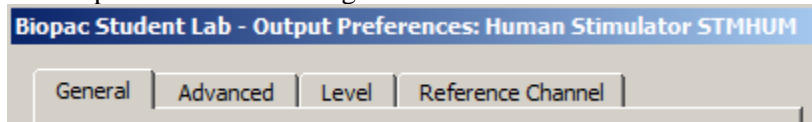
Set the Preferences.
General: Number of pulses, ON/OFF, Event options ô see page 180.
Advanced: Pulse width, Pulse repetition (rate), Verify transducer (STMHUM) ô see page 184.
**Level** (Low Voltage Stimulator and STMHUM only): Pulse level ô see page 187.
Reference Channel (Low Voltage Stimulator, Pulse Sequence and STMHUM only): Channel assignment, signal generation ô see page 188
Once configured, Preferences may be saved using the **Save Settings** command, activated by pressing the button at the bottom of the Preferences dialog (see page 180).
Confirm the settings in the control panel. Adjust as desired within the parameters established in Preferences.
Entry limits: Settings entered into the Preferences dialog may establish, or limit, the values in the Output Control panel entry boxes. Pulse settings may be directly entered into the control panel only if parameters established in Stimulator Preferences are not locked to a specific value. A grayed or disabled entry box indicates that the values are locked.
Initiate the pulse sequence as defined in Preferences (see page 180).
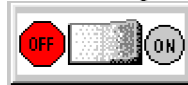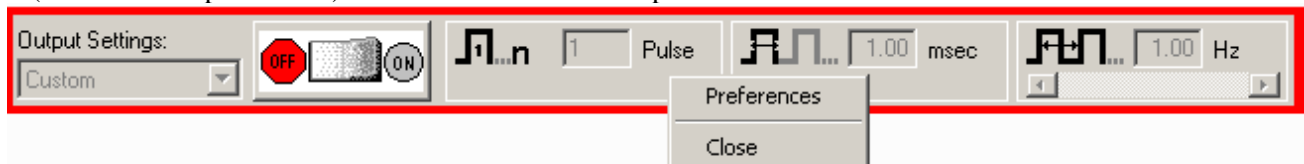
ON/OFF Button in Output Control Panel uses the switch in the Control panel.

Recording uses the **Start /Stop** button in the data acquisition window.

To close an Output Control panel:

Right-click anywhere in the Output Control panel to generate a pop-up menu and then choose **Close**, or select it (or another output control) from the MP UNIT > Output Control submenu.

Pulse Sequence Output Control (Available in MP36 & MP35A hardware only)

This Output Control allows sequences of pulse configurations and delays to be sent to the MP36/35A unit, making it possible to create more complex stimulus setups.

Enabling the pulse sequence output control option will display the following control panel at the top of the graph window:

Pulse sequence configuration is performed in the Preferences dialog of this output control panel. (Accessible via right-click on panel shown above or from File > Preferences) When a pulse train element is selected in the configuration, the controls will become visible in the right hand portion of the preferences dialog. The configuration makes use of three basic building blocks:

A *sequence* consisting of a number of delay and pulse train elements. The final configuration consists of one or more sequences that are outputted in order. Normally the entire configuration is outputted. There is a special operational mode on ÷Start with Recordingø that will take only the indexed sequence matching the current recording segment.

A *pulse train element* consists of Pulse count, Width and Pulse repetition, These elements can be fixed or randomly generated.

A *delay element* that allows for the introduction of time during which no pulses will be generated.

Each one of these building blocks also has a õrepeatö count associated with it that will perform the action a set number of times. (Adjust by selecting the desired ÷Repeatø and inputting a new value) Individual sequences, pulse trains and delays can be added, repeated and reordered as desired. In the right pane of the Preference dialog (shown below), fixed or random pulse counts, widths and repetitions can be configured and combined. As in other Output Controls, custom settings can be saved and organized in a list view. (See below for additional setup dialogs)

For a full explanation of preferences and tabs common to all Output Control panels, see the õOutput Controlö section on page 179.
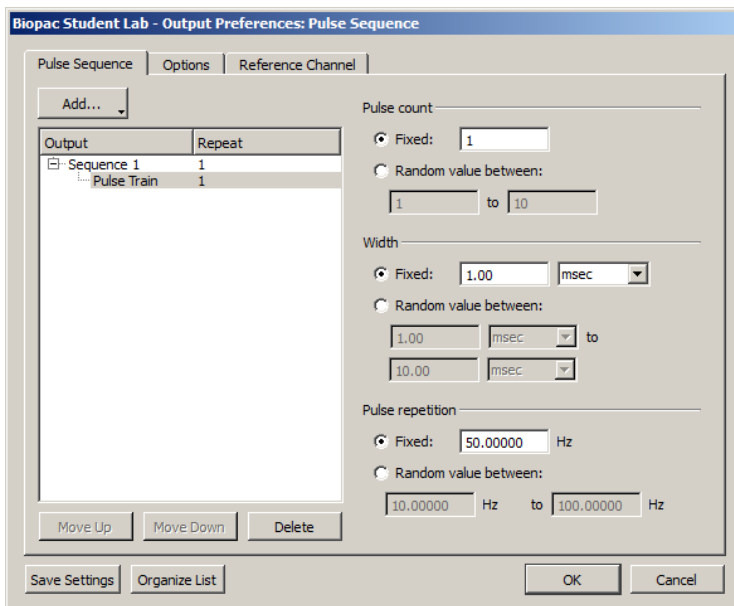
Preferences available in Pulse Sequence tab

Add: Displays pop-up menu for adding Sequences, Pulse Trains or Delays.

**Output:**   Displays the configured sequences and sequence elements for the current or saved session.

Repeat: Editable field for setting the number of times the pulse train or pulse train element is
repeated

Pulse count: Fixed ó a set number of pulses is generated per sequence.

Random ó set a random number of pulses to be generated per sequence.

Width: Fixed ó each pulse width will be of a set duration, in units of microseconds, milliseconds, or seconds.

Random ó sets the pulse width duration to fall between two set time ranges.

Pulse repetition: Fixed ó sets a fixed interval between the start of one pulse to the start of the next pulse

Random ó sets a random interval between two set values for the start of one pulse to the start of the next pulse.

Move Up/Down Delete: Selectively reorders or deletes the various pulse train elements.

Save Settings: Saves modified settings as a custom preset for the current graph, or for all graphs.

Organize List: Orders custom presets into a list and categorizes the custom presets for the current file or globally across the application.
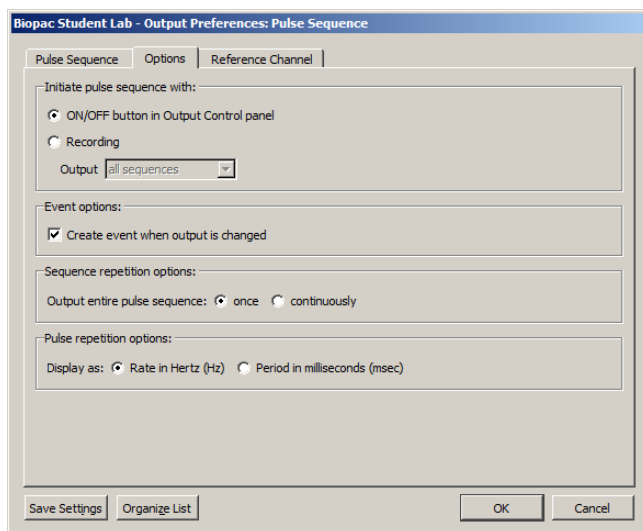
Preferences available in Options tab
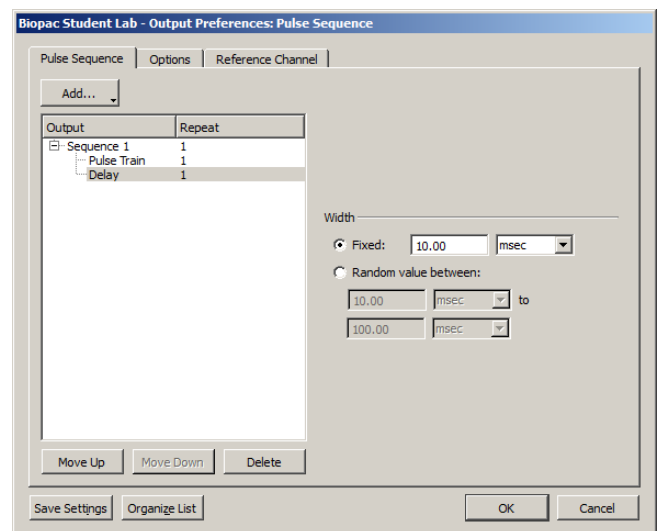
Delay Preferences
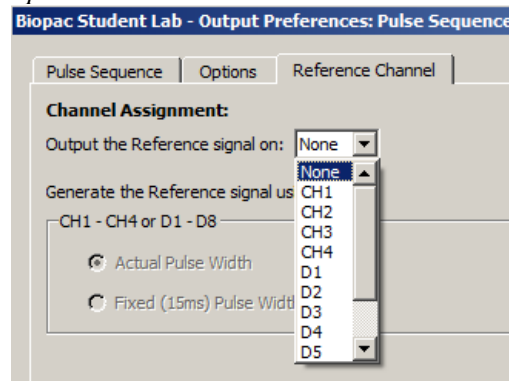
Reference Channel Preferences

About Delay between Pulse Trains:
The amount of actual Delay between pulse trains will vary from the set value depending upon the pulse repetition value that is used. In the example sequence below, a Delay of 100 milliseconds between pulse trains has been set up, combined with a pulse repetition rate of 20 milliseconds. Because the pulse repetition rate is applied before the Delay occurs, the actual Delay between pulse trains in this case will be 120 milliseconds. If it is critical that a Delay reflect an exact value, it is advisable to subtract the selected pulse repetition value when setting up the Delay parameters.
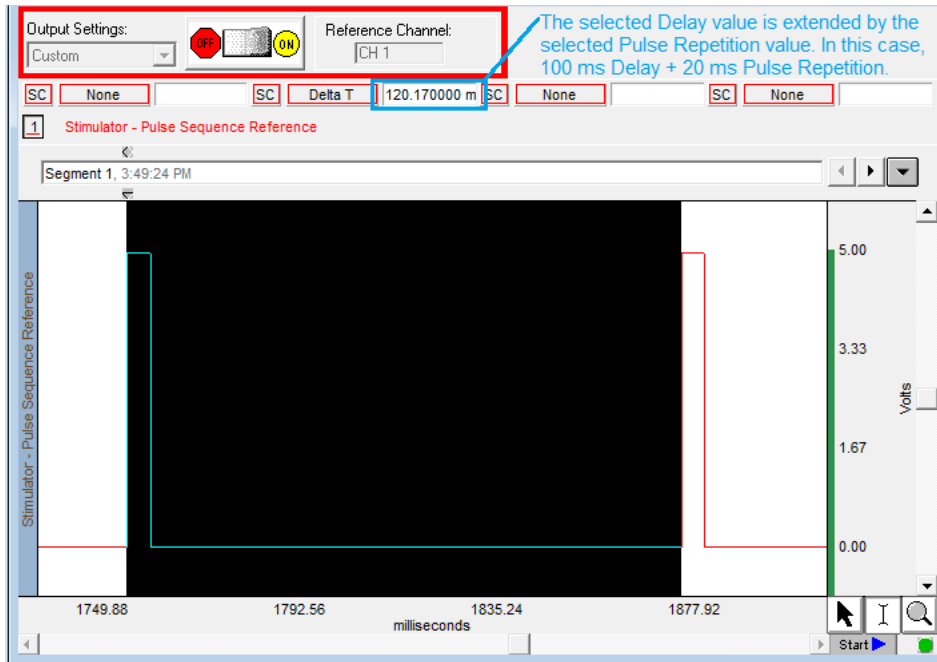
Delay between pulse trains

Visual Stim Controllable LED – OUT4 Output Control

This Output Control is used to set up parameters for the OUT4 LED transducer used for conducting visual stimulus studies, in which flashes of light of varying intensities and intervals are presented to a subject. The OUT4 LED transducer is connected directly to the MP36 Analog Out port.
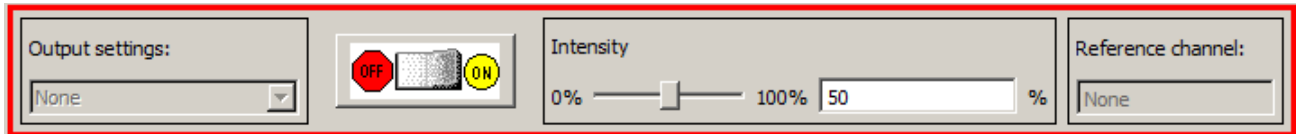
To use this Output Control choose **MP Unit > Output Control > Visual Stim Controllable LED**.

The Visual Stim Controllable LED Output Control panel is identical to the Pulse Sequence control panel, but with the addition of an intensity control for controlling the LED brightness level. The preferences operate identically to those of the Pulse Sequence Output Control covered in the previous section.
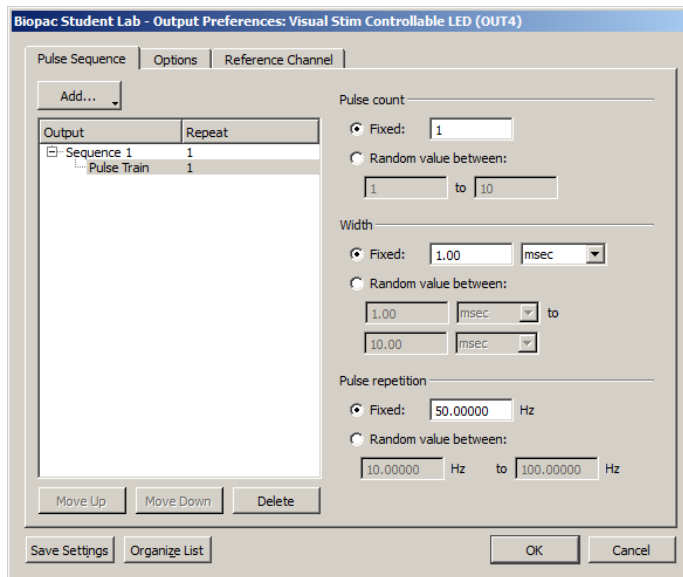
Pulse Sequence Tab for Visual Stim Controllable LED
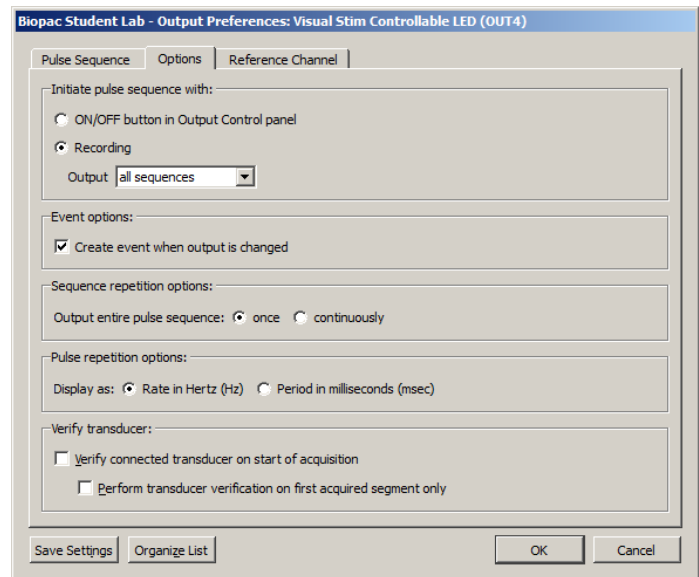
Options Tab for Visual Stim Controllable LED
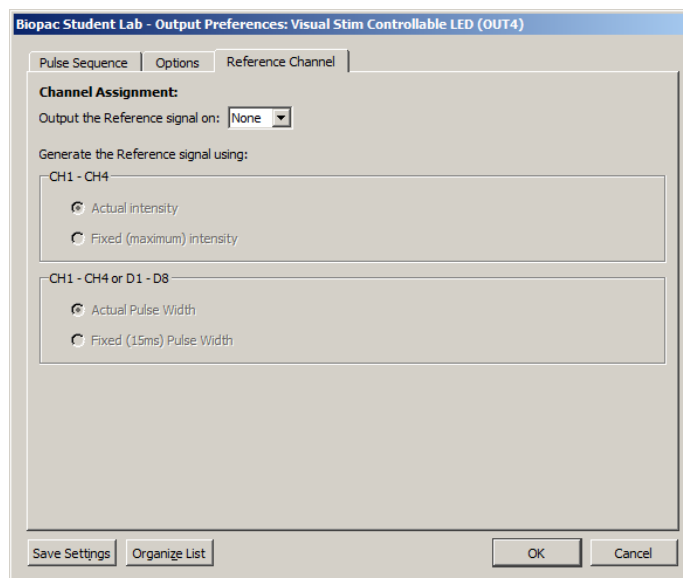
Reference Channel Tab for Visual Stim Controllable LED

For specifics on the Visual Stim LED preferences set up, see the Pulse Sequence Output Control section on page 170.

Arbitrary Wave Output

BSL 4.1.2 and higher supports signal output through one analog channel while data is being acquired. This is configured by using the Arbitrary Wave Output option. . In general, the Arbitrary Wave Output is used in conjunction with an OUT3 Low Voltage Stimulator connected to the Analog Out port (rear panel of MP36).

Four types of signals can be output; Square waveforms, Tone waveforms, Ramp waveforms and Arbitrary waveforms.

Each of these waveform types can be set to repeat signal output either Once or Continuously, and parameters can be set to either Relative or Absolute time scales. Like the standard graph window, the Stimulator setup window plots time on the horizontal axis and amplitude on the vertical axis.

Use the Stimulator window (see following page) to create and shape waveforms for output. Adjust the Stimulator Sample Rate to further control the parameters of the Stimulator Output design.

For any waveform (or stimulus) to be output, the following parameters must be specified; the type of stimulus, the õshapeö of the signal, the output channel to be used, and how many times the stimulus should be output.

The above parameters are set up from within the Stimulator Setup dialog. Regardless of the type of waveform selected, stimulus signals will normally be by clicking the BSL *PRO* graphø õStartö button or by using the On/Off Output Control panel button.

Square Waves

Square waveforms are useful for generating pulse waveforms, which can be used as stimuli or to trigger a stimulus-generating device (such as a flash device or a tone generator).

To output a square wave, choose the õOutput Onceö in the õDurationö section. A rectangular wave should appear in the window. The shape of the wave can be controlled by manipulating the various segments of the wave. and BSL *PRO* allows flexible configuration of the level (amplitude) and width (duration) of each segment.

In a square wave, each of the editable segments is oriented horizontally, with vertical segments connecting the adjacent sections of the wave. The first segment of a pulse waveform is the segment that appears at the far left of the waveform section. By positioning the cursor on this segment of the waveform, observe that the box at the bottom of the screen that the level (vertical offset) of the first segment is 0 Volts, and the width of the first segment is 500 msec.

To adjust the level of a segment, either:

  a) Enter the desired level in the Seg # Level box; or
  b) Position the cursor on the first segment of the waveform and drag it up or down using the mouse (segment 2 is selected in the preceding dialog, and appears in red).

To change the duration of a segment, either:

  a) Enter a value in the Seg # Width box at the bottom of the Stimulator Setup dialog; or
  b) Position the cursor on the first *vertical* segment in the setup dialog, click the mouse button, and drag the vertical segment left or right. Moving the first vertical segment left shortens the duration of the first segment, whereas moving the first vertical segment right lengthens it.

Each of the segments in the wave can be õeditedö in this way.

Tone Stimuli

Tone waveforms allow for the creation of pure tone signals of any duration, magnitude, and frequency. This option outputs a pure sine wave, which is useful for audiological and stimulus response testing.

A tone waveform is comprised of two segments, with only the second segment being the actual tone itself. This allows a pre-signal delay to be included (by setting the level for Segment #1 to 0 Volts and the duration to a desired value).

To set the duration of the tone, adjust the length of segment #2 (by changing the Seg #2 Width value box or by clicking and dragging the segments within the window). As shown, there is an additional (uneditable) section of the waveform *after* the second section. This segment returns the last value from segment two, and continues to output that signal level until the acquisition is terminated (if the stimulator is set to output once) or until another signal is output (if the MP System is set to output continuously).

There are three additional parameters for Tone waveforms: frequency; magnitude; and tone phase.

- Tone frequency refers to the frequency of the second segment of the waveform. This can be set to any value, although the most common settings are between 20 Hz and 20,000 Hz.
- Magnitude refers to the peak-to-peak range of the signal, which can range from ± 0 to ± 10 Volts.
- Phase of the stimulus signal can be any value equal to or greater than 0 degrees. Phase settings of more than 359 degrees will be rescaled to fit the 0°-359° range. In other words, setting the phase to 360° or 720° has the same effect as setting the phase to zero degrees.

Ramp Wave

Ramp waveforms are useful for constructing a monotonically increasing or decreasing stimulus signal.

Ramp waves are comprised of three segments and the amplitude and duration can be set discretely for all three sections.

Arbitrary Waveform

The Arbitrary waveform option is used to to set a waveform's shape and length using standard editing functions.

- The length of an arbitrary waveform is only limited by the available memory.
- Unlike the other types of waveforms, Arbitrary waveforms have no segments, so the õshapeö of the waveform is determined by selecting an existing waveform and the only parameters that can be set are Scaling, Repeats, and Trigger.
- Maximum continuous output is 20 kHz.

To set up the Arbitrary Wave Output:

1. Select MP36 > Output Control > Arbitrary Wave Output.
2. Right click the Arbitrary Wave Output Control panel and choose õPreferencesö to launch the Stimulator setup window.
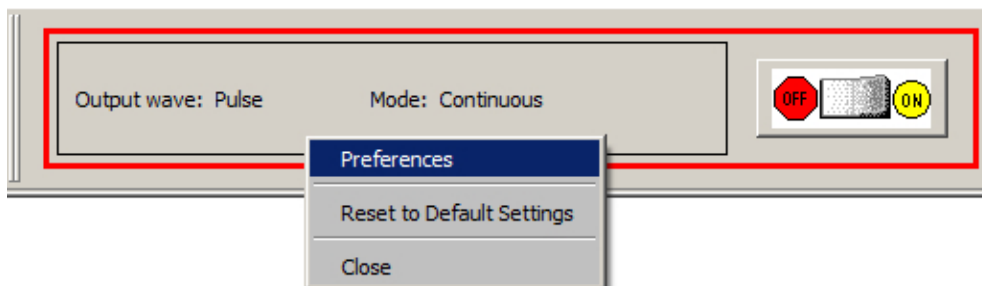
3. Set the desired waveform type and stimulator options in the Stimulator window. (See following page.)
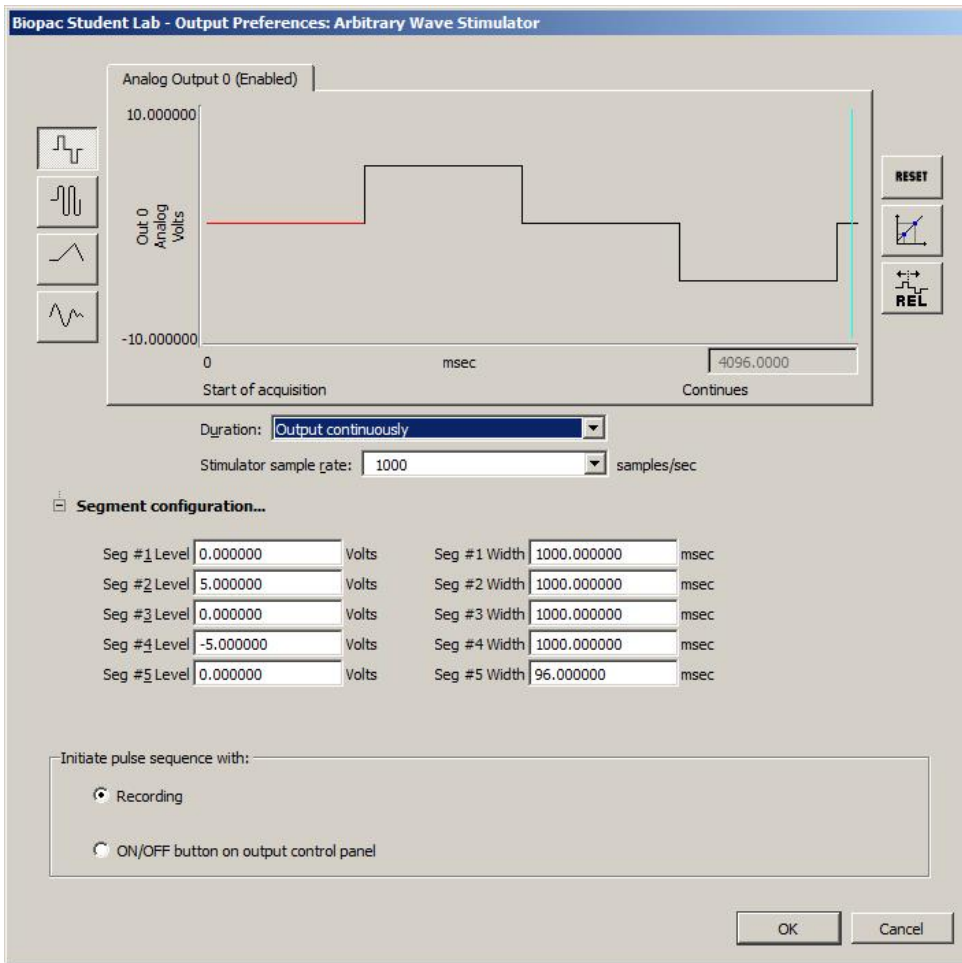
Stimulator Icons			
Waveforms:			Square wave
			Tone (sine) wave
			Ramp wave
			Arbitrary wave
Parameters:	RESET		Reset the display (use after adjusting the time scale)
			Scaling (rescale Stimulus signals to different units)
	REL		Set time base to relative
Output:			Sets Stimulator to be active when õStartö button is clicked OR when toggled via the ON/OFF button on the Arbitrary Wave Output control panel.

Sound Sequence Output Control (MP36/35/45)

This Output Control offers users the option of configuring and customizing sounds to be outputted for aural stimulus experiments. The control panel and Preferences dialogs used for Sound Sequence closely resemble that of Pulse Sequence. The built-in sound resource (a default õclickö) may be used or any other file in *.WAV format can be substituted via the õFileöand õBrowseö button. The õWidthö and õPulse Repetitionö values are dependent upon the duration of the sound file selected for output. The õTestö button will output an audio sample of the selected sound resource.
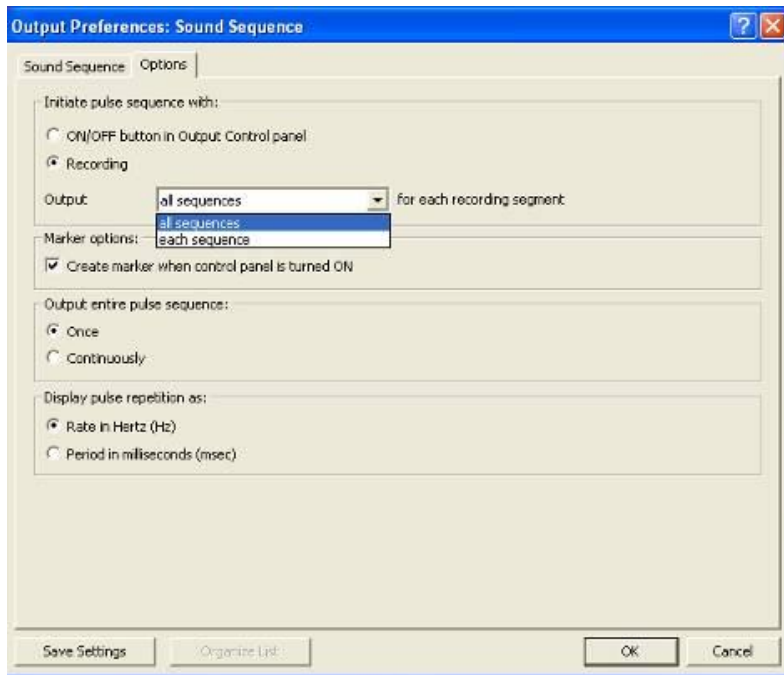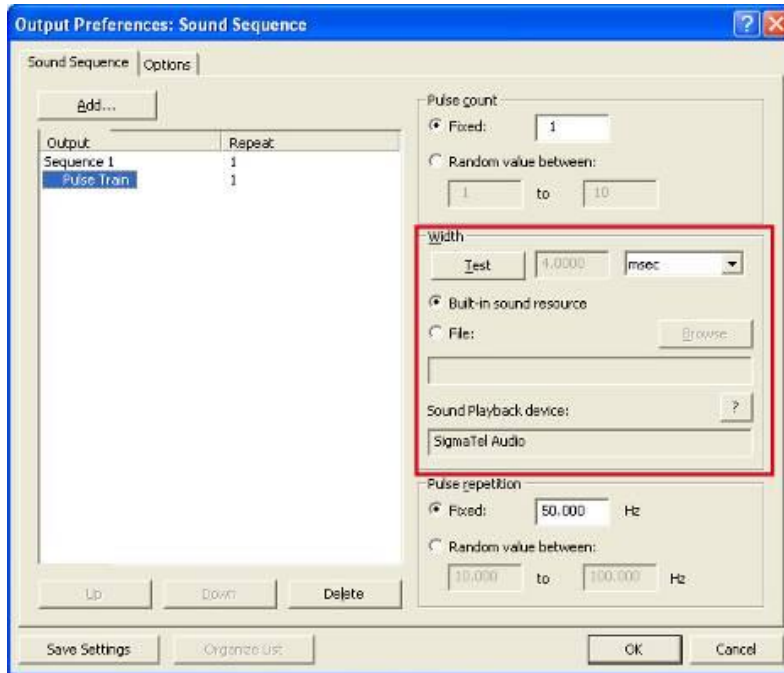
The option *all sequences* means that each configured sound sequence (regardless of number) will be outputted within the same segment. If "Once" is selected in the "Output entire pulse sequence" option, a configured sequence will be heard one time only. If "Continuously" is selected, the first Sound Sequence will be repeated after the last one has completed, looping the pattern repeatedly until the recording is stopped.

The option *each sequence* means that each sound sequence will be outputted on a segment-by segment-basis only. For example, if one Sound Sequence is configured, it will only be heard during the first recording segment, but not during the second recording segment). If two Sound Sequences are set up, the first one will be heard during the first segment and the second one during the following segment.. If no additional Sound Sequences have been configured, nothing will be heard during the third segments and beyond. (Exception: If "Save Once" acquisition mode is used, the Sound Sequence will be repeated when the recording is overwritten during subsequent passes).

Delay before first Pulse	Initial delay from start of acquisition to start of first pulse.
Number of pulses	Number of successive pulses that will be sent out at the specified Pulse Width, Repetition and Level. Set for Single (1), Multiple, or Continuous (Cont).
Pulse Level	Amplitude of the pulse, expressed in Volts.
	Note: The output of the BSLSTM is 0 Volts when the pulse is not active.
Pulse Repetition	Can be expressed as **Period** (ms) or **Rate** (Hz).
Also called — Events per second Pulse frequency Pulse sequence Pulse train Repetition rate Sample train	*Period:* Time between pulses; measured in milliseconds from the start of one pulse to the start of the next pulse.
	Rate: Number of pulses that occur in a one-second interval; measured in Hertz.
	Rate relates to **Period** as: Rate (Hz) = 1000 / Period (ms)
Pulse Width	Time that the pulse is in the non-zero or active state.

Output Control Panels

The Output Control panels for Pulses, Stimulator ó BSLSTM and Low Voltage Stimulator work in conjunction with Preferences to control pulse output. Control panel functions are detailed here:

OUTPUT CONTROL PANELS	
General Notes	Pulse parameters can interact with each other. For example, the pulse repetition period cannot be set to a value less than the pulse width. In order to simplify the interaction, the Pulse width entry overrides other entries as required; it is the priority parameter. For example, if the pulse width is changed such that it exceeds the pulse repetition period, the pulse repetition period will be automatically adjusted to accommodate the new pulse width entry. If, however, the pulse repetition period is changed such that it is less than the pulse width, the repetition period will be changed, upon attempted entry, to the closest value that can be achieved without changing the pulse width. Entries are checked and rounded (not truncated) as necessary to meet limitations of the hardware or the Preferences. When a file is opened, the output device will not turn ON automatically. A user must manually press either the õRecordö button or the õStartö button. The exceptions are the õVoltage Outputö control panel and the õDigital Outputsö control panel if õSet each Output immediatelyö is selected; these settings will output values immediately. Output control settings are õlocal,ö which means that they are stored at the data file level, not the program level. Use the save as graph template (File > Save As) option to use existing Preferences in new data files. If a file is saved with an Output Control panel visible and then closed, the panel will be visible when that file is re-opened.
Preferences	Right-click a control panel to generate the Preferences dialog, and then select a tab for the settings requiring adjustment. **Output Preferences: Stimulator - SS58L** ? X General │ Advanced │ Level │ Reference Channel │ The File>Preferences menu option can also be used to generate the Preferences dialog.
Output Settings Output Settings: Customize & Save ▼ Customize & Save Single pulse Paired pulses Multiple pulses Output Settings: Default ▼ Output Settings: Custom ▼	Displays the name of the current Preferences setting. The pull-down menu lists the names of all output Preferences saved using the **Save Settings** button (see page 180). The pull-down menu is not accessible when an output pulse train is in progress. If no settings configurations have yet been saved, when the Output Control panel is first opened and no parameters are changed, the Output Settings box displays õDefault.ö When output settings are saved, the Output Settings box displays the name of the last selected setting. Use **Organize List** to change the display order of the menu, rename, or delete items (see page 180). When a saved setting is selected from the pull-down menu, the Output Control panel and all Preferences dialog options will be updated. For Reference Channelô Low Voltage Stimulator; Human Stimulator; Visual Stim Controllable LED (OUT4) and Pulse Sequence only. All Output Settings must use the same reference channel assignment; other parameters can be unique for each setting.
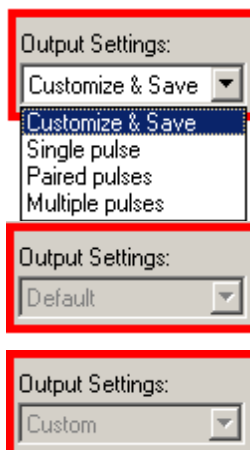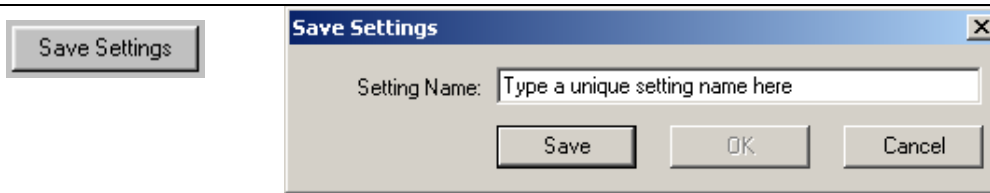
Save Settings

Save Settings

Setting Name: [Type a unique setting name here]

[Save] [OK] [Cancel]

Once configured, Preferences may be saved using the **Save Settings** button at the bottom of the Preferences dialog. **Save Settings** generates a dialog to name and save a defined configuration of Stimulator output settings. Saved configurations are accessible via the Output Settings pull-down menu in the Output Control panel. When a setting is selected from the menu, all current output parameters are updated to reflect the saved settings.
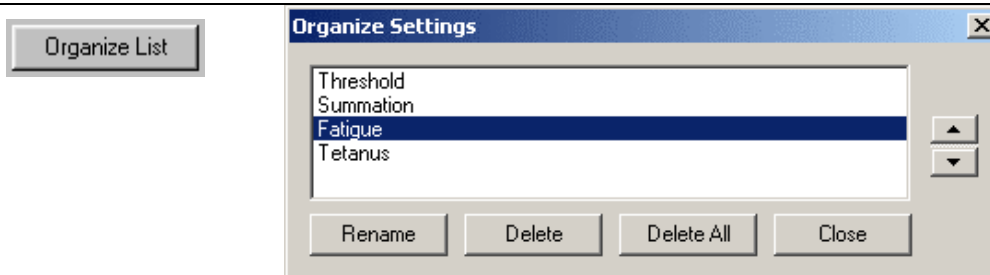
Multiple configurations can be saved as long as each has a unique name; the Save button will be inactive if the entered name is not unique.

Settings can be saved locally (to a specific file) or globally. The data file or template file holds the output parameters as established when the file was saved plus any other named configurations of Output Settings.

Organize List

Organize Settings

Threshold
Summation
Fatigue
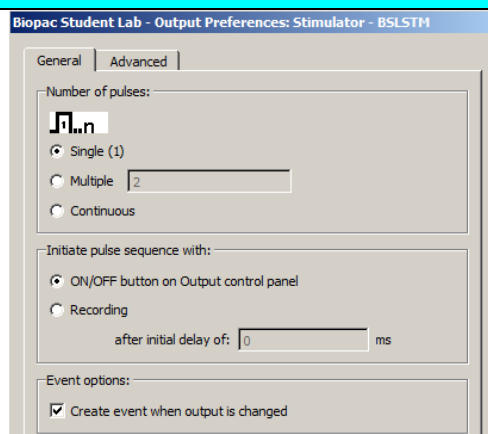Tetanus

[Rename] [Delete] [Delete All] [Close]

Use the **Organize List** button at the bottom of the Preferences dialog to order, rename or delete saved Preferences settings. The up or down arrows are only available if two or more settings have been saved. Select a setting and then click the up and down arrows to set the position, or choose rename or delete. If õDelete Allö is selected, all saved settings will be deleted and the default and Custom options will be reactivated.

GENERAL TAB (OUTPUT PREFERENCES)

General Tab

The General tab is available when using Pulses, Low Voltage Stimulator, Stimulator-BSLSTM and Human Stimulator-STMHUM.

Biopac Student Lab - Output Preferences: Stimulator - BSLSTM

General | Advanced

Number of pulses:
- Single (1)
- Multiple [2]
- Continuous

Initiate pulse sequence with:
- ON/OFF button on Output control panel
- Recording
  after initial delay of: [0] ms

Event options:
- ☑ Create event when output is changed
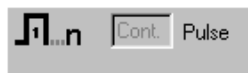
Number of Pulses

Indicates the number of pulses to be output. When the Output Control panel is closed, the pulse output will be immediately stopped.

Single will establish a single pulse for outputting. All pulse repetition options, entry boxes and scroll bars in both the control panel and preferences windows will be disabled (grayed).

Multiple will establish a specific number of pulses for outputting. The selection

will activate an entry box where any value from 1-254 pulses can be entered.

When this option is selected, the Pulse Repetition scroll bar is activated in the Output Control panel.

Continuous will establish a continuous pulse train for outputting. When this option is selected, the Pulse Repetition scroll bar is activated in the Output Control panel.
If õInitiate pulse sequence with ON/OFF button in Output control panelö is set, the pulse sequence will be stopped prior to acquisition and will have to be manually turned back on after the recording.
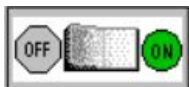
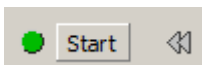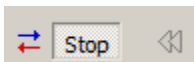|	
Initiate pulse sequence withí ON/OFF Button OFF (red) ON (green) AUTOMATIC START (yellow)	Controls the start and stop of pulses. Changes to Pulse Width and Repetition Rate can be made in the Output Control panel entry boxes during a pulse sequence, and during a recording, if all other Preferences parameters allow it. Any change in the pulse output will occur immediately. ***This allows the stimulator output to be changed "on the fly."*** When õInitiate pulse sequence with **ON/OFF button**ö is selected: The ON/OFF button controls pulse output independent of the acquisition status. OFF is always available. The ON/OFF button reflects the current output state, with one exception: if the pulse sequence lasts less than 0.5 seconds, the button will remain in the õONö state for at least 0.5 seconds to indicate that the ON state occurred. When the Number of Pulses selected is **Multiple**, ON/OFF acts as a momentary switch. Press the ON (green) button to start pulses; it will automatically turn OFF (red) at the end of the specified pulse train. The switch defaults to OFF. Saving a data file or saving as a Graph Template will save all stimulator preferences <u>except</u> the status of the pulse switch, which will always be saved in the OFF position.
Recording Start button Stop button	When õInitiate pulse sequence with **Recording**ö is selected: If the preference setting õInitiate pulse sequence with: ON/OFF buttonö is active, the control panel changes will take effect immediately. If settings are changed during a pulse train, changes do not take effect until the next time the stimulator starts. Pulse output turns ON and OFF corresponding to the Start and Stop of the recording. When in this mode, and not recording, the ON button will display as yellow, indicating that pulse output will automatically begin at the õStartö of the recording. Pulse outputting can be turned OFF during a recording, but it cannot be turned back ON until the end of the recording. When a **Repeat** sequence is running, pressing the OFF button will turn OFF the output <u>for the entire recording sequence</u> and the button will display as OFF until after the last sequence, when the switch will display as yellow ON (automatic start) indicating that pulse output will begin again at the õStartö of the next recording sequence. Pulse outputting cannot be turned back ON during a repeated recording sequence. When the acquisition stops, all stimulator pulses will cease, regardless of the Output Control panel settings. The pulse output will stop concurrent with the end of the acquisition, even if the specified pulse output is not completed before the acquisition ends. When a new acquisition is started, the pulse output will start from the beginning.

In this mode, no changes can be made in the Output Control panel until the recording stops.

Changes made after recording stops will take effect when a new recording is started.

When a pulse is sent out, the event label and indicator arrow will be generated (if the event preference is turned ON and events are displayed).

After initial delay (Applicable to Pulses, Stimulator - BSLSTM, Low Voltage Stimulator and Human Stimulator-STMHUM only)	**After initial delay of …** is enabled only when õInitiate pulse sequence with **Recording**ö is chosen. Specify a delay interval from the start of recording to the start of the first pulse. This is useful for viewing data prior to the stimulus pulse. The BIOPAC output device determines the delay range.

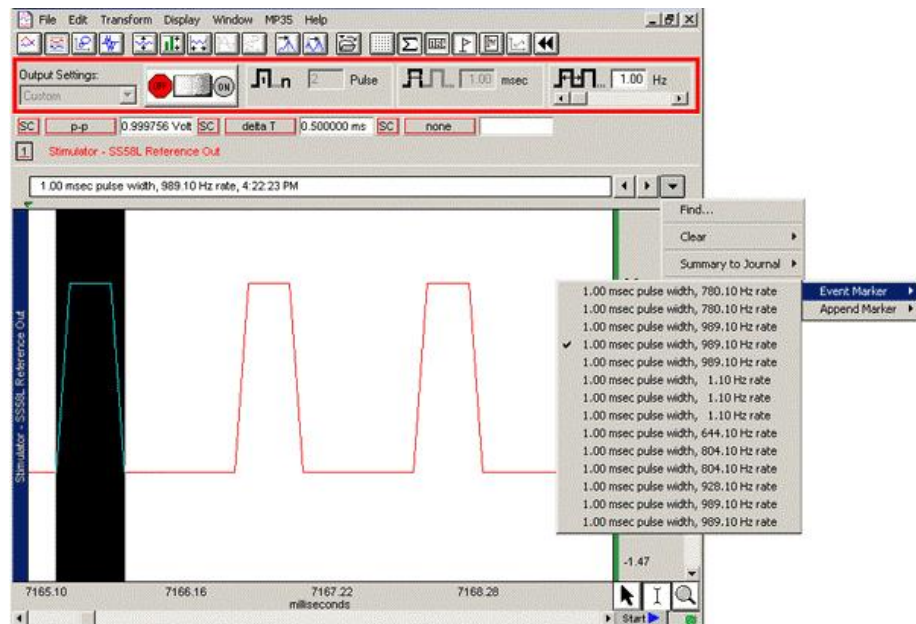INITIAL PULSE DELAY   MP36/35   BSLSTM

Range   0 - 100 milliseconds   0 or .5 - 100 milliseconds*

Resolution   10 microseconds   1.953 microseconds

*Entries greater than 0 milliseconds must be at least 0.5 milliseconds.

Pulse
Events

Event options:

☑ Create event when

An advantage of using the BSL *PRO* software for output signals is that information regarding the pulse is automatically recorded along with the data. The amplitude reflects the output pulse level.

- Events can be automatically inserted and labeled for each Reference pulse or change in pulse train. The label will contain the Pulse width and Pulse rate (and system time stamp if selected).

- Events reflect setting changes made during an acquisition.

- All output pulse information is automatically recorded and archived with the saved data.

Set the event option by clicking in the box to õCreate event when output is changed.ö

Set the õInclude time/dateö option in the global Preferences (MP36R > Set Up Data Acqusition > Event Marking)

☑ Include time
☑ Include date

The event label accurately captures pulse data, but the event arrow may not always line up exactly with the leading edge of the pulse; this typically is not a problem because the recording will include the actual stimulus pulse which can be used for timing measurements.

Depending on the acquisition Sample Rate, the leading edge of the pulse in the recording may not correspond to the exact time the pulse was sentô it may be off by as much as one sample period. If the event precision is critical for the recording, increase the Sample Rate.

To display events, use the toolbar icon or Display>Show>Events.

The **Range** switch on the front of the **BSLSTM** stimulator should be set to 10V or 100V prior to recording and should not be changed during recording; if using a Preset, the corresponding Preset should also be selected prior to recording. The pulse level can then be determined by moving the decimal to the right or left depending on how the range was switched.

ADVANCED TAB (OUTPUT PREFERENCES)

Advanced Tab

(Applicable only to Pulses, Stimulator - BSLSTM, Low Voltage Stimulator and Human Stimulator-STMHUM)
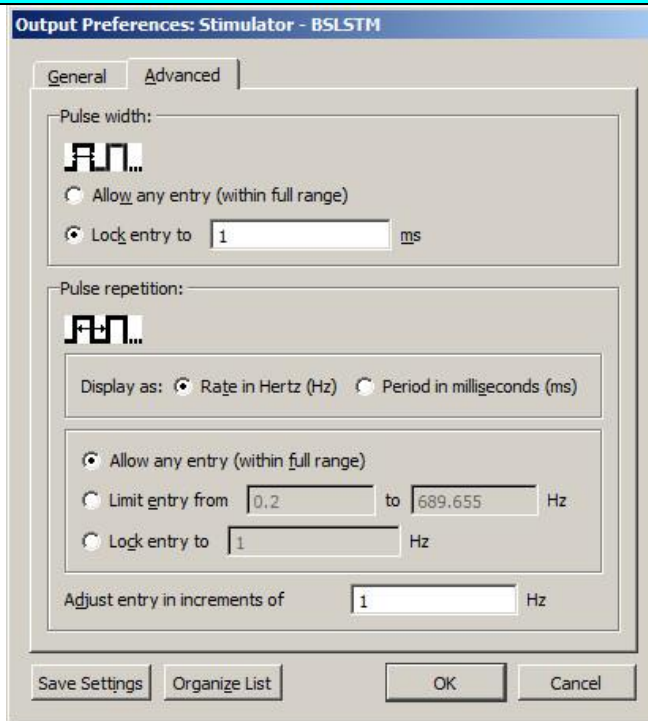
Pulse Width	Indicates the Pulse Width setting, which determines the maximum Pulse Rate frequency. A Pulse Width value can be entered, unless limited by Preferences.

The entry is activated when the value is changed and the Tab or Enter key is pressed; it does not require a stimulator restart to take effect.

The Pulse width entry overrides other entries as required.

An entry may be automatically changed if any of the following conditions apply, in which case the closest possible value will be selected:

It falls outside the allowable range.

It is rounded to .01 millisecond increments (MP36/35 resolution).

Width has been limited by the **Pulse Width: Limit Entry** settings of Preferences.

Allow any entry — Pulse width is limited to the output capabilities of the BIOPAC MP device. This option allows any entry within the allowable range specified below:

PULSE WIDTH RANGE MP36/35 unit

Range   .050 ó 100 milliseconds

Resolution   10 microseconds

Lock entry to — This entry locks the width to a single, specified value (within the allowable range). No other value can be entered.

Pulse Repetition — Indicates the Pulse Repetition period (Hz or ms).

The **Pulse period** must be greater than the **Pulse width**. See õTBPMINö in the Output Preference > Advanced Tab Limits table on the next page.

The full range of acceptable Pulse Rate values is from **.2** to **6,667 Hz.**

The maximum Pulse rate (PRPMAX) depends on the Pulse width setting:

Pulse width 100 ms → maximum Pulse rate = **9 Hz**

Pulse width .020 ms → maximum Pulse rate = **3333 Hz**

The formula for pulse width vs. pulse repetition is *PRPMIN = PW + TBPMIN*

Where: PRPMIN = the Minimum Pulse Repetition Period allowed.
       PW = Pulse Width setting
       TBPMIN = Minimum Time (in ms) between successive pulses
           for the output device (see device specifications)

If õLimit changes from ___ to ____ö is selected in Advanced preferences, then PRPMAX will be determined by the formula above or the specified limit, whichever is greater.

An entry may be automatically changed:

- If it falls outside the allowable range.

- To round it to .01 Hz increments (resolution of system).

- To make it at least 0.1 millisecond greater than the Pulse width.

- By the Pulse Repetition Rate: Limit entry Preference.

- By the Pulse Repetition: Adjust entry increments Preference.

Any pulse width value can be manually entered, but when using the scroll bar or arrows, entries will be constrained by the õAdjust entry incrementsö Preference setting.

Pulse Repetition Scroll Bar	The Pulse Repetition **Scroll Bar** adjusts rate or period by the increment of change and limits established in Preferences. With each click of the scroll bar arrows, the rate will be increase by the specified increment. When õInitiate pulse sequence with **ON/OFF button in Control Panel"** is selected, changes take effect upon release of the scroll box as long as the stimulator is running. The scroll bar is disabled when Number of Pulses is set to õSingleö or Pulse Repetition is set to Lock Entry to...ö
Display as	Pulse repetition can be displayed as **Pulse Rate** (expressed in Hz), or **Pulse Period** (inverse of Pulse Rate, expressed in milliseconds). Pulse Repetition Rate relates to the Pulse Repetition Period as: Pulse Rate (Hz) = 1000 / Pulse Period (milliseconds) The õDisplay asö **units** selection is also used for: Pulse repetition entries in the control panel. Scroll bar increments. The Pulse Repetition Rate: Limit entry Preference. The Pulse Repetition: Lock entry Preference. The Pulse Repetition: Adjust entry increments Preference. When units are changed from Rate in Hertz (Hz) or Period in milliseconds (ms), the limits of the Pulse Repetition range will be converted by the formula: Period increment in ms = Round to nearest whole number [Period Range * (Rate increment in Hz /Rate Range in Hz)] For example, if the Range was 1Hz to 10 Hz with an adjustment increment of 1Hz, the proportional calculation would be Period increment = 900 ms (1Hz / 9 Hz) = 100 ms

Allow any entry	Pulse width is limited to support the output capabilities of the BIOPAC output device. See Output Preference > Advanced Tab Limits table for allowable range.
Limit entry	Establishes minimum and maximum values that can be manually entered or changed with the scroll bar.
Lock entry	Locks the Repetition to a single, specified value (within the allowable range). No other value can be entered in the control panel.
Adjust entry	Controls the scroll bar or scroll arrow increment; does not apply to manual entry.

Output Preference > Advanced Tab Limits

		Pulses MP36/35	BSLSTM MP36/35	SS58L MP35 Only	Low Voltage Stimulator MP36	STMHUM MP36
Pulse width						
	Range (ms):	0.05 - 100	0.05-100	0.05-100	0.05 . 100	0.1-1
	Resolution (ms):	0.01	0.01	0.01	0.01	0.01
Pulse Repetition						
	Rate range (Hz):	0.2-6,667	0.2 -689	0.2-10,000	0.2- 10,000	0.2-6667
	Period range (ms)	.06-5,000	0.5-5,000	0.1-5,000	0.1-5,000	0.15-5,000
	TBPMIN Minimum time between Pulses (ms):	0.01	0.450	0.05	0.05	0.05
	Resolution (ms):	0.01	0.01	0.01	0.01	0.01
Initial Pulse Delay						
	Time range (ms):	0-100	0-100	0-100	0-100	0-100
	Resolution (ms):	0.01	0.01	0.01	0.01	0.01

LEVEL TAB (OUTPUT PREFERENCES)

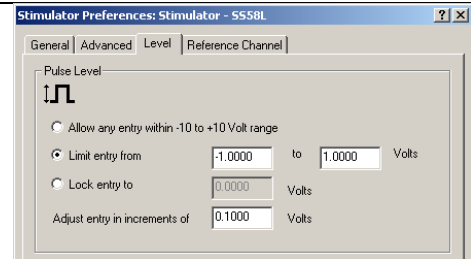|	
About Level	Low Voltage Stimulator and Human Stimulator-STMHUM allows the software to specify the pulse amplitude. The amplitude can be set to any value within the limits of the stimulator; the range is -10 to +10 Volts for the Low Voltage Stimulator and 0-+100 V for the Human Stimulator-STMHUM
Pulse Level Low Voltage only	The **Level entry box** allows the user to manually enter any value within the limits of the system, or within the limits of the Preference settings from the Level tab. The Level entry box will be inactive (grayed) if: The Level preference õLock entry toö is active. If õInitiate pulse sequence with Recordingö is active (from the General tab) and a pulse sequence is in progress or õwait for triggerö is in progress. Use the entry box or the scroll bar to set the Pulse level. When a value is entered which is out of range, the value will be rounded to the closest value obtainable after the õEnterö or õTabö key is pressed. If õInitiate pulse sequence with ON/OFF button in control panelö is active (from the General tab), then values entered during a pulse sequence will take place immediately. If õInitiate pulse sequence with Recordingö is active (from the General tab), any entry made between acquisitions will take place on the next õStartö of acquisition.
Allow any entry	The level is limited to the output capabilities of the stimulator. This option allows any entry within that range.
Limit entry	This entry reduces the range of the stimulatorøs output capabilities.
Lock entry	This entry locks the level to a single specified value (between -10 and +10 V).
Adjust entry	This setting affects the scroll bar or scroll arrow increment only; it does not apply to manual entry. The smallest increment is 5 mV, as limited by the MP36/35. The specified increment is used to round manual entries to the closest obtainable value.

REFERENCES TAB (OUTPUT PREFERENCES)
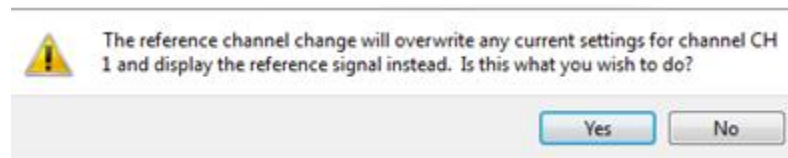
Reference Channel
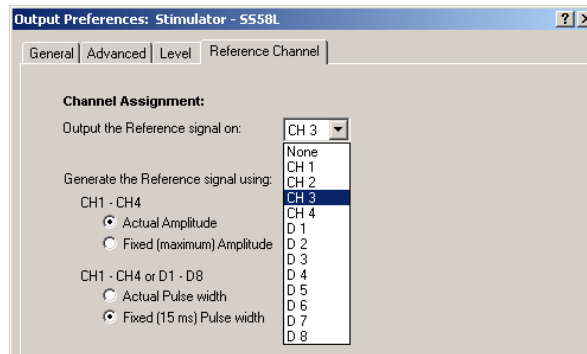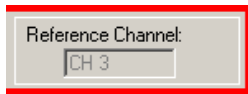
This option allows monitoring of the output signal on one of the analog or digital input channels without making any physical connections. This is an internal, hardware/firmware, feature that recreates the output signal and allows recording in õreal time.ö The assigned reference channel will override any õrealö input signal.

The reference signal is <u>not</u> the real signal, but is a very accurate õestimateö of the real signal. The pulse timing accuracy will be within 100 microseconds. If an analog input channel is used as the reference channel, the pulse level will be accurate within 5%. If the stimulation encounters a load that reduces or distorts the pulse output, the reference signal will not reflect this amplitude distortion.

If a digital input channel is used as the reference channel, only a digital representation of the pulse will be generated; 0 to 5 volts.

Channel Assignment   Use the pull-down menu to choose which analog or digital input channel will be used as the output reference channel.

When a new reference channel is assigned, a warning will be generated indicating that this setting will overwrite the existing Channel Setup parameters for the selected channel.

For example, if CH1 is set up for ECG data and then selected as the Reference Channel, the ECG parameters will be replaced. If another channel is then selected, CH1 will be reestablished with the default analog input parameters, and the ECG settings would need to be recreated via presets or manual entry.

The reference Channel label should read: (Selected Output) - Reference Outö.

When an Analog Input Channel is assigned as the Reference channel, that channel (as viewed from MP UNIT > Set Up Data Acquisition > Channels) will be in a locked mode and the Preset pull-down menu will be disabled. The assigned reference channel will be inactive for õrealö inputs until the Reference Channel Preference is changed to õNoneö or another channel.

Once the control panel with an assigned Reference channel is closed, the data Acquisition Settings > Channels will automatically update to the default settings.

Generate using	Specifies how the Reference signal should be shown.
	If using **analog** input from CH1 - CH4, an actual or fixed (max) amplitude and actual pulse or fixed pulse width can be selected. Fixed pulse widths are useful when the pulse width is much smaller than the sample interval (1/sample rate) is used.
	For example, Frog muscle stimulation uses a 1 ms pulse width and a sample rate of 2000 samples/second to capture the muscle response. At this sample rate, the stimulus pulse cannot be reliably recorded. By using the fixed width of 15 ms, the pulse should be recorded.
	If using **digital** input from D1 - D8, select actual or fixed (15ms) pulse width.

Usage Guidelines & Setup Summary for BSLSTM Output Control

HUMAN SUBJECT SAFETY
Before using the stimulator on human subjects, it is very important to limit the energy the stimulator outputs. For optimal safety:
Before powering on the BSLSTM stimulator, set the voltage level to zero by rotating the LEVEL knob on the front of the BSLSTM fully counterclockwise.
Use BIOPAC HSTM Series Probes. These probes MUST be used in order to limit the energy the stimulator can output.
Never create an electrical path across the heart.
Never use on subjects with pacemakers.
Read this manual and the BSL Hardware Guide to become familiar with Stimulator operation.

1. Connect the BSLSTM Stimulator to the MP UNIT and power on both units. (For instructions on how to connect the BSLSTM to the MP UNIT Acquisition Unit, refer to the *BSL or MP Hardware Guides*.)

2. Connect the Stimulator Trigger cable to the Analog Out port of the back of the MP36R hardware.

3. Connect the Stimulator Reference Output cable to an Input Channel on the front of the MP36R hardware. This channel will be set up in Step 8 below as the Stimulator Reference Channel.

4. The **Reference pulse** has a fixed Pulse width of 15 milliseconds, so chosen so that the Sample Rate of the recording may be as low as 100 samples/second and still capture the Reference pulse.

5. Before powering on the BSLSTM stimulator, set the voltage level to zero by rotating the LEVEL knob on the front of the BSLSTM counterclockwise all the way to the left.

6. Open a new data acquisition graph.

7. Confirm that **Events** are activated. Events are activated by default. If not activated for a given recording, choose **Display > Show > Events**.

8. Set up the **Stimulator Reference Channel**. This is the Analog Input Channel on the front of the MP36R that receives the Stimulator Reference Output cable from the back of the BSLSTM. Remember, the reference channel is is generated from the stimulator and not the software.

9. Choose MP UNIT > Set Up Data Acquisition > Channels. This will generate a Set up Channels dialog.

10. Select the **Acquire**, **Plot** and **Enable** options for the analog channel to use as the Stimulator Reference Channel.

11. Click **Presets** and scroll to select õStimulator (0-10V)ö or õStimulator (0-100V)ö to match the Range switch setting on front of the BSLSTM.

12. Click **Setup** to view or change the analog channel parameters. Review the BSLSTM Stimulator section (page 168) and Analog Channel Setup section (page 101) before modifying channel/preset parameters.

13. The Gain and other input parameters may be set as desired.

14. Click OK to accept the parameters.

15. Close the Set up Channels window.

16. Adjust the voltage output of the stimulator by using the **Level** control on the front of the BSLSTM.

17. Rotate the **Level** knob clockwise to increase and counterclockwise to decrease, reading the voltage in the BSLSTMøs digital display.

Stimulator Safety Features

The stimulator cannot operate unless its Output Control panel is open.

The Pulse ON/OFF Switch on the Stimulator Output Control panel must be OFF in order to open and configure Stimulator Preferences.

If the Stimulator Output Control panel (or the BSL *PRO* application) is closed in the middle of a pulse train while the stimulator is running, the stimulator will shut down and the pulses will stop.
If another data acquisition window is activated, the stimulator will stop and remain OFF unless restarted using the parameters associated with the new data window. The only exception is that if the stimulator is ON and the data window corresponding to current stimulator parameters is acquiring data, then the stimulator will continue to run until the end of the acquisition.

Chapter 9   Set Up Event Marking

Events (Markers)

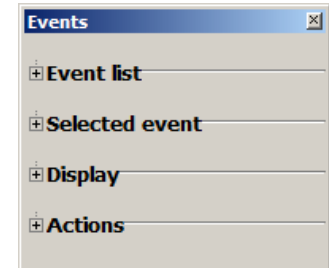Event Toolbar   Event Insertion   Event Control

Event (Marker) Overview

For detailed analysis, it can be useful for waveforms to have extra information associated with them. This information might include waveform boundaries from ECG analyzers, spike classifications from a spike sorter, heartbeat classification from a PhysioBank file, or even detailed user notes. BSL *PRO* uses õeventö functionality to store and manage this information.

An event is a piece of information associated with a specific time in a waveform. An event can capture points of interest within a file (i.e. subject moved, dose added) or on a particular channel (i.e. T-wave onset). Once events are marked in the file, BSL *PRO* can use the event information for analysis, including measurement (page 205) and cycle detection (page 282).

▪ An event has the following pieces of information associated with it:
- o Event type
- o Sample location: the time position in hardware samples where the event is defined.
- o Channel: the channel for which the event is relevant.
    - o Some events, such as the time of the start of an appended segment, may be relevant to all of the channels of a graphô these are õGlobalö events.
- o Label: a string of text that can be entered either automatically or by the user to provide more information about an event. Labels can be fixed or sequential in BSL *PRO* and up.

▪ Different event types can be entered automatically or manually. These different event types allow events to be filtered and also support analysis routines that key off of these events.
- o Event insertion tool
- o Set Up Event Marking (see page 193) to manually insert events during acquisitions
- o Copy/paste measurements and Copy/paste wave data operations can insert events at the selection boundaries; choose õMark with eventsö under Preferences (see page 192)
- o Cycle Detector Output Events option (see page 282)
- o Contextual menu in Event region

> Insert New Marker
> Paste Marker Summary to Journal

Event Toolbar

The event toolbar displays global events and provides a quick editing area for event descriptions. The right button toggles visibility of the Event Palette for detailed control (see page 194). The palette will õrefreshö when events change the event configuration, such as horizontal scrolling, scale changes, changes in the selected event via clicking in the graph window, editing of the event label by using the event bar, transformations that define new events for the graph, waveform editing operations, and additions of new events by clicking the event bar at the top of the graph window.

Event Tooltips

If events are being displayed within the plotting area and tooltips are enabled, a tooltip will be associated with every event in the plotting area. The tooltip includes the event type description, the user-defined label (if present), the time location of the event, and the amplitude of the waveform at the event location. While this information can be drawn directly on the graph, event tooltips assist in browsing event information when the screen becomes too crowded and there is not enough room to display all of the times, amplitudes, and labels.

Event tooltips are displayed under the event icon.

- If the event is being plotted directly on the waveform, this will be the point on the waveform associated with the event.
- If there is an indicator and the event icon is at the top of the indicator, the tooltip will be anchored at the top of the indicator.
- If the events are being plotted at the top of each track, the tooltip is anchored at the top of the plotting area directly underneath the event icon.

Event tooltips will not be displayed if tooltips are disabled, if events are only being displayed in the event bar at the top of the screen, if X/Y mode is in use, or if events are not currently visible.

Event Preferences
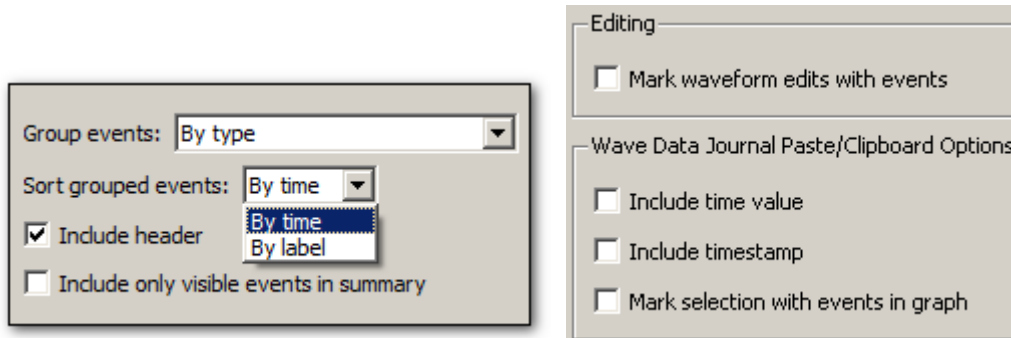
Preferences > Event Summary and Waveform

Use the õEvent Summaryö section of the Preferences dialog to set options for pasting summaries of events into the journal. (Preferences shown above and listed below are from BSL *PRO*)

- Group events

  Sorted by type   sorted by event type descriptions first

  Sorted by channel   grouped based upon where they are defined (Global events appear first, followed by groups for each individual channel).

- Sort Grouped events

  Sorted by time   sorted in order by increasing time

  Sorted by label   sorted alphabetically by label

- Include only events visible on the screen

  Determine if the summary is generated for all of the events that are in a graph, or only for those events that are currently visible on the screen. If there are thousands of events in a file, this feature allows the list to be pared down to those of interest.

Event summary options will be saved with the graph if the graph has a graph journal, and can be pasted into the journal using õSummary in Journalö Event Palette Actions command (see page 198).

Other event preferences are available under Preferences > Waveforms

- **Mark waveform edits with events**

- **Mark selection with events in graph**ô create events at data selection bounds. This includes selection events (selection begin and selection end) for global events when measurements or waveform data are pasted. When selected, measurement pasting will result in an automatic execution of the õMark Selectionö feature manually accessible from the Event Palette.

- **Include time value**ô include the time value (relative to start = 0) for the paste.

- **Include timestamp**ô Include time and date stamps for when the paste occurred; this timestamp will match any timestamp pasted into the journal. When selected, any selection events added to the graph will have their labels set to match the timestamp.

- **Auto-paste results in independent journal** (Preferences > Journal)ô Selection events and time stamp events can be automatically inserted to an independent Journal.

Combine these options to retain enough information to reproduce measurement results and correlate measurement results with specific areas of the graph; this helps verify the accuracy of measurement results made through manually constructed graph selections.

Any change to these settings will be retained within a saved graph file and will become the default for newly constructed graphs.

Event Marking Setup
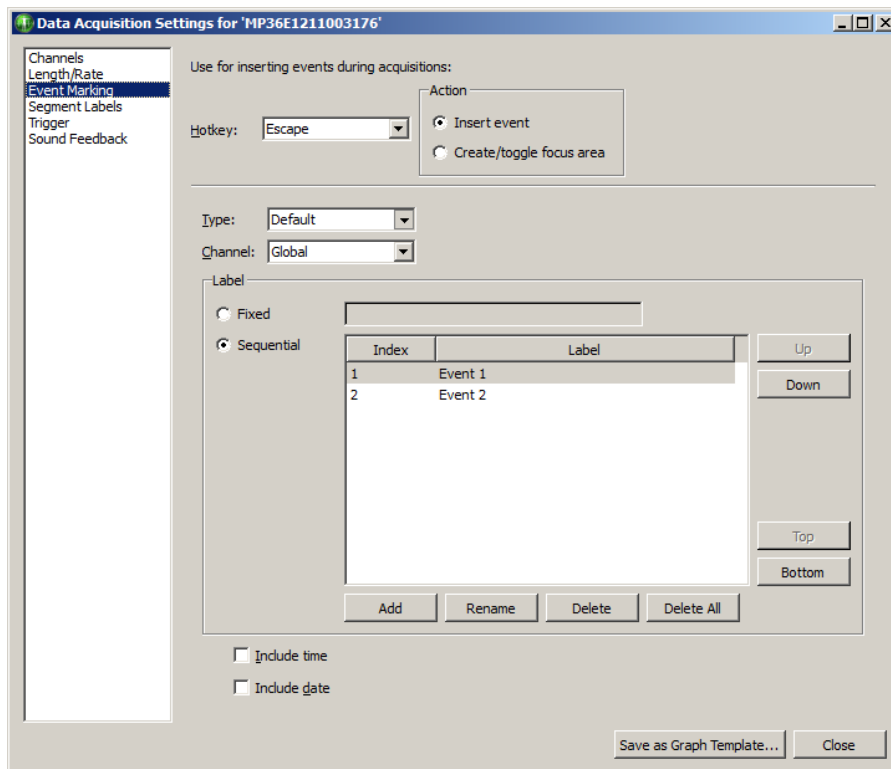
Events of different types can be inserted during acquisition, whether or not events are visible in the graph. When a *hotkey* is pressed during acquisition, an event will be inserted into the graph at the end of the most recently acquired data. Each hotkey can have a different configuration, adjustable through a dialog accessible via the õMP > Set Up Data Acquisition > Event Marking...ö menu item.

Hotkey	Assign Escape or F1 through F9. When a different hotkey is chosen, the other controls of the dialog change to reflect the configuration of the new hotkey.
Action	Choose whether the Hotkey assignment creates an event or a focus area.
Event type	Lists the standard hierarchical menu of available event types; Types are detailed on page 199. Choosing a new type from the pull-down menu will change the type of event inserted when the hotkey is pressed during acquisitions.

Channel   Contains a õGlobalö entry and all of the channels (analog, digital, or calculation) set to
                      õAcquireö in Set Up Channels.

- õGlobalö will define global events drawn in the event bar above the graph data
- Choosing a new channel from this menu will cause events to be inserted on the
  appropriate channel of the graph when the hotkey is pressed.

Label   Edit field for label text and toggle optional inclusion of time stamp and/or date stamp. Stamps
                      correspond to the time of the system clock when the key was pressed, that is, the time of the
                      event insertion in õreal clock time.ö

- Fixed - Provides a fixed label from text entered into the label field to the right. This label
  is used every time the assigned hotkey is pressed. (BSL *PRO* and higher)
- Sequential - Labels for events will iterate sequentially through the entries in the table
  index when the assigned hotkey(s) is pressed. The area under ‑Labelø is editable for
  entering text. (BSL *PRO* and higher)

Additional Controls	Function
Add	Adds an editable label field to the list.
Rename	Allows renaming of the existing segment label.
Delete	Deletes a selected custom label.
Delete All	Deletes all custom labels.
Up	Incrementally moves a selected label up the list.
Down	Incrementally moves a label down the list.
Top	Moves a selected label to the top of the list.
Bottom	Moves a selected label to the bottom of the list.
Include time	Adds timestamp to labels when checked
Include date	Adds current date to labels when checked

Create/Toggle Focus Area Action

Selecting the ‑Create/Toggle Focus Areaø action presents a similar setup dialog, but dictates that hotkeys
setups will be assigned to defining Focus Areas instead of inserting events.
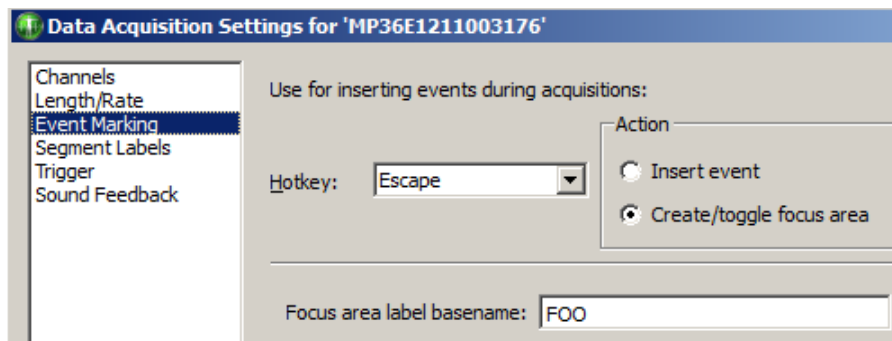
When this option is chosen, pressing an associated hotkey during a recording will initiate a focus area in the
graph. Toggling the same hotkey will conclude the focus area. The focus area will appear highlighted and
outlined in the graph following the second (termination) keystroke. As with events, multiple hotkeys and
labels can be assigned.

Example for setting up a Focus Area Hotkey:

- Choose the desired hotkey from the Hotkey list.
- Under Action, select ‑Create/toggle focus areaø
- Assign the focus area a label by typing it into the ‑Base focus area labelø field.
- If additional focus area hotkey assignments are desired, choose another hotkey
  from the list, and repeat steps 2 and 3.
- When focus area hotkey assignments are completed, click OK.

- If the same hotkey combination is repeated to create subsequent focus areas, the base focus area
  label will remain the same but with incrementing numbers appended to the title.

- If a different hotkey combination is used for subsequent focus areas, unique base focus area names will be used as assigned.

- Starting a focus area assigned to one hotkey and then starting another focus area assigned to a different hotkey will terminate the original focus area and start a new one.

- Focus areas can be created and toggled while a recording is in progress.

Event Palette
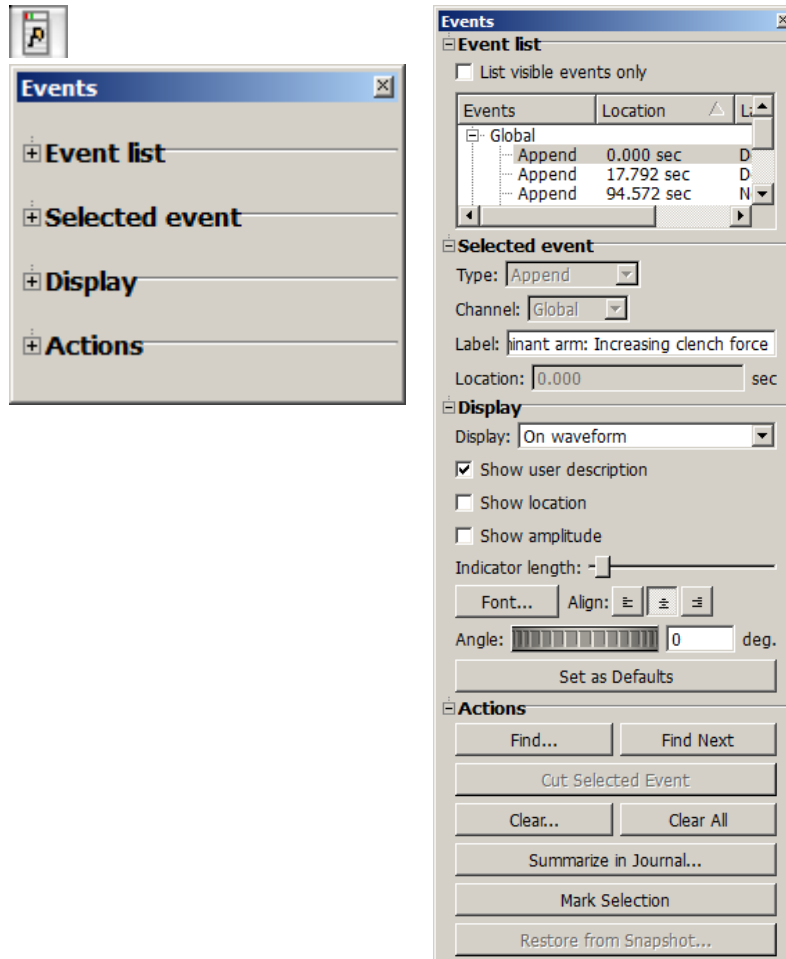
The Event Palette is a floating window that provides a quick summary of events for the active graph and can used to examine, search, and modify events. Events can be extracted in a time range for a specific event type and specific channels.

There is only one visible event palette for the entire application. The palette consists of four sections: event list, selected event, display, and event actions. Each section can be shown or hidden by toggling the disclosure button next to its title.

- ➲ Event List, see page 195.
- ➲ Selected event, see page 196.
- ➲ Display, see page 196.
- ➲ Actions, see page 198.
  - o See the Event Journal Summary enhancements.

Event List
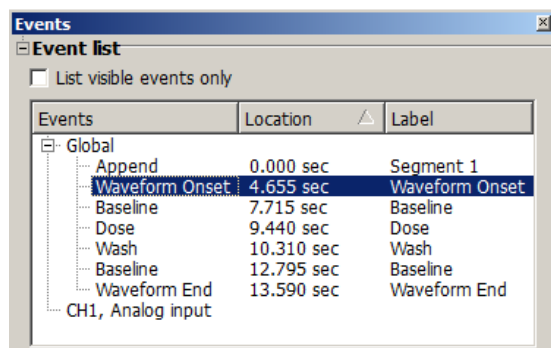
The event list provides an expandable, scrollable, hierarchical view of the events in the topmost graph. Events are grouped by their channel on the top level.

The event list has three columns of information:

- Events: the readable type for each event

- Location (Time): the time location for each event

- Label: the user defined description for the event.

Sort the contents in ascending or descending order on each column by clicking the column header. Events and Description will sort in standard alphabetical order, Location will sort based on the numerical sample location of each event.

Select a single event from the event list by clicking on a single event. The event will be selected in the graph window and made visible if it is not currently displayed.

List visible events only toggles the checkbox to switch between the two display modes.

- When enabled, the event list will display only those events that are being displayed on the plotted portions of the graph. As the user navigates through the graph with the scrollbars, horizontal scale, or other means of changing the amount of visible data, the event list will continually refresh to contain the new set of visible events.

- When disabled, the event list will display all of the events for the entire graph. This can allow for easier navigation through graphs with hundreds of events, such as PhysioBank files.

Selected Event
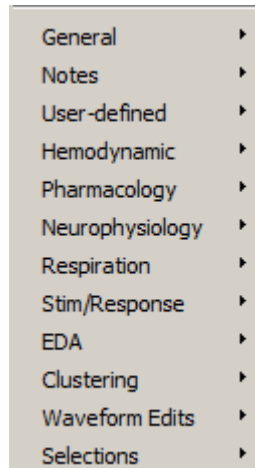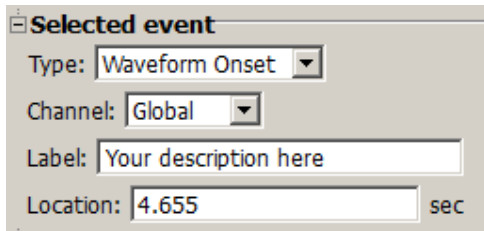
Event type options are detailed on page 199.

When a single event is selected, the type, channel (or õGeneralö for global events), user-defined label, and location of the event will be filled in and can be edited. The controls can display information about only one event at a time; if no event is selected, the controls will be grayed out.

Event Location

õLocation defines the position where the selected event occurs, relative to the first sample in the file. To change the location of an event, change the position entered in the Location box. Precision matches the horizontal axis setting.

Events may also be repositioned using the mouse. Option-click the event icon in the graph and hold down the mouse while dragging; the event will be repositioned at the horizontal position where the mouse button is released.

Display
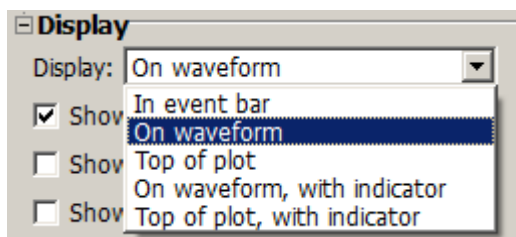
Event display location   *Event display detail*
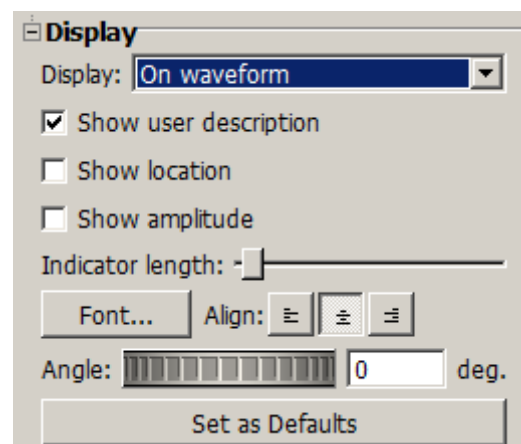
Display controls determine the location and detail of events to be drawn in the frontmost graph.

➲ Locationô Choose one of the five display methods (described on page 197).

➲ Detailô the three checkboxes to establish how much information to include with events.

➲ Indicator lengthô Set the slider to shorten or lengthen the indicator line. This option is only active if the display mode is õOn waveform, with indicatorö or õAt top, with indicator.ö

➲ Font ó Align ó Selects font style and alignment of Event labels.

➲ Angle ó Determines the angle in degrees that the Event text can be displayed in the graph. Value can be positive or negative.

➲ Set as defaults ó Saves the selected display settings.

| Location & Display	Description
In event bar 	Event icons are displayed in the global event bar located on top of the plot area in the graph window. This does not allow for distinguishing what channel a specific event belongs to. ▪ To select the event, click the icon in the event bar.
On waveform 	Event icons are displayed above or below the actual sample in the source channel corresponding to the location of the event. ▪ To select the event, click the event icon on top of the waveform.
Top of plot 	Event icons are displayed at the top of the channel track, either on top of the grid or in a channel-specific event bar. ▪ To select the event, click the icon at the top of the channel track.
On waveform, with indicators 	Event icons are displayed above the data with a vertical line of configurable length running through the data sample of the source channel at the eventøs location. ▪ To select the event, click the event icon or the indicator line.
Top of plot, with indicators 	Event icons are displayed at the top of the channel track with a vertical line of configurable length running through the data sample of the source channel at the eventøs location. ▪ To select the event, click the event icon or the indicator line.
Detail	When an event is being plotted within a graph, either on the top of a channel or floating above the data, the event's location, description, and amplitude of the waveform at that location can optionally be displayed along with the event icon. Plotting of additional information can be used for graphical annotations on the data and for clarifying event location for hardcopy or presentation.
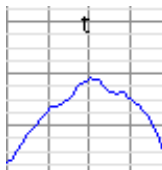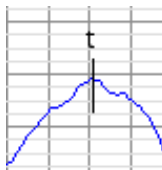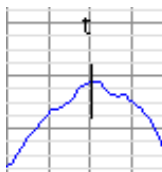
Actions
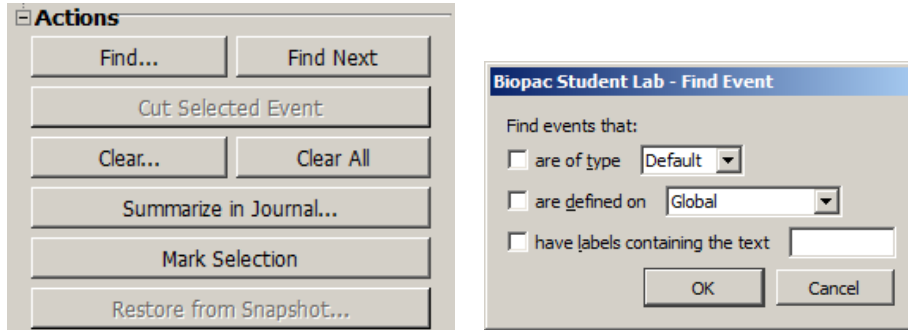
Actions Button	Description
Find	It is easy to create many more events then one can easily scroll through and locate in a list. Find controls the automatic location of events based on established search criteria. Click the Find button to generate the Event search criteria dialog, and then combine or restrict information to define desired events: event type, specific channel location, or label search. Click õFind Firstö to search for the first event in the graph that matches the criteria. If found, the event will be selected and made visible in the graph window.
Find Next	Finds the next single event that matches the established search criteria until no remaining events match the search criteria.
Cut Selected Event	Active only when an event is selected, removes the selected event from the graph.
Clear *Clear all*	Generates a search criteria dialog (identical to the Find dialog) and removes all matching events from the graph. There is also an option to clear events defined within a focus area without affecting the remaining events, or to clear events defined outside of a focus area while leaving events within the focus area intact.
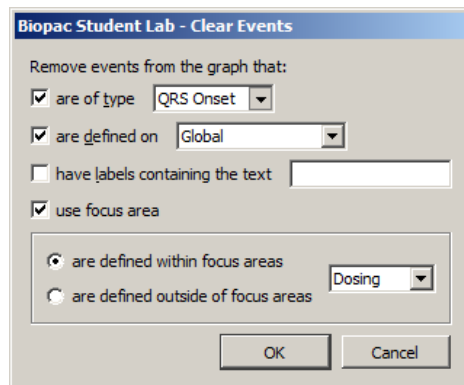
Summarize in Journal	Displays a dialog with controls that affect which events are included in the summary.

Events can be filtered by visibility on the screen. Creates a textual summary of all of the events in the journal.

- ▪ See õEvent Preferencesö on page 192 for more information about modifications to the traditional event summary.

Event Journal Summary Enhancements
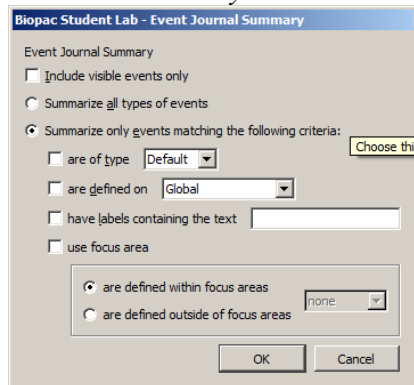
Events to be included in the summary can be filtered using the same criteria as Find... in the Event Palette. By adding the ability to summarize only events matching specific criteria, textual reports of arrhythmias or other infrequently occurring events of interest can be generated with ease. Events defined within or outside of focus areas can also be included or excluded from the summary.

When õSummarize in Journalö is clicked on the event palette, a dialog will be displayed with controls that affect which events are included in the summary.

If no Journal is open for the current graph, a prompt will be displayed to create one.
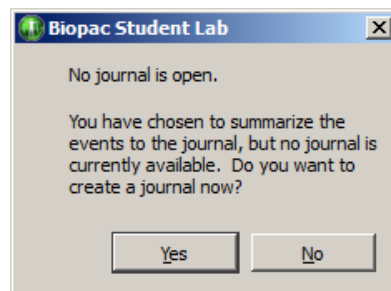
Mark Selection	Defines two new Global events in the graph at the precise time locations of the currently selected area (the highlighted wave data section). If there is no selection in the graph, this button has no effect. The events that are inserted will have the õSelection Beginö and õSelection Endö event types.
Restore from Snapshot	This feature not available in BSL *PRO*. (Used in Acq*Knowledge* Research software only).

Event Type Options

Event Types are pre-defined options for assigning event information. The Event Type is for marking purposes only and does not imply any analysis has or will occur for the event.

Once Event Types are defined, some analysis functions can be automated, including measurement (page 205) and cycle detection (page 282).

Event classifications:	*Event classifications* group similar event types together into a logical category. Event classifications present event types in a hierarchical fashion and allow other event classifications to be contained within them.
Default General ▸ Notes ▸ User-defined ▸ Hemodynamic ▸ Pharmacology ▸ Neurophysiology ▸ Respiration ▸ Stim/Response ▸ EDA ▸ Clustering ▸ Waveform Edits ▸ Selections ▸	For example, the õHemodynamicöevent classification includes a õBeatsö sub-class with pre-ventricular contraction and escape beat event types.

Event type	Classification
Global	This is the same as ±untypedqmarkers from BSL *PRO* 3.6 or earlier. Unrecognized event types will be classified as global events.
Append	Automatically inserted by the program on append operations. Custom Append labels can be created in MP > Set Up Data Acquisition > Segment Labels. (See page 207.)
Notes	Annotation event to add notes on the data.
User-defined	Hotkey insertion for user-specific events; 9 types can be inserted via the keyboard during acquisition.
Pharmacology	Basic pharmacological events: baseline, washing, and dosing.
Waveform Edits	Automatically inserted by the program on cut or paste operations in a graph file. The description consists of the edit operation performed and a timestamp. Insertion of waveform edit events is off by default, but can be turned on for GLP purposes.
Selections	Used to mark boundaries of selected areas.

| Classification	Pre-defined Event Type Options	
Default	%Esc+key inserts global event.	
General	Waveform onset or end	Recovery
	Change in signal quality or rhythm	Stimulator
	Maximum or minimum	Reset
	Communication lost begin and end	
Hemodynamic > ECG Complexes	QRS onset, peak, and end	U-wave peak
	T-wave onset, peak, and end	PQ junction
	P-wave onset, peak, and end	J-point
	Q-wave peak	ST segment change
	S-wave peak	T-wave change
Hemodynamic > Beats	Normal	Nodal premature
	Paced	Supraventricular premature
	Fusion of paced and normal	Premature ventricular contraction
	Unclassifiable	R-on-T premature ventricular contraction
	Left bundle branch block	Fusion of ventricular and normal
	Right bundle branch block	Atrial escape

	Bundle branch block	Nodal escape
	Atrial premature	Supraventricular escape
	Aberrated atrial premature	Ventricular escape
Hemodynamic > Blood Pressure	Systole	End systolic pressure
	Diastole	End diastolic pressure
Hemodynamic > Impedance	A-point	X-point
	B-point	Y-point
	C-point	O-point
Hemodynamic > Monophasic AP	Plateau	Upstroke
Hemodynamic > Other	Start of ventricular flutter	Pacemaker artifact
	Ventricular flutter wave	Isolated QRS-like artifact
	End of ventricular flutter	Non-conducted P wave
Notes	Arrow· short, medium, or long	Star
	Flag	
Pharmacology	Baseline	Wash
	Dose	
User-defined	User Type 1-9	
Waveform Edits	Cut	Paste end
	Paste begin	
Selections	Selection begin	Selection end

Event Measurements

Measurements are a quick way to extract information from a graph. Three measurements extract information from events. When combined with the Cycle/Peak Detector (page 282), they are also powerful data reduction tools. These event measurements can provide quick summaries of event information, compute mean intervals between event types, and detail other operations.

- evt_ampl   Event Amplitude Measurement (see below)
- evt_count   Event Count Measurement (see page 203)
- evt_loc   Event Location Measurement (see page 203)

## Event Amplitude Measurement
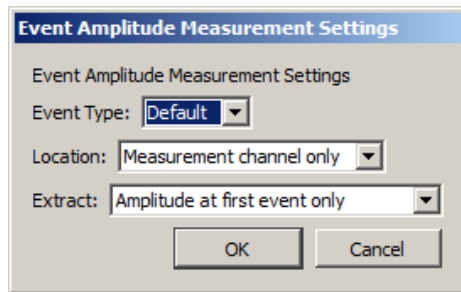
evt_amp   Extracts measurement results where events are defined. Note that the amplitude is always taken from the measurement channel, which may be different from the channel on which the events are defined. Useful for extracting information such as the average T wave height within the selected interval. The measurement result is displayed without units (matching Value and other amplitude events).

Select Event Amplitude or click the measurement info button to generate the settings dialog.

Event Type   Determines the type of events that will be processed; Types are detailed on page 199.

Location   Determines where the processed events need to be defined. The menu options are:

- Measurement channel onlyô Only extracts amplitude values for events that are defined on the channel specified in the measurement channel pull-down menu. Global events and other channel events are *not* included.
- Global events onlyô Only extracts amplitude values for events that are defined as global events appearing in the event bar; changing the measurement channel will not affect the measurement result. Channel events are *not* included.
- Anywhereô Extracts amplitude values for events defined on any channel and also global events; changing the measurement channel will not affect the result

Extract   Determines what processing will be performed on the amplitude values extracted from events that match the Type and Location settings. The processing options are:

- Amplitude at first event onlyô The value of the measurement channel at the time of the first matching event in the selected area.
- Amplitude at last event onlyô The value of the measurement channel at the time of the final matching event in the selected area.
- Sum of amplitudes at all eventsô Computes the sum of the value of the measurement channel from each matching event in the selected area.
- Mean amplitude from all eventsô Computes the average amplitude value of the measurement channel from all of the event locations in the selected area.
- Minimum amplitude from all events
- Maximum amplitude from all events
- Median value of amplitude from all eventsô Computes the median of the set of measurement channel amplitudes at all events.
- Peak to peak interval of the set of amplitudes from all eventsô Takes the peak-to-peak difference from the set of measurement amplitudes at all events (max - min).
- Standard deviation of amplitudes from all eventsô Computes the standard deviation of the set of measurement channel amplitudes at all events.

If there are no matching events of the selected type in the selection, the measurement result will be zero.

Event Count Measurement
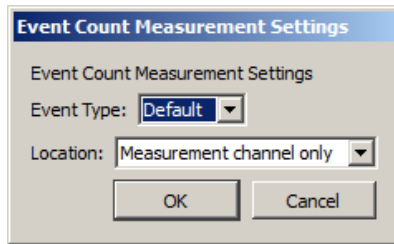
Event Count Measurement Settings

Event Count Measurement Settings

Event Type: Default

Location: Measurement channel only

OK   Cancel

evt_count   Evaluates the number of events within the selected area. The measurement result is unitless.

Select Event Count or click the measurement info button to generate the settings dialog.
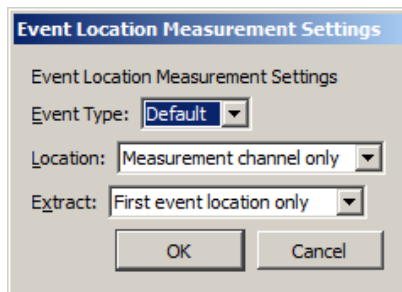
Event Type   Determines the type of events that will be counted; Types are detailed on page 199.

Location   Determines where the counted events need to be defined: the pull-down menu options are:

- Measurement channel onlyô Only includes events that are defined on the channel specified in the measurement channel pull-down menu; global events and other channel events are *not* included.

- Global events onlyô Only includes events that are defined as global events appearing in the event bar; channel events are *not* included. Changing the measurement channel will not affect the measurement result.

- Anywhereô Includes events defined on any channel and also global events. Changing the measurement channel will not affect the measurement result.

If there are no matching events of the selected type in the selection, the measurement result will be zero.

Event Location Measurement

Event Location Measurement Settings

Event Location Measurement Settings

Event Type: Default

Location: Measurement channel only

Extract: First event location only

OK   Cancel

evt_loc   Extracts information about the times of events. The measurement result will take on the units of the horizontal axis; if specific units were set for time or frequency via Preferences, those units will be used.

Select Event Location or click the measurement info button to generate the settings dialog.

Event Type   Determines the type of events that will be processed; Types are detailed on page 199.

Location   Determines where the processed events need to be defined. The menu options are:

- Measurement channel onlyô Only extracts the time of events that are defined on the channel specified in the measurement channel pull-down menu; global events and other channel events are *not* included.

- Global events onlyô Only extracts the time of events that are defined as global events appearing in the event bar; channel events are *not* included. Changing the measurement channel will not affect the measurement result.

- Anywhereô Extracts the time of events defined on any channel and also global events. Changing the measurement channel will not affect the measurement result

Extract   Determines what will be extracted from events that match the Type and Location settings:event

- First event location onlyô The measurement will equal the time at which the first matching event in the selected area is defined.

- Last event location onlyô The measurement will equal the time at which the final event within the selected area is defined.

- Sum of all event locationsô The times at which all matching events are defined are added together to produce the measurement result. This sum of times can be combined with Event Count measurements to compute average intervals over the selected area.

If there are no matching events of the selected type in the selection, the measurement result will be zero.

Printing Events

When a graph is printed and events are displayed onscreen for the graph, event icons will print as they are displayed. Event icons will be scaled, depending on the printer's DPI, to be proportional to the vertical scale plotted on the screen. If events are located at linearly interpolated positions, event icons will be dimmed on the printout (see the Variable Sample Rate section).

Event display setting	*Printed result*
Global events	Global events are drawn above and outside of the data plotting rectangle in the printout. If the event labels are close together, their alignment will be staggered to show separate lines of label text.
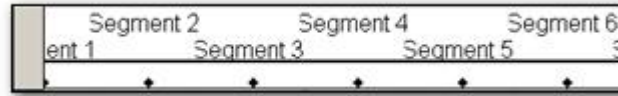
In event bar	All events are drawn above the data area of the printout. Only labels may be drawn with the events.
Top of plot *or* Top of plot, with indicator	Channel-specific events are drawn at the top edge of their channeløs track. No indicator lines are drawn. Depending on the display settings of the graph, the event label, amplitude of waveform at the event location, and Time of the event may be printed *below* the event icon
On waveform *or* On waveform, with indicator	Channel-specific events are drawn immediately above the position of the waveform sample at their location and will appear to be printed immediately above the data of the waveform. No indicator lines are drawn. The vertical printing position of an event icon will be identical for õOn waveformö and õOn waveform, with indicatorö displays. Depending on the display settings of the graph, the event label, amplitude of the waveform at the event location, and time of the event may be printed *above* the event icon.

õDraw vertical divider at event locationsö option in the Print Setup dialog.

- Enabled: draws a dashed vertical line at the precise time location of each event. Vertical divider lines for the event type will extend

Global	Through all channels of data
In event bar	Through all channels of data
Top of plot	From the top to the bottom of the relevant channel track
On waveform	From the top to the bottom of the relevant channel track

- Disabled: prints only the event icon, label, amplitude, and time. No indicator lines will be printed for the event display. The vertical divider can be used in place of indicator line drawing.

Event Selection

Individual events can be selected according to click locations.

When an event is selected, the event icon will be drawn based on the graphic type:

- Specific õselectedö graphicô the selected graphic is drawn or if none, an inverted global graphic.
- No associated graphicsô the global event graphic will be used.

Events and Graph Selections

When an event on a waveform plot occurs within a selected area of the graph, the event icon and indicator line (if present) will be inverted along with the grid, background, and wave data. Event types that don't have a selected graphic will appear as global events if the events are selected events and they are contained in an I-beam selection.

Events and Waveform Editing

Waveform editing will adjust event locations for channel-specific events. Waveform editing will never alter the time values for Global events (not associated with any specific channel, such as append events).

Copy   When a portion of a waveform is copied the channel events will also be copied to the clipboard.

Cut   When a portion of a waveform is cut, any channel events within that selected area will be removed and channel events to the right of the removed area will be shifted to the left.

- If waveform editing event insertion is active, a waveform edit event will be inserted at the location of the edit operation indicating a õCutö operation in its description.

Paste   When the waveform is pasted from the clipboard, the channel events will appear at their same locations and any channel events to the right of the end of the pasted segment will be shifted by the length of the pasted segment.

- If waveform event insertion is active, a waveform event marker will be inserted at the beginning and at the end of the pasted segment.

Constructing Graph Selections from Events

Graph selections can be defined from events (in addition to the I-beam tool). Holding down the Command/Open-Apple key (Alt on PC) while double-clicking an event icon in the graph window will place a cursor at the event location; this is a zero-width selection, equivalent to single-clicking with the I-beam tool without dragging.

- To create a graph selection from events, hold down the Command (Alt on PC) key and select an event by clicking on the event icon in the graph window or its entry in the event list.

- To align the boundaries of the graph selection with the time of the previously selected event location and the time of the newly selected event, hold the Command (Alt on PC) key when selecting the new event.

- To make a graph selection match the time between two events, click to select the first event, hold down the Command (Alt on PC) key, click again to select the second event. On this second click, the selected area of the graph will change to align with the two events.

Event Plotting and Variable Sampling Rate

Event positions are defined in terms of the hardware sampling rate. The Variable Sampling Rate feature can generate waveforms with a sampling rate lower than the hardware sampling rate. Through explicit event definition, waveform downsampling, or other operations, events on a downsampled channel may not align with an actual waveform sample, but rather occur at a hardware sample position in between waveform samples. These events will be drawn using linear interpolation when applicable, and only if the waveform is being drawn in line plot mode. In step plot and dot plot modes, regular event drawing routines will be used with the vertical position and amplitude of the nearest waveform sample to the eventøs left.

When an event is to be drawn on an intermediate position on a waveform, the linearly interpolated value will be calculated for the hardware sample location. The interpolated value will be derived from the closest waveform sample to the left and to the right. The vertical position on the waveform of the event and indicator line will match the vertical position of the linearly interpolated sample amplitude. This will place it immediately above the line connecting the two waveform samples on screen.

If an event is being drawn using linear interpolation

- Event icons will be dimmed, regardless of their display position (on waveform or top of the plot).

- Indicator lines will be drawn on the waveform at a linearly interpolated position and the indicator line will be a gray dashed line instead of a solid black line. (Indicator lines are never printed.)

- Amplitude labels, if included with the event, will correspond to the linearly interpolated amplitude at the event location and the linearly interpolated amplitude will be drawn in *italicized text*.

- Watch the Event Marking Tutorial video for a detailed explanation of this feature.

Chapter 10   Other MP Menu Commands

Show Input Values
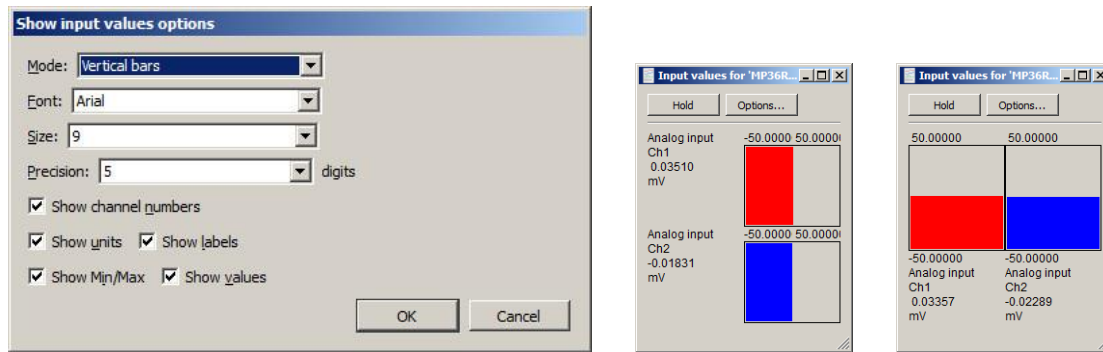
The Show Input Values option of the MP menu generates an Input Values window, which displays channel values in real time, whether an acquisition is in progress or notô which allows values to be displayed prior to or after an acquisition.

The Input Values display can be set to numeric, horizontal or vertical bar graph format, and it can be resized and moved to any position on the screen. To set the display mode, use the õModeö menu generated via the õOptionsö button.

Note The Input Values window only displays values for channels that were Set Up with the õValuesö box checked (see page 30 for more information).

Hold   Regardless of the display options selected, the display can be õfrozenö at any point in time by clicking the Hold button. Clicking this icon will hold the values at their level(s) when the icon was pressed. The window will remain frozen until the icon is clicked again. Once the values are õunfrozen,ö the values will return to the standard real time display mode.

Options   **Mode** controls the format of the values display.

- Numeric Valuesô displays the voltages of the appropriate channels numerically.

- Bars: Horizontal bars or Vertical barsô the range of values of the bar graphs corresponds to the range for that channel in the graph window. To see the bar õbounceö less for a particular channel, increase the units per division; to fill more of the window space, decrease the units per division in the graph window.

Font and **Size** determine text display from computer-installed fonts.

Precision controls *the total number of digits* displayed.

Show controls the amount and type of information displayed regarding each channel. Click in the box next to each option to activate it.

- **Channel Numbers** will display the channel numbers (A1 for the first analog channel, for example).

- **Units** will display the units for each channel (as indicated in the main graph window). By default, each channeløs display units are scaled in terms of Volts, but this can be changed by clicking in the amplitude scale units area in the graph window.

- **Labels** will display the channel labels (ECG 1, Respiration, etc.) along with the input values. This feature is especially useful when values from multiple channels are being displayed simultaneously.

- **Min/Max** will display the range of values associated with the data. This range corresponds to the upper and lower display limits for each channel as it appears in the graph window.

- **Values** will display number values along with the horizontal or vertical bar chart.

Segment Labels

Selecting Segment Labels from the MP >Set Up Data Acqusition menu launches a setup dialog for assigning user-defined labels to append event segments. The Segment Label options are applied to the active graph only. The selected settings will be saved with the graph, but will not be applied globally to existing or subsequent graphs.
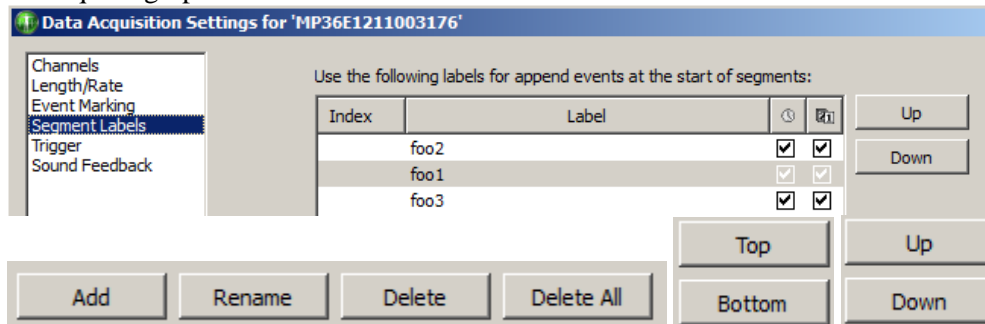
- ▪ Add   Adds a segment number to index. Segment text can be edited under ─Label╕
- ▪ Rename   Used to rename an existing segment label.
- ▪ Delete   Deletes a selected segment from Index.
- ▪ Delete All   Deletes all segments from Index.
- ▪ Top/Bottom Moves selected segment to top or bottom of Index.
- ▪ Up/Down   Incrementally moves a selected segment up or down the Index.

Enabling checkboxes below the icons adds time/date stamps to the segment label.

Trigger (Not supported in MP45 hardware)

Using a trigger allows an acquisition to be started õon cueö from a trigger connected to an analog input channel (CH1 to CH4). By default, the trigger is off, and during a normal acquisition, the MP UNIT will begin collecting data following a mouse click the Start button in the lower right hand corner of the screen. When Triggering is used, acquisition will begin when the established trigger level is reached.

To begin an acquisition with a trigger:

1) Select MP > Set Up Data Acquisition **>** Trigger to generate the Triggering dialog:
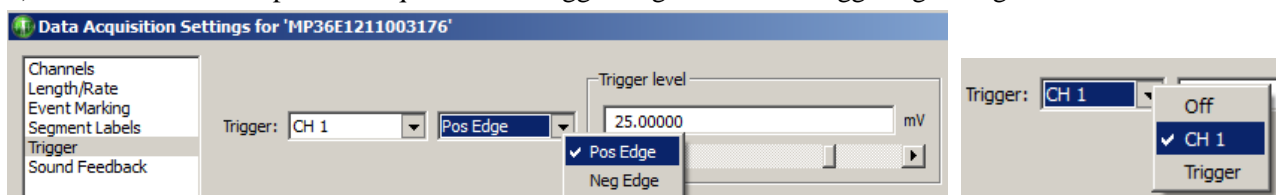
2) Choose a channel from the Source pull-down menu. Select CH1, CH2, CH3, CH4 (MP UNIT front panel), Digital Channels D1-D8, or an external Trigger (MP36/35 back panel).

External Trigger requires a TTL signal from a third-party device such as a stimulator, pump, presentation program or force plate.

External Trigger Note: Due to processor limitations at sampling rates of 25 kHz and higher there may be an occasional delay of up to 40 milliseconds between detection of an External Trigger and the start of data acquisition. Use either an analog or digital channel as a trigger when acquiring data at 25 kHz, 50 kHz or 100 kHz, if accurate timing of the start of acquisition is required.

3) Choose **Pos Edge** or **Neg Edge** from the menu to select whether a positive or negative edge will trigger the acquisition. Look at the nature of the signal to determine which is most appropriate.

- ➢ A **Positive edge** occurs when the signal begins below the threshold and crosses above it.
- ➢ A **Negative edge** occurs when the signal begins above the threshold and drops below it.

4) Set the **Trigger level** by entering a value or by moving the scroll bar to adjust the threshold value.

When setup is complete, close the setup window and click the Start ▶ button to begin acquisition as soon as the trigger is activated.

The setup shown above is set to start acquisition when a level of 25 mV is reached on analog Channel 1.

Sound Feedback

Sound Feedback generates a setup enabling acquired data to be redirected to the computerøs default audio output device. This feature can be used to monitor waveform data as sound through the computer speakers or headphones.
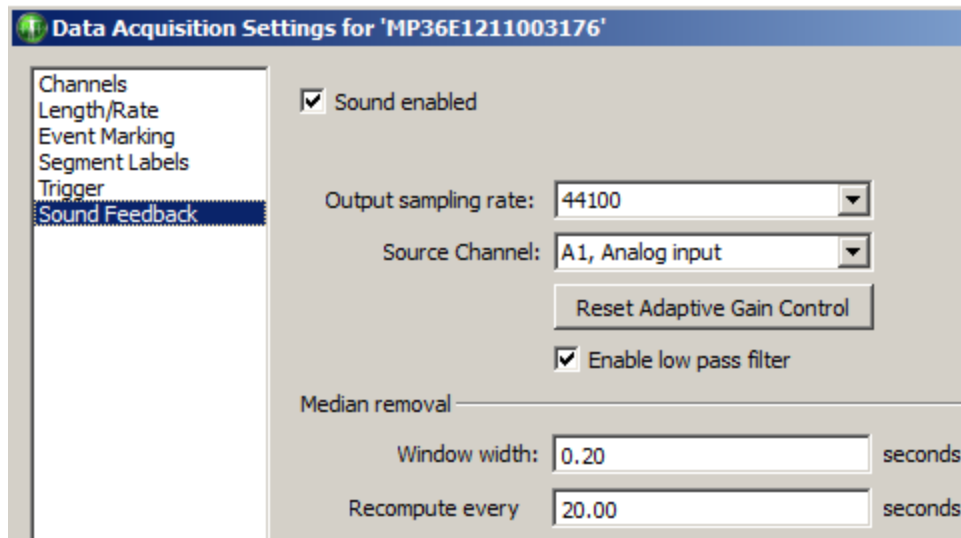
Access Sound Feedback via MP > Set Up Data Acquisition > Sound Feedback.

SOUND FEEDBACK CONTROLS	FUNCTIONS
Sound enabled	Turns sound feedback of data on and off.
Output Sampling Rate	Selects from available sampling rates of the default audio device.
Source Channel	Selects the analog, digital or calculation channel from which the audio will be acquired.
Reset Adaptive Gain Control	Resets gain control to adapt to the current level of the signal. Use after sound feedback has started to re-adjust the level after accidental spikes or large artifacts.
Enable low pass filter	Applies a low pass filter at the Nyquist frequency (50% of the acquisition sampling rate). This IIR filter can help smooth out transition artifacts due to upsampling of data to the audio sampling rate. (Enabled by default)
Median removal controls (Window width, Recomputate)	Removes baseline offset from the output signal.
Window width	Sets width of median removal window (in seconds). Must be a positive value.
Recompute every	Provides the time duration (in seconds) after which the median of the data is regenerated from the raw source data. Must be a positive value.

Gauge
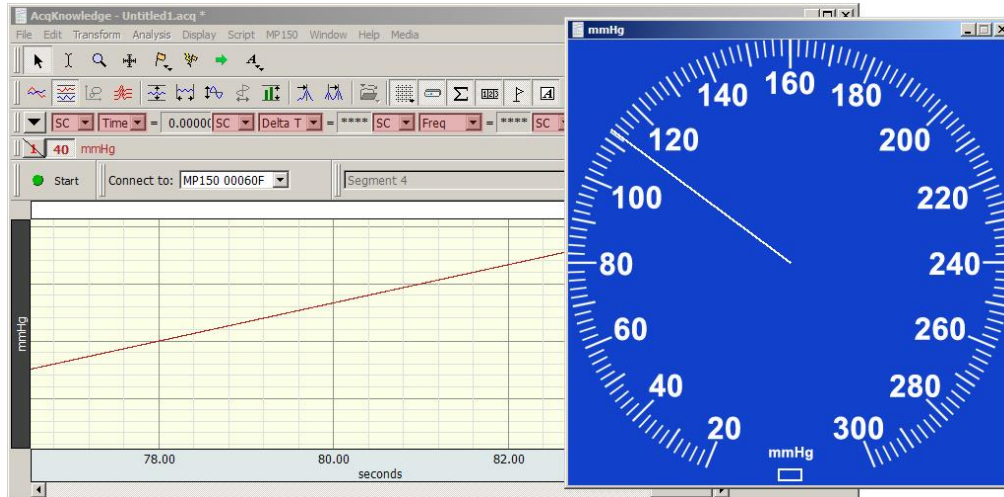
The Gauge is accessed via MP > Show Gauge. The optional %Gauge+ display shows one channel of data in a gauge/dial indicator format.

The Gauge displays as a separate window, viewed simultaneously with graph and other windows.

The Gauge Window:

- Will display one channel of data: analog or calculation
- Updates and displays simultaneously with the graph window. For analog channels only, the display will update when the recording is stopped, but at a slower rate when recording is running.
- Can update during and in between acquisitions for all MP devices; display may be updated at a rate slower than the sample rate and may display a value that represents the average of several samples.
- The background image (BMP, JPG or TIFF), indicator origin, range, length, thickness and color are all user-configurable. An optional range band overlay can also be enabled.
- Selectable gauge bitmaps include Blood Pressure Cuff, BPM or Stopwatch
- All window preferences as well as the window visibility, size and position will be saved with the file.
- Window sizing is õfixedö to the size of the background image, meaning it will have a 1 to 1 correspondence with the monitor pixels

Gauge Preferences
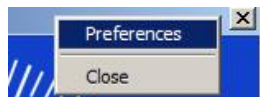
Gauge Preferences are accessed by right-clicking over the gauge and using the contextual menu. There are four tabs for setting the various Gauge parameters.

Background is the default tab presented in Gauge Preferences and contains options for setting the Background image.

Channel	Provides a pop-up menu for assigning any one of the ENABLED analog or calculation channels.
Background Image	Displays the path and file name of the current background image. The default image is a blue blood pressure gauge sized at 451 x 451 pixels.
Browse	Allows alternative background images in different directories to be used in place of the default gauges. The Browse location will default to the file path used by the currently selected background image. To change the background image, click the õBrowseö button and locate the desired file. After the background image is specified, the pixel **Width** and **Height** will be updated. The **Width** and **Height** fields are not editable.
Use Default	Displays a menu of available default background images. **(Pressure, Stopwatch and BPM)**.

Indicator

The õindicatorö or õneedleö is a simple line vector drawn from an assigned center point to an endpoint calculated according to the õLengthö parameter. The indicator always rotates around the origin from low to high values in a õ**clockwise**ö fashion.
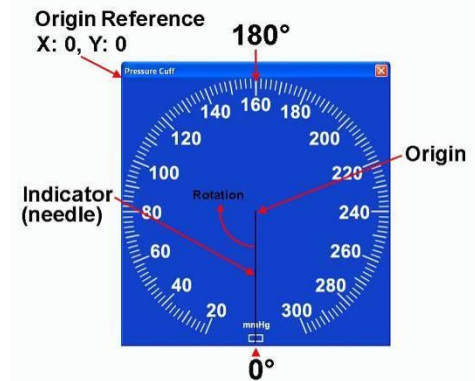
Origin	Is the center point of the indicator line referenced from the top left of the image not the top left of the window meaning neither the frame of window nor the title bar is included. The õXö parameter specifies the horizontal distance in pixels and the õYö parameter the vertical distance. õXö cannot exceed the Width of the background image and õYö cannot exceed the image Height. The *default* values are: Origin: X: Width/2, Y: Height/2. **Note that the pixel count starts at "0" so a 225 pixel square image will have its center point at 112 pixels.**
Length	Specifies indicator span in pixels starting from the õOriginö. Default is the smallest of the Length or Width dimensions divided by 2.
Thickness	Specifies the indicator width in pixels, with a selectable range between 1 and 10. The default is 1 pixel.
Color	Specifies color of the indicator õneedleö as Black (default) or White.

When recording is stopped

If the source channel is a Calculation channel, no gauge updating will occur when the recording is stopped. Under this circumstance, the õWhen recording is stoppedö options become available. This allows the user to specify whether the indicator should not be displayed, should be reset to zero, or should retain the last value.
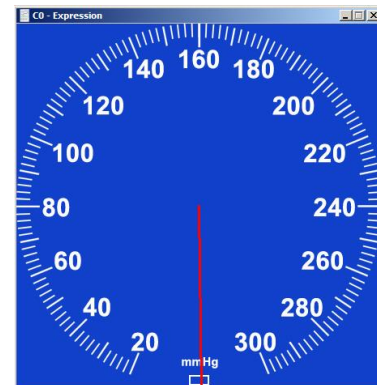
Mapping

For setting up two point mapping: Input to Angle

Input   Defines the input values in the scaled units. The units shown in the example are volts, but would reflect the units of the source channel (mmHg, psi, etc.). The Input mapping of the upper scale value is set to a default of 50 of the source channel unit type.

Angle   Any angle can be entered, but 0, 360, 720, etc degrees means that the indicator will always be pointing straight down.

When assigning mapping angles: Because the indicator õneedleö must rotate clockwise, the first value should be the lower angle. The first value also defines the indicatorøs starting angle but does not to need to be 0 degrees. For example, the Stopwatch Gaugeøs starting angle should be 180 degrees (pointing straight up). If half-circle gauges are used, the starting angle may be 90 degrees.

Indicator is limited to specific mapping

If this option is enabled, and the indicator needle reaches its mapped upper limit, it will stop rotating and turn red. If this preference is not selected, the needle will not change color if the defined mapping limits are exceeded and the needle will just continue in a clockwise rotation.

Range Band (Default OFF)
Use the Range Band as an optional feature to highlight a specified area of the Gauge View.
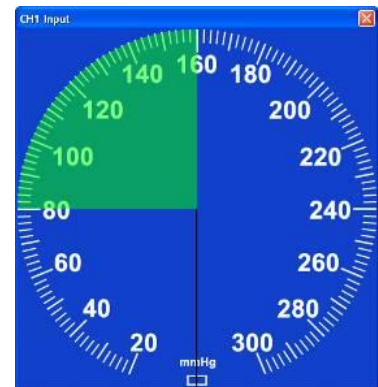
Start/End   Defines a õpieö shape (defined by Mapping values) sourced from Gauge center and superimposed over the background image.

Color   Clicking on the color bar will bring up a color palette, which allows any color to be selected. The default color is green.

Opacity   Used to adjust the transparency of the Range Band. 100% means the background image will be fully obscured behind the range band, and 0% means the Range Band itself will not be visible. The default setting is 50%.

Segment Timer %Stopwatch+option

In addition to the standard Gauge described above, the Segment Timer Gauge option offers an analog õStopwatchö view of an acquisition in progress. As the recording progresses, a circular onscreen stopwatch gauge displays the elapsed time with a sweep-second indicator. All customizable parameters shown above for the default Gauge view are applicable to the Stopwatch view. A custom mapping for the Stopwatch view can be created, or use the pre-configured õSegment Timer Gaugeö graph template in the Sample Data folder.

Using the Segment Timer graph template ó open the sample template in the following directory:

Main drive\Program Files\Biopac Systems, Inc\Biopac Student Lab 4.1\Sample Data\English-en\PRO\Segment Timer Gauge.gtl

Clicking =Startø will show the Stopwatch in progress. The template is setup to record ECG Lead II on CH 1 and is tied to a new Segment Timer calculation channel. However, no connections are needed to verify the segment timer and the template can be customized as desired. To change parameters, choose Preferences from right contextual menu with mouse positioned over the gauge window. When the recording is stopped, timer indicator will also stop. When the next recording segment begins, the segment timer will reset to 0. (This default can be changed in the Gauge Preferences).
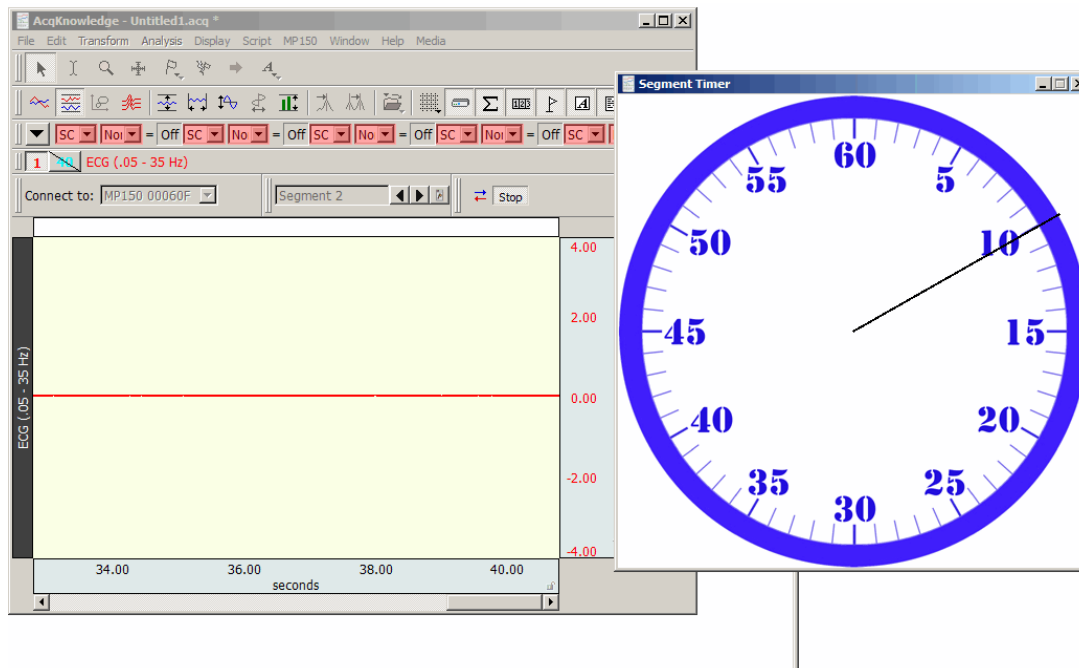
To configure a new Segment Timer Stopwatch view:

1. Set up desired acquisition parameters and channels.

2. MP menu > Set Up Data Acqusition > Channels > Calculation tab and choose the Segment Timer preset.

3. MP menu > Show Gauge and open Preferences by right-clicking the contextual menu over the Gauge window.

4. In the Gauge Preferences, choose õC0 ó Segment Timerö for the Channel and õStopwatchö, as shown on right.

5. Choose the õMappingö tab, enter the following Input to Angle mapping values and click **OK**:
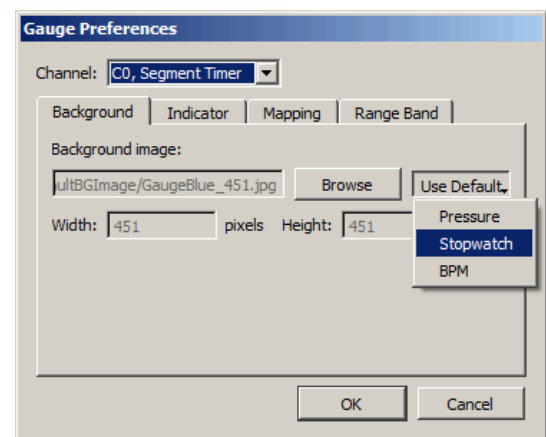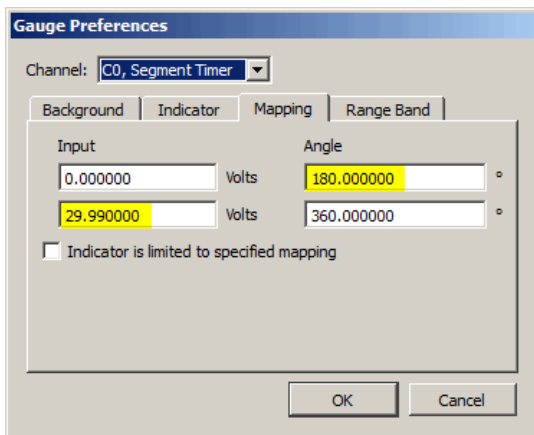
6. Start the acquisition. Note the Stopwatch view will accurately reflect the time scale of the recording in progress.

Autoplotting and Scrolling

Autoplotting, Scrolling and Sweep Display Modes

The Autoplotting, Scrolling and Sweep options controls how data is displayed on the screen during an acquisition. By default, Acq*Knowledge* displays the most recently collected data first, and if more than one screen of data is to be collected, then the time scale will õscrollö so that the newest data is always on the right edge of the screen.

When Scrolling is disabled and Autoplotting is enabled, the screen will be cleared when the data reaches the right edge of the screen, and plotting is redrawn from the left.

When both Scroll and Autoplot are unchecked, the incoming data will be plotted until the screen is full. Once the screen is full, data will continue to be collected, but only the first screen is displayed. By default, the hardware will display the first eight seconds of the data record, but this can be reset manually by changing the horizontal scale. To toggle Autoplot ON or OFF in the middle of an acquisition:

➢ select Ctrl+T (Windows) or Command+T (Mac OS) on the keyboard, or

➢ Choose the MP menu and enable or disable õAutoplottingö

Sweep display mode is similar to an oscilloscope sweep display in which data is plotted left to right, but old data remains visible on the screen while new data is incoming. This type of display is also seen in some clinical devices.

In order for Sweep display to function:

▪ Autoplotting must be enabled

▪ Scrolling must be disabled

▪ Sweep must be enabled

In this configuration the old data remains visible while incoming data in the form of a black vertical line õsweepingö across the old data from left to right. The old data and horizontal time scale are redrawn with once the line sweeps across its axis.

The sweep will be reset if scale modifications that affect the vertical or horizontal scale are performed. This includes: autoscaling, zoom, window resizing, end of acquisition. Sweep can be toggled from the hardware menu during acquisition and is data view independent. The sweep state is saved in graph files and templates.

Sweep mode is applicable in Scope, Chart, Stacked Plot, and Split View modes. It is not supported in XY mode.

Manual, Autoscrolling and Sweep options can also be accessed via the ⟫M , ⟫A , or ⟫S button in the lower right region of the horizontal axis region. For full details on this tool, see Autoscroll Horizontal Axis Controls on page 48.

Warn on Overwrite

Selecting the õWarn on overwriteö option from the MP menu will generate a prompt each time a new acquisition is started:
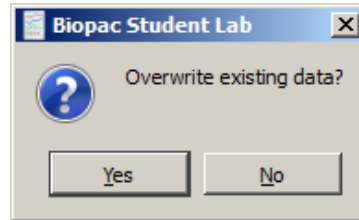
Clicking õYesö will erase the current file and overwrite with a new acquisition. If the currect file needs to be saved, click õNoö and open up a new file.

This prompt will appear at the beginning of each acquisition when the MP System is in Repeating/Autosave mode, so itøs recommended to uncheck the õWarn on Overwriteö under the MP menu.

Organize Channel Presets
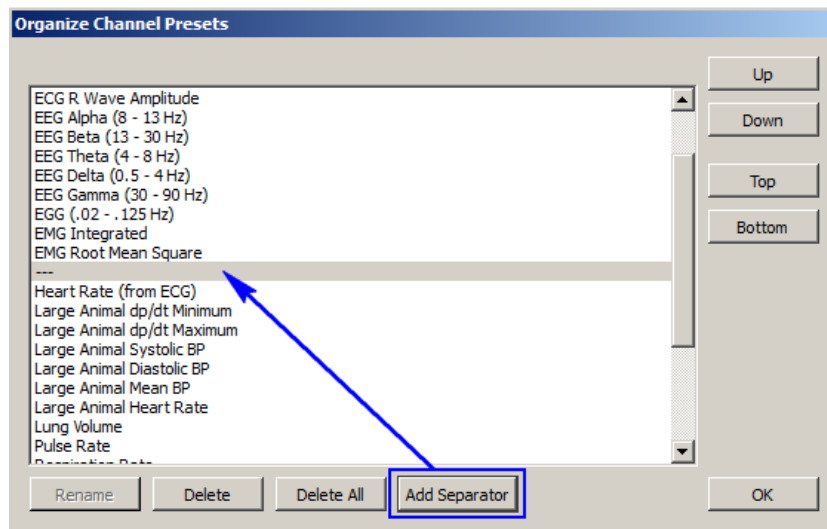
The Organize Channel Presets option controls the channel presets (established or new) in the MP > Set Up Channels dialog. Presets can be added, rearranged or deleted. Organizing Presets are useful for placing the most frequently selected Presets at the top of the menu, or grouping related Presets, such as established ECG Presets and newly-created channel Presets.

Click a Preset description to select it, and then use the buttons to organize the Presets.

Up and **Down** buttons move the selection one space at a time.

Top and **Bottom** buttons jump to the start or end of the list.

 Rename a Preset by typing in a new description and clicking OK.

> Any name currently used by a Preset or any name that matches a Calculation type (Integrate, Rate, etc.) cannot be used.
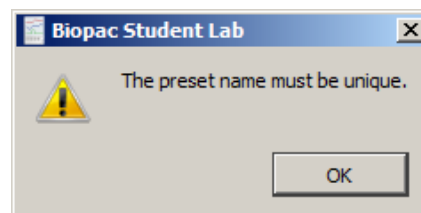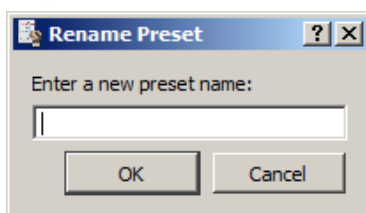
Delete a Preset by selecting that option. The Default Analog Input preset cannot be delted. When deleting a Preset, a confirmation dialog will appear because it is an <u>irreversible</u> action.
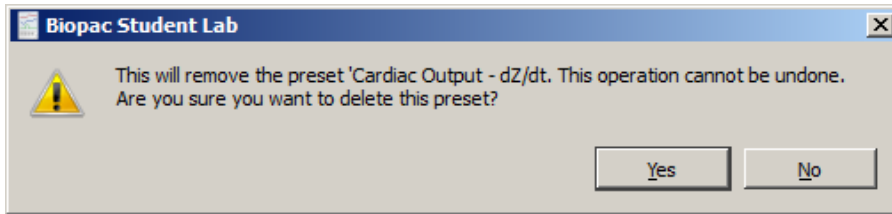

Add Separator adds a new Separator entry to the Preset list and is useful for dividing different Preset types. If a Preset is currently selected in the list, the Separator will be added below it. (See diagram above) If no preset is selected, the separator will be added to the end of the list. Separators can be rearranged or deleted in the same manner as Presets. The default location for Preset files is Computer > Local Disk > ProgramData > BIOPAC Systems, Inc > Biopac Student Lab 4.0 > Presets.

Exit Playback Mode

This option is enabled when Open File for Playback (see page 37) has been selected. Select to resume acquisition functionality (changes Playback menu to MP menu, Replay button to Start button).

Manage Hardware Connections
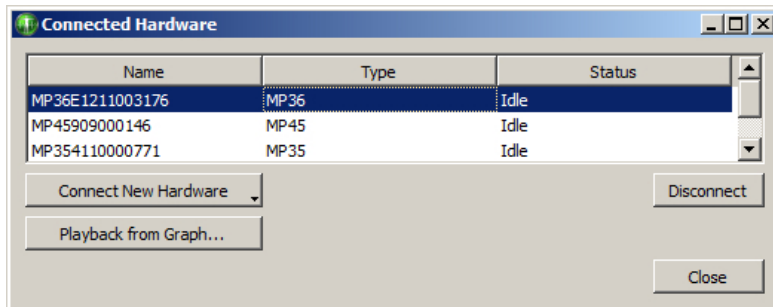
The Manage Hardware Connections option enables easy connection and disconnection of new hardware on a global level, and allows switching from one particular hardware unit (or hardware type) to another. The following controls are available:

Connect New Hardware

Choosing "Connect New Hardware" opens a dialog for selecting and adding additional hardware units. Once a new hardware unit added, it will be available for use in the application, and will appear in the connected hardware list. The example below shows connection of two additional MP units.
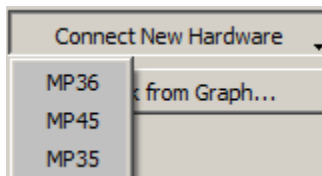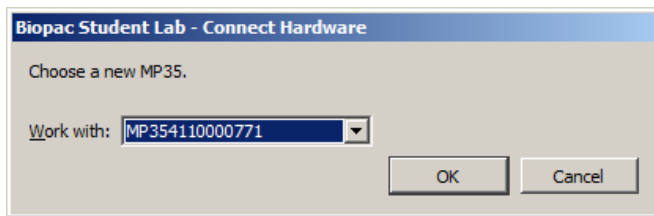

To connect new hardware:

1. Make sure the new hardware type is powered on and plugged into a computer USB port.
2. Click the arrow at the lower right of the "Connect New Hardware" button.
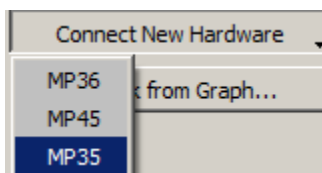
3. Select the new hardware type from the list.
4. Choose the desired hardware from the "Connect Hardware > Work with" list and click OK.

Disconnect

Click the Disconnect button to remove from any available hardware from the list.

Playback from Graph

Use as a shortcut to enter Playback Mode. For more information on Playback Mode, see page 37.

Part Cô Analysis Functions

Overview

This section describes how to analyze data; in most cases, analysis is performed after the data has been collected. This involves creating, managing, and saving files, as well as editing data, performing mathematical transformations, and displaying data in various ways. Many of the functions covered here are also discussed in *Part A—Getting Started*. Features that can be computed during an acquisition (primarily transformations and calculations) are discussed in *Part B—Acquisition Functions*.

For general information about sections of the graph window, and to become familiar with the õlook and feelö of BSL *PRO*, turn to the *Editing and Analysis Features* chapter. Descriptions of functions can be found in the chapters describing each menu. All of the commands discussed here can be found under the File, Edit, Transform, or Display menu items.

Menu	Seeí	Type of Commands
File	Page 220	General file management commands, including opening, saving, and closing files. Export data files.
Edit	Page 241	Cut, copy, and paste between and within files. Export data files.
Transform	Page 250	Operations that primarily modify the data in the graph.
Analysis	Page 276	Operations that primarily derive data and measurements from the graph.
Display	Page 314	Control how data appears on the screen either during or after an acquisition.
Media	Page 343	Capture and Playback controls to synchronize video/audio with data.

Toolbars

Many of the most commonly used features in BSL *PRO* can easily be executed with a mouse click. The toolbar contains shortcuts for some of the most frequently used BSL *PRO* commands; icons are grayed out when they are not applicable. Custom toolbars can be created by clicking the Customize Toolbars icon.

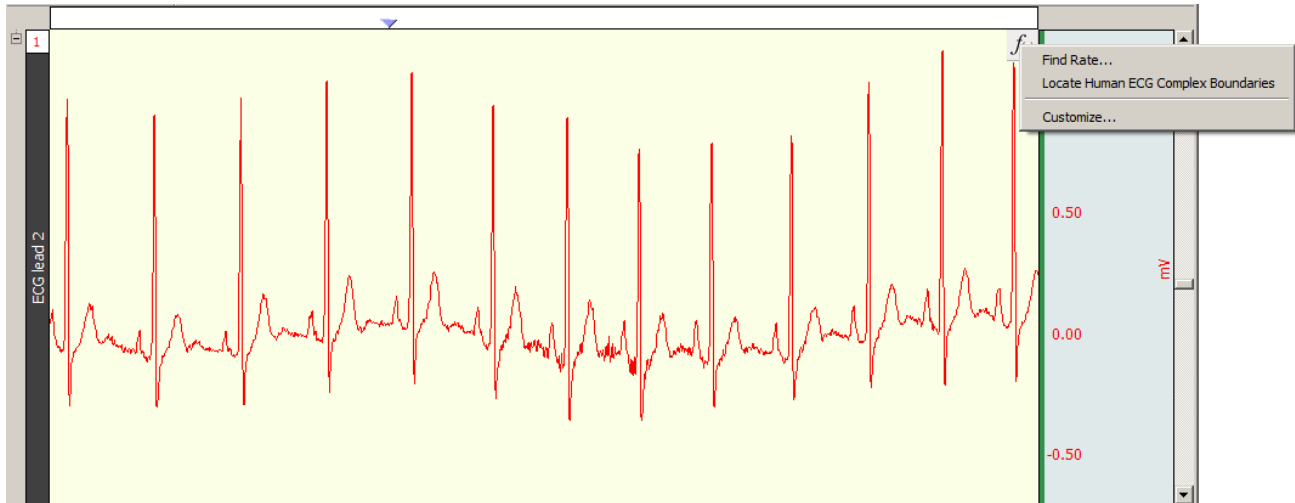Click Display > Show > Tool Bar to view the icons. Click an icon to activate it.

See page 51 for Toolbar icon definitions.

Shortcuts

Keyboard shortcuts are detailed on page 61.

Mouse shortcuts are detailed on page 63, including contextual menus.

Analysis Shortcuts

In BSL *PRO* 4.1.3 and higher, Analysis Shortcut buttons are available within individual graph channels. Analysis Shortcuts offer quick access to common Specialized Analysis options. Clicking the shortcut presents a pop-up menu containing analysis options relevant to the signal type present in the selected graph channel.

This feature is helpful for avoiding the confusion of having to scroll through a lot of unrelated Analysis menu items when wishing to apply a transformation.

The Analysis Shortcut appears as a small button in the upper right corner of the graph channel. In order for this button to become active, one of the following configurations is necessary:

- A specific preset signal type must be configured under the hardware menu (MP > Set Up Data Acquisition > Channels > Presets or MP36 > Channels > Setup > Advanced > Signal Types) and data acquired under those parameters.

- Or post-acquisition, a specific signal type (ECG, EMG, etc.) can be assigned in the Channel Information dialog. This will activate an Analysis Shortcut corresponding to the assigned signal type.

  1. Choose Display > Channel Info… (or right click in a graph channel and choose õChannel Infoö from the contextual menu.)

  2. Choose the appropriate signal from the õType:ö pop-up menu. See page 329 for more information about the Channel Information dialog.
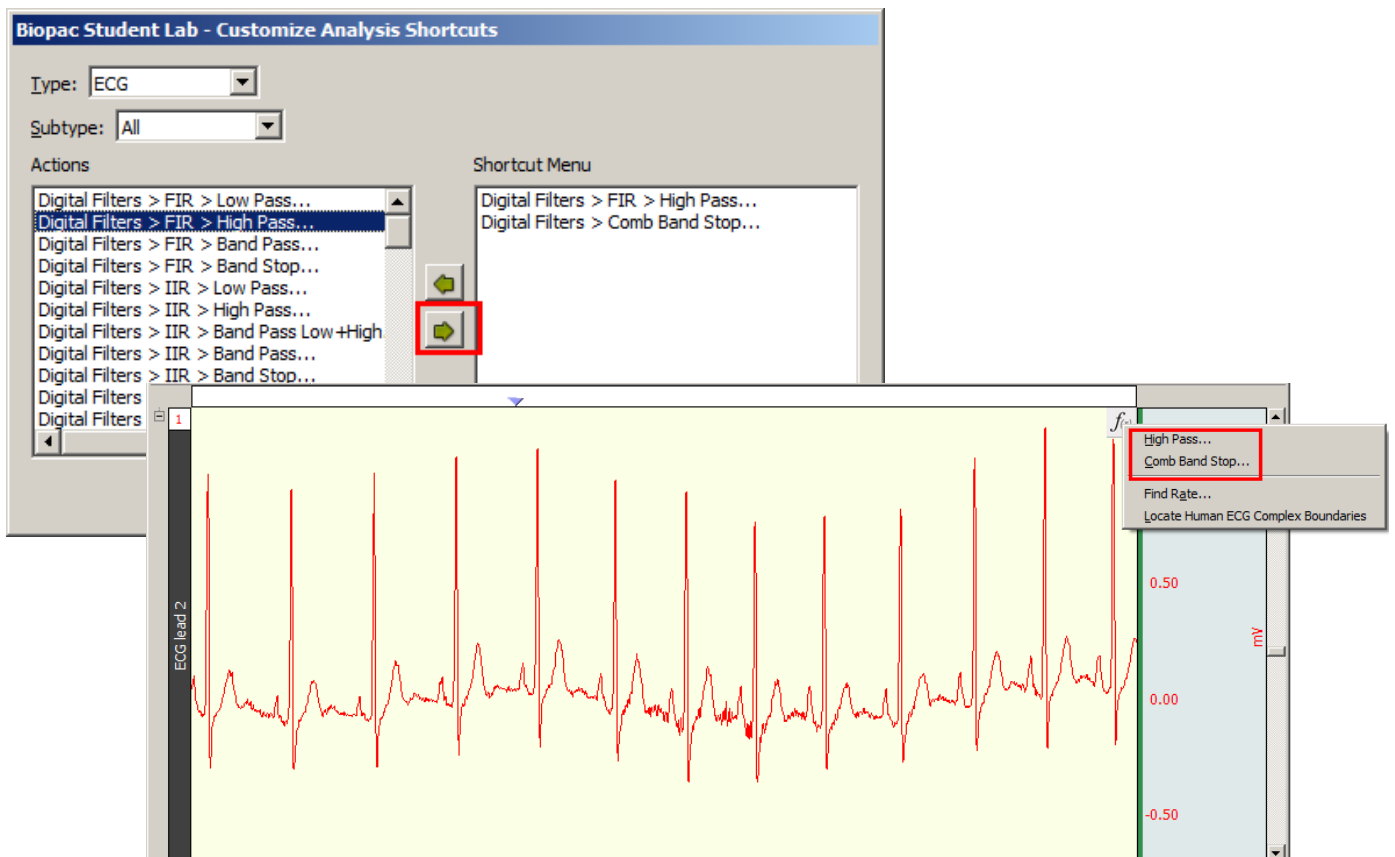
Creating Custom Analysis Shortcuts

Custom transformations and analysis routines can be added. To add a custom item:

1. Right click the Analysis Shortcut button and choose õCustomize.ö (The õCustomizeö item will only appear if the button is right clicked.

2. Choose an option from the õActionsö list and click the right-pointing green arrow to add the item to the shortcut. (Any number of custom items can be added.) Click OK.


3. Custom shortcut items will be present in the graphø Analysis Shortcut list for the selected signal type. (ECG for the above example.) Items can be removed via the õClearö button or by selecting an item and clicking the left-pointing green arrow.

   TIP: Using the Alt or Option key in combination with the left-pointing green arrow will remove all shortcut items.

Chapter 11 File Menu Commands

Overview
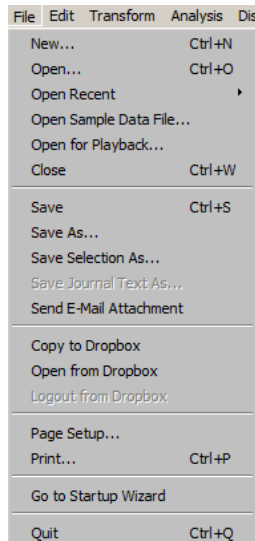
Most of the items in the File menu are standard menu items and follow the standard Windows conventions (for MPWSW) or Macintosh conventions (for MPWS). By default, all files are created and saved in the BSL *PRO* file format, a proprietary format used to store binary data. Data can be read in from either text files or BSL *PRO* files, and can be saved in text, graphic, or binary format. As a rule, storing data in the BSL *PRO* format saves information in the most compact format possible and takes up less disk space than other file formats. Normally, the most common format is working with graph windows and saving data in the BSL *PRO* format.

BSL *PRO* also supports an online journal that can be used to store waveform data (in numeric format) or to make notations and comments in a text file.

New
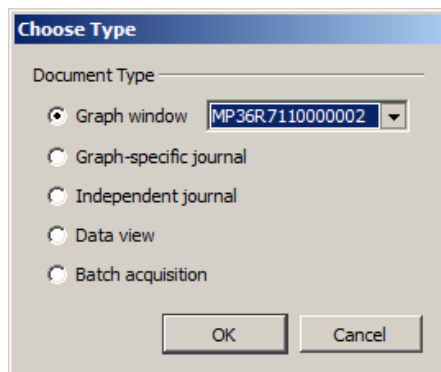
Graph Window

In many cases, itøs necessary to create a new graph window before beginning an acquisition. When a new graph window is created, any of the window parameters can be modified, including horizontal scale, vertical scale, window size and position. In addition, the acquisition parameters for sampling rate, number of channels, and acquisition length can be reset. These settings take effect once an acquisition begins.

New > Graph-specific Journal

Creates a graph-specific journal; see page 48 for details.

New > Independent Journal

Creates an independent journal; see page 48 for details.

New > Data View

Creates a new Data View for the active (frontmost) graph, and names the new window õData View of

÷Filenameøö. . For Data View details, see page 38.

New > Batch Acquisition

Use the Batch Acquisition feature to configure advanced experimental setups and acquire data from a sequence of templates. Each template in the Batch may have different acquisition settings, channel configurations, and stimulator setups. Use a Batch for long duration experiments with hardware setting changes across segments, to automate routines, or to run multiple experiments on the same experimental setup in succession.

- For example, if an experiment has a preparatory period, a stimulus period, and a response period, three graph templates could be batched:
  - A template to acquire for the length of the preparatory period
  - A second template with a stimulator configured for the stimulus period
  - A third template to acquire the response period without stimulation

All three templates could be added in sequence to a single Batch Acquisition, which would then acquire all of the data for all three templates with a single start.

To create a new batch, choose File > New > Batch Acquisition to generate the Batch dialog.
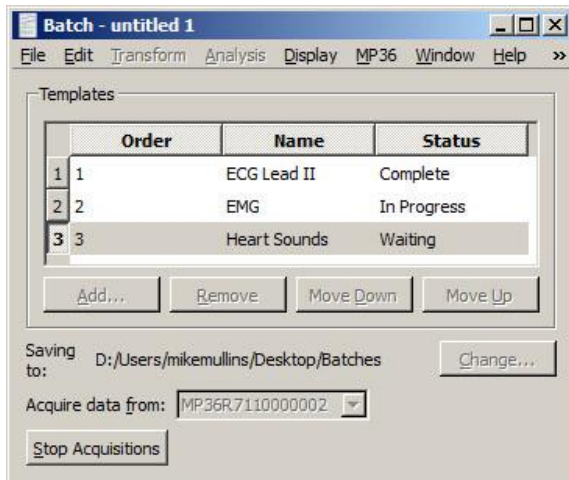
The Templates controls at the top allow addition, removal, or re-ordering of the templates.

- Double click a template in the list to open the output graph from the most recent acquisition.
- Batch acquisition cannot combine acquisitions that do not end, so the acquisition storage mode for template files cannot be set to õSave last,ö õAutosaveöor õRepeat forever.ö

Status

N/A   No status is available for the template, no batch acquisition has been performed.

In Progress Data is currently being acquired for the template.

Waiting   A batch acquisition is in progress but has not yet reached the step where the template is used.

Complete   Data acquisition for the template has been finished successfully and has been saved to disk at the batch output location.

Error   A batch acquisition was aborted manually or due to communication errors. The data for the template may not have been saved or may be unreliable.

             Batch Errors
             Misconfigured templates and misconfigured averaging templates may generate the Adjust Length/Adjust Latency/Abort Acq warning prior to the start of acquisition. Clicking õAbortö will halt the batch acquisition. Misconfigured templates may result in those rare cases where data was acquired into a graph template with a different hardware configuration prior to saving the template to disk.

Saving to:

Use the õChangeö button to specify the directory where the acquisition output should be saved.
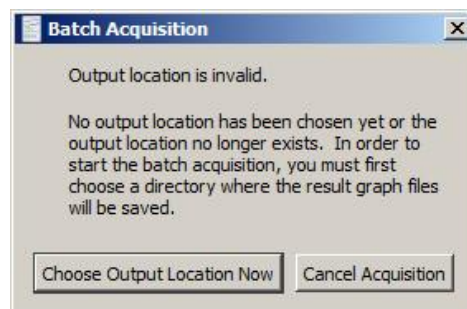
Acquire data from:

Specify the MP unit that should be used for the Batch Acquisition.

This menu lists all of the available hardware units. Entire menu dimmed out while batch acquisitions are in progress.

Start/Stop Acquisitions

| Start Acquisitions | Stop Acquisitions |

Toggles to starts and stop batch acquisitions; dimmed when the specified MP unit is being used to acquire data unless it is a batch acquisition that is in progress. Batch acquisitions may be terminated by using either a control in the batch user interface or by clicking the õStopö button in the graph window actively acquiring data for the current template of the batch. During the execution of an individual template acquisition, errors may occur that abnormally terminate that acquisition (i.e., communications errors with the MP unit, errors in calculation channel, disk errors, etc.). When the acquisition in progress is terminated due to an error, the batch acquisition will be halted as well.

- If a batch acquisition is aborted early, the batch output directory will contain the full result graphs for all of the templates that were previously completed successfully. It will also contain a partial graph file for the template that was being used at the time the acquisition was aborted. Templates that were not used will not have any associated graph files.

Resume

| Start Acquisitions | Resume Acquisitions |

When a batch acquisition is terminated prematurely, the acquisition may be restarted from the first template in the sequence or from where it was stopped (e.g. the template with the error status).

Batch Acquisitions can be saved for use at a later time using File > Save Batch Acquisition As. Batch Acquisition files retain all of the settings for their individual templates and can be used even if the original templates used to configure the batch no longer exist or have been moved. Each template is acquired and saved into an output graph file that can be opened at a later point in time to examine the results.

File	Edit	Transform	Display
New...			⌘N
Open...			⌘O
Open File for Playback...			
Close Batch Acquisition			⌘W
Save Batch Acquisition			⌘S
Save Batch Acquisition As...			
Page Setup...			
Print Graph...			⌘P

To open a Batch Acquisition, use File > Open and select type õBatch Acquisition.ö

When a batch acquisition is started, the templates will be executed in the order indicated in the batch to acquire data from the specified MP unit. Files are autosaved before the next acquisition is started.

- If the batch acquisition completes successfully, the batch output directory will contain all of the graph files that were created during the acquisition. Each output graph is saved into a user-specified directory and is titled õBatch *n* - template nameö where *n* is the order in the acquisition sequence.

Open

The File > Open command generates the standard file open menu, and supports a variety of different file formats from the popup menu at the bottom of the dialog.
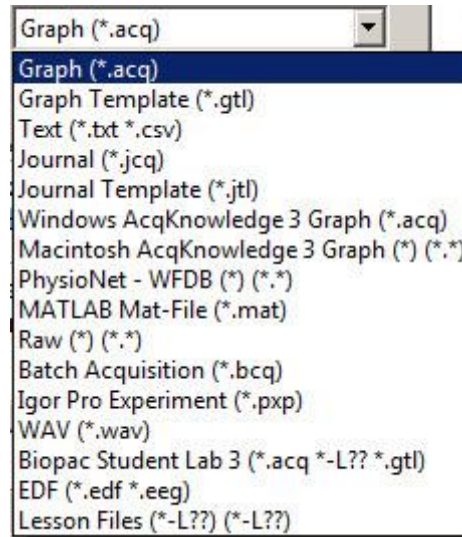
Multiple files

To open multiple files in a single dialog, hold the Shift key down and select multiple files. The Command-A key combination will õSelect Allö files in the dialog. BSL *PRO* can only recognize one Journal file at a time, so multiple selection is disabled when the file type is set to Journal or Journal Template.

Graph The default file formats (*.acq) is referred to as õBSL PROö files. The BSL PRO file format is the standard way of displaying waveforms in BSL PRO. These files are stored in a compact format that retains information about how the data was collected (i.e., for how long and at what rate) and takes relatively little time to read in (compared to text files, for instance). BSL PRO files are editable and can be modified and saved, or exported to other formats using the Save as command. Format options for the graph file include

- **Graph**ô BSL PRO
- **Windows Acq*Knowledge* 3 Graph**ô previous release Acq*Knowledge* format
- **Macintosh Acq*Knowledge* 3 Graph**ô previous release Acq*Knowledge* format
- **BSL PRO 3**ô previous release BSL format
- **Lesson Files**ô opens files in BSL Lessons format

BSL File Import Notes

BIOPAC produces two different software lines, the Acq*Knowledge* software for research and the BSL software for higher education. These two applications use different file formats, making it difficult to analyze data recorded in one with the other.

Hardware and calculation channel settings are also imported. This allows for the migration of some older BSL *PRO* templates.

Importing is limited to graph files created with BSL 3.6.6 or higher. It is not possible to import files created with earlier versions of BSL. To import from earlier BSL versions, those files must first be opened with BSL 3.6.6 or higher and re-saved to disk to update the file format. The updated files can then be imported directly into BSL *PRO*.

This file does not appear to be a BSL graph file.

The file "rat eeg test.acq" does not appear to be a supported BSL 3.6.6 or BSL 3.7.x formatted graph file. It may have been created with an unsupported BSL version or a different application. Attempt to open anyway?

Cancel   Open Anyway

When saving files, BSL *PRO* must save using the BSL *PRO* graph file format or another available export format.

Template   Graph Template files (*.GTL)

This powerful feature allows for creation of a template file with predefined experiment parameters. Simply click "Start" to run the experiment.

The Graph Template option creates a copy of a master file so frequently-used master settings can be maintained. Graph template files open to previously saved setup parameters (as established under the MP menu) primary graph window size.

This feature can be especially useful for recreating protocols in the laboratory. Set up an experiment and save it as a Graph template, then simply open the Graph template file and click the Start button to acquire data under the same settings.

When a Graph template file is opened:

NOTE
a) The graph window will not contain any data. (Since no data is saved in the template, arbitrary waveform output setups, which require a source date file, will not function in a template.)
b) The journal window will contain text entered and saved with the templateô this is a handy way to place instructions or information about the experiment for future reference.

BSL *PRO*) *PRO* Lessons files are available for over 30 applications. Just open the graph template file to establish appropriate settings for the selected application, and then click Start. *PRO* Lesson files were installed to the *PRO* Lessons folder and can be used to establish the settings required for a particular experiment. *PRO* Lesson procedures are included in a sub-folder in the *PRO* Lesson directory, (Main drive:\Program Files\Biopac Systems, Inc\Biopac Student Lab 4.0\PROLessonsSupport\all lang), or accessible from the lessonø Help menu.

Text   *.TXT*. Text files are a convenient way of transferring information between applications, and most spreadsheet and statistics programs are capable of importing or exporting data in a text file format. BSL *PRO* assumes that the text file contains numeric data laid out in columns and rows, and that there is some delimiter between each column. It also assumes that each column represents a distinct variable or channel of data. Normally, the values in each row represent the state of each variable at different points in time. When a text file is opened, the numeric values will be plotted as waveform data in a standard graph window and non-numeric values will be ignored. Each column of data is read in as a separate channel.

Options

When the Files of type: Text option is selected, an Options button is activated. Clicking on this button generates another dialog that allows control over the amount and type of data to be read in, as well as the time scale for data display.
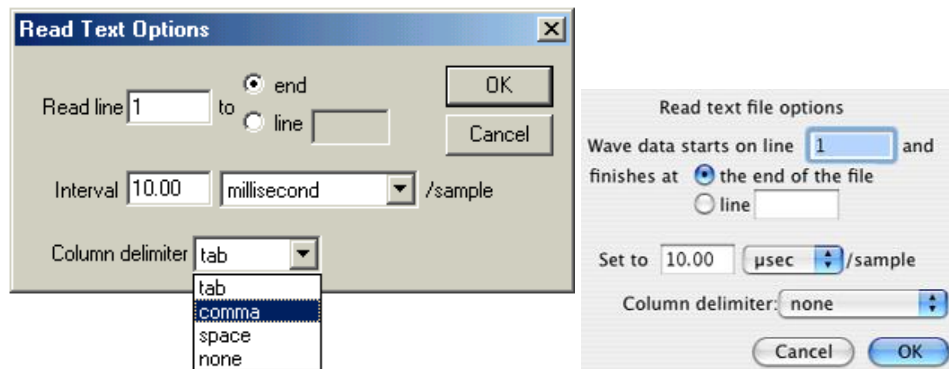
Read Line

> To control how much data is read in, enter a value in the read line box at the top of the dialog. This tells BSL *PRO* which row contains the first data point in the series. By default, this is set to 1, although itøs possible to set it to another value since some applications (usually spreadsheets) generate a õheader,ö or text information at the top of a file. A limited amount of data can be read in by entering a value in the box to the right of the line box. This value indicates the last line to be read in as data. By default, text files will be read in starting at line one and data will continue being read in until the end of the file is reached.

Interval

> To control the horizontal scale (usually time) for the text file after it is displayed in the graph window, change the Interval between sample points, which can be expressed either in terms of time or frequency. For example, if data was collected at 50 samples per second, there is an interval between sample points of 0.02 seconds. BSL *PRO* would then assume that there is a 0.02 second õgapö between the data point in row two and the data point in row three (and all subsequent pairs of adjacent rows). Likewise, if a data file spans 10 seconds and has 100 rows of data, the interval between sample points will be 0.01 seconds.

> Most files contain time domain data, although some applications generate frequency domain data (the results of a spectral analysis, for example). The principle here is the same as with time data, that there is some interval between different frequencies. If a text file contains 20 sample points covering the range between 0 and 60 Hz, then the interval would be set to 3Hz per sample.

Column Delimiter

> This setting tells BSL *PRO* what characters indicate a õgapö between two columns. This can be set to tab, comma, or space. All text files must have some sort of column delimiter, unless there is only one channel of data present.

> - Tab delimited text files ô the most common typeô have a tab between each column for every row of data. These files are most often generated by spreadsheets and similar packages.
> - Comma delimited files place a comma between each column of data for each row, much the same way as a tab delimited file. Statistics programs such as BMDP and SAS frequently create these types of files.

Journal   **.JCQ—*Opens an independent journal; see page 48 for details.

Open the journal file from the File Menu (File > Open > Journal); right-clicking or double-clicking a saved Journal file will open a blank application window.

Jrnl   **.JTL—*Opens a journal template; see page 48 for details.
Temp

- Space delimited files are also commonly created by statistics packages, and place some number of spaces (usually two) between each column of data for every row which contains information.

- None. If unsure of which delimiter to use, select auto and BSL *PRO* will automatically select a delimiter.

When either tab or comma is selected, BSL *PRO* will read in a new column each time it sees a delimiter, even if there are no numeric values between delimiters. For example, the following text file will read in three channels of data, although the channels will be of different lengths.

```
0.301424, 0.276737, 0.045015
0.338723, 0.808811, 0.542627
0.354271, 0.506313, 0.715995
0.001325, 0.762115
946207, 0.894992
0.926409,
```

Sample text file

The first channel will contain six data points, the first being 0.301424 and the last value being 0.926409. The next channel will contain three data points, starting with 0.276737 and continuing through 0.506313. The software considers that there are no other data values for channel two. The third channel starts with the entry 0.045015 and the last data point for this channel is 0.894992. There are only five data points in the last channel.

PhysioNet PhysioBank is a public service of PhysioNet and offers downloadable archives of gigabytes of õstandardö data for cardiac arrhythmias, gait analysis, and other types of physiological signals. BSL *PRO* can use PhysioBank data directly and can be integrated with other software tools that understand this interchange format.

A PhysioBank file is usually comprised of several files, including a header file (usually õ*.heaö), and all of the files must be located in the same directory for the PhysioBank record to open successfully. Open using the header file.

Opening a PhysioNet file will import data and annotations into a new graph window. If õatruthö annotations exist, they will be translated into appropriate events on the appropriate channel. All annotation types are retained except LEARN annotations, which are treated as UNKNOWN.

MAT MATLAB® format BSL *PRO* can open files created as a MATLAB work space.

- WindowsÎ can open MATLAB v6 compatible MAT files, including MATLAB 7 if the õv6ö flag is specified in MATLAB before saving.

- MacÎ can open MATLAB v7 compatible MAT files, including V7 format. Only ASCII text is supported; Unicode text within MATLAB v7 is not supported.

- Interoperability with earlier versions of MATLAB is not guaranteed.

Uses the õMAT-fileö binary format to load numerical and textual information. If the MAT-file is properly formatted with the following arrays, BSL will reconstruct the graph with appropriate sampling rate, channel labels, units, and data:

data   units   labels   isi   isi_units   start_sample

- MATLAB files open with no Start button.

- If the MAT file is missing any of the expected variables or contains extra variables, only one two-dimensional array variable can be imported into a graph. A MATLAB Import Options dialog will be generated. Choose which variable data is stored in, what dimension maps to samples, channel indices, and sample rate, and then click OK to open the file.

- If BSL *PRO* canøt recognize the file format, an error prompt will be generated and a blank graph window will be opened.
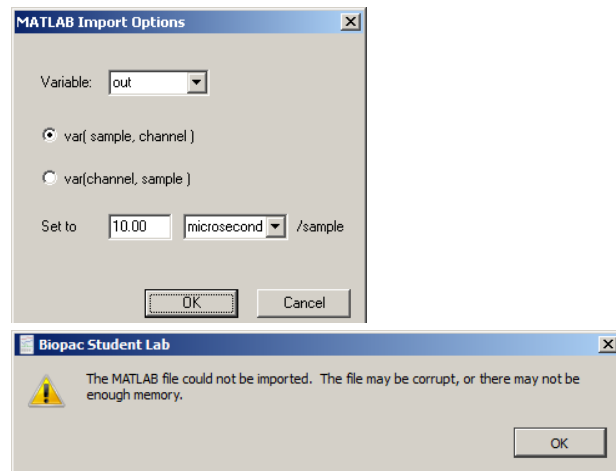
Raw   This low-level data exchange option interprets all data at a single sample rate; variable sample rates are not supported. All of the data will be unscaled when opening (importing) files. That is, a value of 0 will be imported as a zero voltage. Scaling will need to be manually applied to the data. Options to open (import) raw data:

Data type:	32-bit or 64-bit IEEE floating point format or 8-, 16-, and 32-bit integer formatted data
# of channels:	Enter the number of channels stored in the data file as a positive integer less than or equal to 60.
Layout*:*	*Packed sequential*: All of the data for an individual file is located in a single block of the file and multiple channels follow one another.
	Interleaved: Data is grouped into a single õframeö for each sample location with one data element for each channel, so data for a particular channel is spread throughout the file (similar to Linear PCM audio file format).
Endian:	Little and big endian byte ordering, matching the data formats of x86 and PowerPC/Sparc, respectively. Set to big for Mac-Power PC generated raw files (default), or to little for Mac-Intel generated or Windows-generated raw files.
Set to *x*/sample:	Specify the *inter sample interval* of data in the file, which will be translated into an appropriate sampling rate. The edit field will accept an arbitrary floating point number. The units menu contains sec, msec, sec, MHz, kHz, Hz. The edit field will be dynamically converted to match the units selection; no conversion will be used when switching between frequency and time.

Batch   Batch files (*bcq) is the format used for a saved Batch acquisition setup. All previous configurations are saved in this file, so a Batch experiment can be rerun without having to repeat the setup. When a saved Batch file is opened, the batch setup window appears with previous graph templates intact. From here, the setup can modified and saved under the same or a different name. See page 220 for details on setting up Batch Acqusitions.

Igor Pro   Igor Pro Experiments (compatible with Igor Pro 3.1, 4.0, and 5.0).

The waves contained in an Igor Pro packed experiment can be opened (imported) in BSL *PRO* provided that the packed experiment files comply with the following:

- Ö59 waves
- no text waves
- no complex waves

- all waves in Version 2 or Version 5 format (Igor defaults)
- all waves one-dimensional (vectors)
- all waves multiples of the same fundamental inter sample interval

If the wave has an associated wave note, it will be used as the channel label.

WAV   WAV files containing 60 channels or less can be imported. When this format is chosen, the list of available files will be filtered such that only files ending in the õ.wavö extension or having the õWAVEö type are shown. When a WAV file is selected, it will be analyzed to determine if it is compatible with the BSL *PRO* application.
If the file is compatible, a new graph window will be created displaying the data contents of the WAV file.

- Each channel will be numbered õChannel *n*ö where *n* is an increasing digit. These channels will be unitless in amplitude.
- All of the data will be converted into the 64 bit floating point format for storage in memory and in the ACQ formatted files on disk.
- The horizontal axis of this graph will be set to time and the sampling rate set to match the rate as specified in the WAV file headers.
- This graph will be marked as an imported graph into which data cannot be acquired.
- This will dim the start button and any appropriate hardware menu entries that would be used to access the invalid hardware settings.

EDF   Opens files with .eeg and .edf extensions saved in European Data Format (EDF). Data is imported entirely into memory in a newly created graph window titled after the filename, similar to other file import routines. All scaling factors will be applied to the data as it is imported, and it will be converted to double precision floating point format. Since EDF format includes data that is not used by BSL *PRO*, only the following items are imported:

- channel data
- channel labels
- units
- sampling rate (taken from maximum sample rate of all channels)

All other information stored in the EDF file will be discarded when the file is imported. Only 60 channels of data can be imported from an EDF file. Channels will be imported starting with the graph file index 1. If there is a 60th channel, it will be placed into the channel with index 0. If an EDF file contains more than 60 channels, only the first 60 channels will be imported and a prompt will advise that not all of the channels could be imported.

Lessons Files   Lessons Files is the file format created when running BSL Lessons. These are similar in appearance to BSL *PRO* *.acq graphs and can be opened in the *PRO* application when this format is selected.

Open Recent

The File > Open Recent command generates a list of recently used files. These files can be opened directly from the list or with a Ctrl (PC) or Command (Mac) keystroke combination.
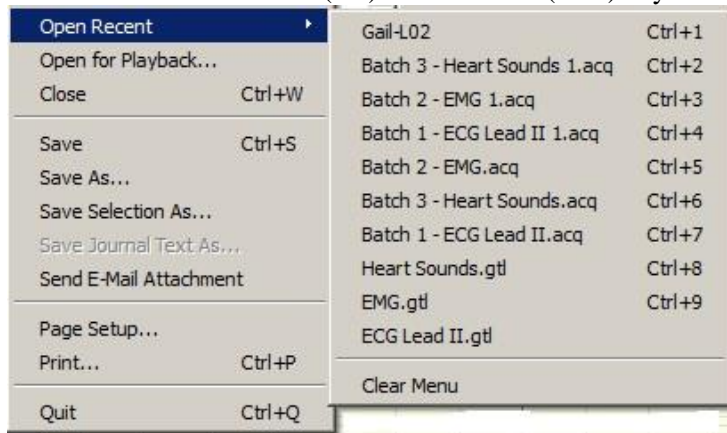
The listed files appear in the order they were opened, with the most recently-opened file appearing at the top. Default number of files appearing in the list can be modified in the Preferences. (Display > Preferences >Other)
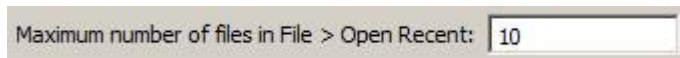
Open Sample Data File

The File > Open sample data File command provides a shortcut to the Biopac Student Lab Sample Data folder. Open the õPROö folder, select the desired sample data file and click OK. The file format is set by default to *PRO* sample data files (*.acq format). To open BSL Lesson sample data files, choose õLesson Filesö from the file format menu and click OK. To open sample graph templates (*.gtl files), choose õGraph Templateö from the file format menu and click OK.
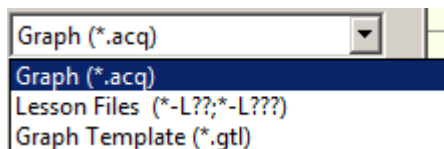
Open for Playback

The File > Open for Playback command generates a standard file open dialog; see page 37 for Playback details.

Close

This File menu command will close the active file window and prompt to save if necessary.
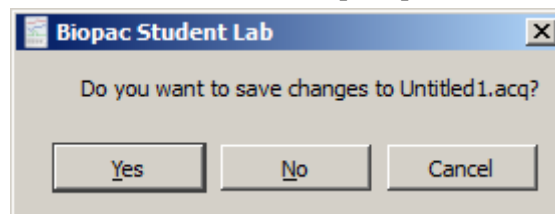
Close without saving

- *Windows*ô click the ⊠ in the upper right corner of the file window

- *Mac OS*ô click the 🔴 in the upper left corner of the file window

    Click õNoö in the save changes prompt..

Close during acquisition
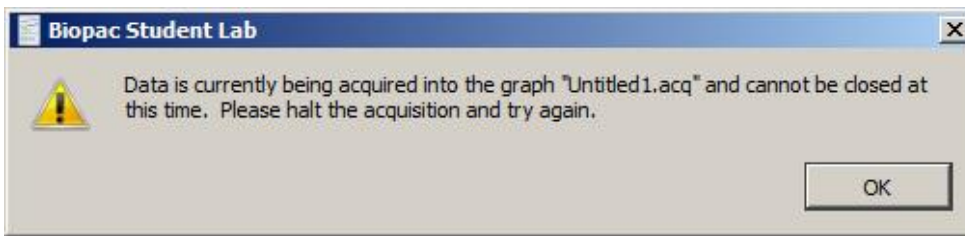
Close multiple data views

Set the level of close functionality under Display > Preferences > General.
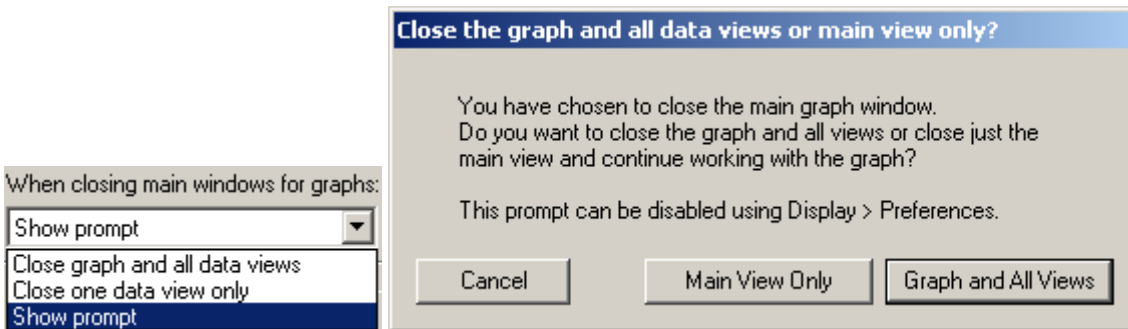
Save
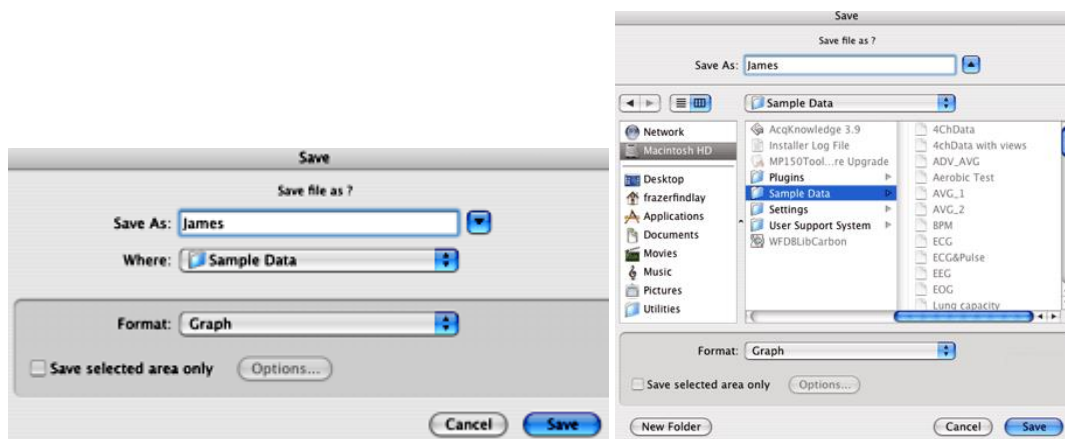
This menu command will save any changes made to a file. If more than one file is open, this command only applies to the active window. For untitled files, a name file prompt will appear for saving under a unique title. The file will remain open after saving, allowing work on the file to continue.

- The Save menu is dynamic and corresponds to the type of file being saved, i.e. Save Graph, Save Journal.

Files should be less than 2 GB, except BSL 3 õGraphö files on the Mac, which can be larger if not compressed. Data files greater than 2GB can be opened, but edit, transformation and analysis operation cannot be performed.

To save data in another format (such as a text file), use File > Save As.

Save As

Choosing File > Save As produces a standard dialog that allowing data to be saved in a variety of different formats and to any location.

Graph BSL *PRO* format

The default file format for the File > Save as command is to save files as a BSL *PRO* 4.0 *.acq file, which is designed to be as compact as possible. These files can only be opened by BSL *PRO*, but data can be exported to other formats once it has been read in.

- To save in the previous release format, choose **Windows Acq***Knowledge* **3 Graph**. When a file is saved in Acq*Knowledge* 3 format, the following calculation channel types will revert to Integrate: Band Stop Comb Filter, Adaptive Filter, Rescale and Metachannels.

GTL Graph Template

This feature can be especially useful for recreating protocols in the laboratory. An experiment can be set up and saved as a Graph template. Then simply open the Graph template file and click the Start button to acquire data under the same settings.

The Save As Graph template option saves the setup parameters established under the MP menu and retains the size of the primary graph window. In general, the minimum file size for graph templates is 700 K-800 K; file size may increase as setup options are enabled.

When a file is saved as a Graph Template:

   a) No graph data will be saved.

N O T E

- Since no data is saved in the template, arbitrary waveform output setups, which require a source date file, will not function in a template.

- In order to save the data the graph must be saved as õFile of type .ACQ.ö

   b) Journal text will be preserved. Any entered text will be saved to the Journal window and stored with the templateô this is a handy way to place instructions or information about the experiment for future reference.

TXT *Text*

Saves graph data in text format. When Save As Text is selected, an Options button is generated. Clicking on this button generates a Save Options dialog that allows control over how much data is saved and the format it is saved in.
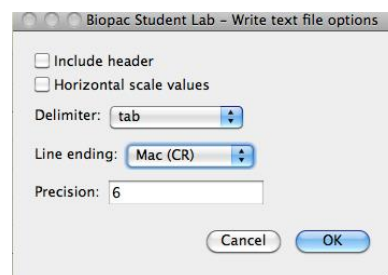
Header

When the first box is checked, a õheaderö is included at the top of the text file that contains information about the sampling rate, number of channels, date created, and other information relating to the data.

This information is frequently useful, but some programs will attempt to read in the header information as data, which could result in nonsensical results. Itøs recommended to include the header as it can always be edited out later using a text editor or the journal.

Selected Section

>Checking the second box instructs BSL *PRO* to save only the selected section of the file. This is useful for saving a brief segment of a long file. When this option is checked, the highlighted area of data will be saved from all channels. When only one data point is selected, the entire file will be saved. To save only a portion of the selected channel, either remove other channels or copy the data through the clipboard. See page 245 for more information on how to copy data through the clipboard.

Horizontal Scale

>The third checkbox allows inclusion of the horizontal scale (usually time) values in the text file, along with the data to be saved. This is useful for producing time series plots in other applications, as well as correlating events to time indexes in graphing and statistical packages. Since a separate row is generated for each sample point, To exceed the limitations of programs if data is collected at a fast sampling rate (many spreadsheet programs are limited to about 16,000 rows). It may be helpful to consult the section on resampling data after an acquisition is completed (page 270).

Column Delimiter

>When data is saved as a text file, each channel of data is saved as a separate column, with the number values for each data point saved in rows. Use the pop-up menu to select the delimiter to separate the columns of data in the text file. By default, a tab is placed between each column for every row of data; this format is called a tab-delimited text file and almost all applications will read in tab-delimited text files. However, data can also be saved in a comma-delimited format or space-delimited format.

Line endings

>>Use to create text files that are compatible with Classic Mac OS applications (Mac), Unix-compatible applications (Unix), or PC-compatible applications (DOS).

Precision

>>Use to define the number of significant digits used for the horizontal scale when pasting wave data. Very high sampling rates may require more than the default value of 6 digits to accurately resolve the inter-sample interval.

PhysioNet This format requires that the WFDB library is installed on the computer. PhysioBank is a public service of PhysioNet and offers downloadable archives of gigabytes of õstandardö data for cardiac arrhythmias, gait analysis, and other types of physiological signals. BSL *PRO* can use PhysioBank data directly and can be integrated with other software tools that understand this interchange format.

>Saving a file in PhysioNet (WFDB) format will export the entire contents of the graph to a PhysioBank record. The record will consist of multiple files, all in the location specified for export. There will be a header file (*.hea) and a single data file for each channel of the graph (starting with õdö and ending with the base name of the header file). The files must not be separated for a successful move or copy.

Export Limitations

>*Precision* Some precision may be lost due to differences in binary representation between BSL *PRO* and PhysioBank formats.

>*Events* Events will not be exported to the PhysioNet format.

>*Channels* Only 32 channels of data can be exported from a graph (the max allowed in a PhysioBank file).

>*Rate* If exporting a graph that uses variable sampling rates, all of the channels in the exported file will be downsampled to the lowest waveform

sampling rate of the source graph.

*.MAT MATLAB MATLAB® format. Uses the õMAT-fileö binary format to save numerical and textual information as Filename.mat.

- WindowsÎ and MacÎ create MATLAB Version 6 files, which are compatible with both MATLAB Version 6 and MATLAB Version 7.
- Interoperability with earlier versions of MATLAB is not guaranteed.

The following variables will be in the workspace when the file is opened in MatLab.

data	Contains the data of the graph in floating point format, for all of the channels of the array. The first dimension of this array is the amount of data in each channel, the second dimension increments with each channel. Therefore, each column contains a full channel of data that can be accessed in MATLAB via data (1:length, [channel number]).
units	This string array contains the textual representation of the units of the samples stored in data, with one element per channel of data.
labels	This string array contains the labels of each of the channels, with one element per channel.
isi	This floating point array of one element gives the number of units of a single inter sample interval of the data.
isi_units	This single string array provides a units string for a single unit of isi. Time data will always be õms,ö frequency data will always be õkHz,ö and other values will be represented by an Arbitrary horizontal axis type in an ACQ graph.
start_sample	Contains the time offset of the index 0 sample of data in isi units. This will be 0 for many graphs, but if only a selected area of a graph was exported into the MAT file, the start_sample will contain the offset from the original data corresponding to the start of the data array in the MAT file.

Raw Options to save (export) data for low-level data exchange are:

Data type:	32-bit or 64-bit IEEE floating point
Layout:	*Packed sequential*: All of the data for an individual file is located in a single block of the file and multiple channels follow one another.
	Interleaved: Data is grouped into a single õframeö for each sample location with one data element for each channel, so data for a particular channel is spread throughout the file (similar to Linear PCM audio file format).
Endian:	Little and big endian byte ordering match x86 and PowerPC/Sparc data formats, respectively. To exchange with Windows applications or Mac-Intel, set to little endian; to exchange with standard Mac applications, set to big endian.

Raw Data Export Limitations

Formats	Raw export only allows data to be saved in 32-bit and 64-bit IEEE floating point format.
Rates	All files will be interpreted at a single sample rate; variable sample rates are not supported. If a graph with variable sampling rates is exported, channel data for downloaded channels will be padded to match the highest waveform sampling rate.
Length	If channels have unequal lengths, the overall file length will match the longest channel. Shorter channels will be padded at the end using their final sample value so that all channels contained in exported files will be equal in length.

Scaling   When integer-valued analog channels are exported from BSL *PRO* to raw files, all relevant scaling and offset will be applied— the data in the file will appear the same as if the channel had been internally converted to floating point format before export.

If the value of a channel is outside the maximum/minimum value that a chosen export data type can represent, the value will be clipped accordingly. (BSL *PRO* uses a 64-bit data type, so this should only be a problem if exporting to 32-bit floating point values.)

Igor Pro   Igor Pro Experiment format.
An BSL *PRO* graph will be saved (exported) to a single packed experiment file, with each channel saved into a separate Igor wave that preserves the channel label, waveform sampling rate, and unit information. Vertical units will be stored as data units, and horizontal units will be stored dimension units; extended units are supported. The scaling of each wave will be adjusted to match the waveform sampling rate. All data will be stored in 64-bit floating point format in a one-dimensional wave. The waves will be named incrementally from õwave0ö and the channel label will be stored in the wave note field. Files will have the type/creator pair õIgsU/IGROö and a õ.pxpö extension will be added to the file name for compatibility with Igor Pro for WindowsÎ .

WAV   This option saves the graph data into a WAV audio file for exchange with other applications. The õ.wavö extension will automatically be added if the save as filename does not end with it.
The õSelected area onlyö checkbox will be active for WAV export. When checked, only the highlighted area will be exported to the WAV file. The final sample of this range is not included in the export, mirroring the other file export routines of BSL *PRO*.
All exported WAV files use the 64 bit floating point format, which preserves full operational precision. Most audio applications should be able to support floating point WAV files. Exported data will not be normalized when it is exported. Any normalization to audio ranges should be performed prior to exporting the data.
WAV files are normally either one or two channels (e.g. mono or stereo). BSL *PRO* graph files, however, usually contain more than two channels. Although they can contain more than two channels, most audio applications may not be able to recognize these multiple channel files.

- If a graph file contains only one or two channels of data, a WAV file will automatically be created without further interaction.
  - Graphs with a single channel will result in mono WAV files.
  - Graphs with two channels will result in stereo WAV files.
- If a graph contains more than two channels, the user will be presented with the following choice:

WAV File Export

Channels to include in WAV:
- all channels
- selected channel only (mono)

Cancel   OK
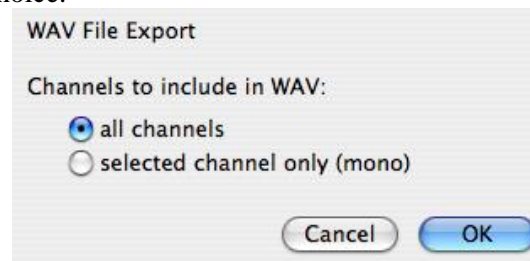
  - **all channels**— create a multiple-channel WAV file with one channel per channel of data in the graph. While this WAV file may be easily opened by some applications, it may not be fully compatible with audio applications and other applications expecting two channels or

less.

- o **selected channel only**ô create a single channel mono WAV file using only the data of the selected channel. This will be the selected channel in chart mode, the active channel in scope mode, or the vertical channel in X/Y mode. This single channel export may be useful for exporting audio channels that are recorded along with physiological data, such as heart sounds, audio stimuli, and the like.

After a WAV file is exported, the WAV file will not be reopened; the open graph will be left unmodified. To view the exported file, import the WAV file.

EDF   Saves file in European Data Format (EDF). The saved file will automatically have an .edf extension added onto it if the user did not include it. Users will be able to save either the entire graph or only a selected portion of data.

BSL *PRO* does not retain sufficient information to accurately complete an EDF header. When exporting, the following default values will be used:

EDF Header Element	*Default*
subject ID	Empty*
recording ID	Empty*
recording date	Set to the modification date of the graph file on disk. If no graph file is on disk, the current date is used.
recording time	Set to the modification time of the graph file on disk. If no graph file is on disk, the current time is used.
transducer description	Empty*
filter description	Empty*
	* Empty: indicates that the field will be left blank

All other fields will be filled with corresponding information from the graph, including channel titles, sampling rates, channel units, and scaling factors. Variable sampling rate information will be preserved as it can be expressed in the EDF format.

EDF is used by many applications and online recording databases to store information, particularly EEG recordings. EDF is an open file format originally developed for sleep studies. It stores continuous time recordings of data in a binary format. Since its original proposal, EDF has been adopted by a number of open source and commercial tools as a supported data file format. Usage has also expanded beyond sleep studies into other types of recording.

JPG   BSL *PRO* also supports formats for saving graphical information. Most drawing, page layout, and word processing programs can read .JPG files. This is particularly useful for writing reports. A. JPG file can be opened in any standard drawing program and can then be embellished or used to highlight any particular phenomena of interest.
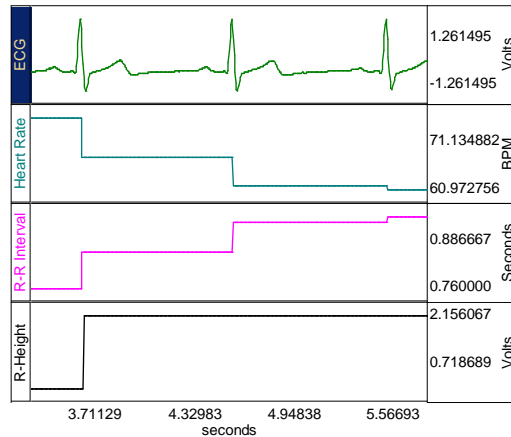
When data is saved as a graphic, only the data currently on the screen is saved. For example, if a data file that spans eight hours has only two minutes displayed on the screen, only two minutes of data will be converted to a graphic file. Since BSL *PRO* uses information about the computer screen in creating the graphic file, the default resolution of the file will be the same as the window. Most word processors and graphics packages allow for some way to resize and scale graphics.

Compressed   Saves a compressed BSL *PRO* formatted file. The degree of compression varies based on data characteristics, but will generally achieve about 60% compression. Saving small files (less than 200K) may have little effect. Using a sample file as an example:

ECGdata.acq   166 KB
ECGdata_Compressed.acq   38 KB

Compressed graphs no longer allow data acquisition and will open with no Start button.

A warning prompt will be generated when attempting to compress a graph in which data can be acquired (Start button active):

You will no longer be able to acquire data into this file.

Once the graph is saved in the "Compressed Graph" format, you will no longer be able to acquire any data into the file. Are you sure you want to compress this graph?

No   Yes
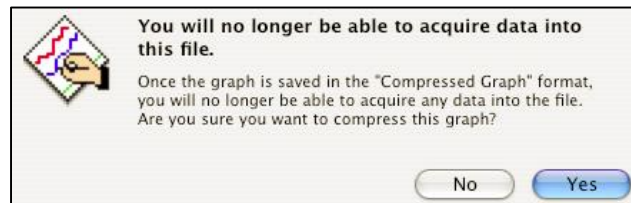
Excel Spread-sheet   Excel Spreadsheet Exportô Graph data can be saved directly to an Excel spreadsheet by using the Excel Spreadsheet format in File > Save As. Each channel will be placed into its own column of the spreadsheet. Only 65K sample points can be exported at a time, however, so long or high sample rate data acquisitions may not be able to be saved in a single spreadsheet.

- Also available for File > Save Journal Text As, Find All Cycles journal, and Specialized Analysis tools.

Note   The Excel spreadsheet option requires Excel or a compatible spreadsheet application that can read Excel files (OOo, Symphony, etc.). If Analysis results are exported to an Excel spreadsheet, and a compatible application is not available, results will open as a text document the data and nonsense characters.

Save Selection As

To save only the data that has been selected with the I-beam tool, choose File > **Save Selection As**; this option saves the selected area to another file and does not affect the currently-open file. Specify file name and file type and then click Save.
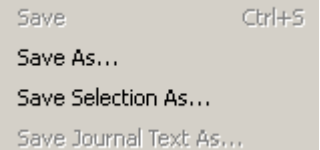
Save Journal Text As
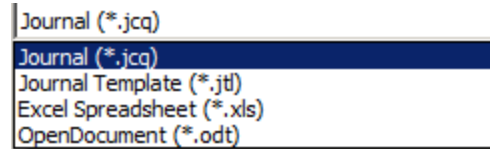
Choosing File > Save Journal generates a save dialog to save the journal text as a separate file. Specify file name and file type and then click Save.

Journal *Text (*.TXT) format*—Saves an independent journal; see page 48 for details.

Jrnl Temp **.JTL format*ô Saves a journal template; see page 48 for details.

Excel Spread- sheet *Excel Spreadsheet File (*.XLS)*ô Journal text can be exported directly into an Excel spreadsheet by using the File > Save Journal Text As with the Excel Spreadsheet format. Each line of text in the journal will be saved as a single row with tabs separating columns. A selected portion of a journal can also be written to a spreadsheet. This export allows for textual data reduction results to be easily exported into a spreadsheet to allow for further analysis.

- Also available for File > Save As, Find All Cycles journal, and, for Specialized Analysis tools.

Note The Excel spreadsheet option requires Excel or a compatible spreadsheet application that can read Excel files (OOo, Symphony, etc.). If Analysis results are exported to an Excel spreadsheet, and a compatible application is not available, results will open as a text document the data and nonsense characters.

OpenDocument **.ODT format*ô Saves journal in OpenOffice/NeoOffice document format.

File Format prompts

When a file open or save function requires a format change for compatibility or alters file content, a prompt will be generated to require the user to confirm the option to update format or convert and save. It is recommended that the file be opened as a Biopac Student lab 3 file and many older file types cannot be successfully converted to Version 4 files.

Created with a previous version of BSL

Saving as a "Graph Template" will erase all data
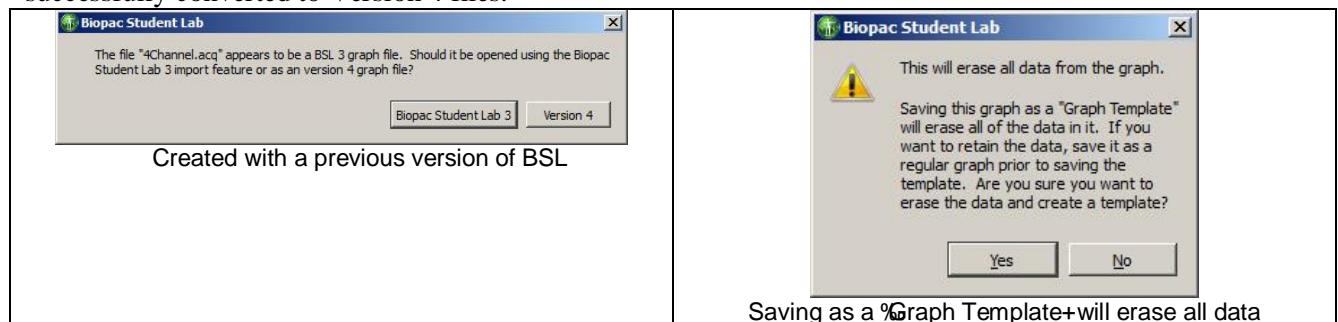
Send Email Attachment

Use this feature to create an email attachment containing an image of the active BSL *PRO* graph, along with the journal contents.

When using this feature:

- o The default email program will launch, along with a "compose new email" window.

- o An Open Document (*.odt) text file containing an image of the currently opened graph and associated journal text will be copied to the attachment field. The formatting and images present in the journal should be preserved.

- o Further details can be typed into the body of the email prior to sending.

In order to open the attachment, the email recipient must have a word processing application compatible with *.odt file format, such as OpenOffice, NeoOffice or Microsoft Word[i] .

Copy to Dropbox . Open from Dropbox

The Dropbox options allow for copying or opening BSL data files to or from a Dropbox account directly from within the BSL application. This is useful for storing files online where they may be accessed from any computer. In order to use this feature, access to an active Dropbox account is necessary.
To create a Dropbox account, go to www.dropbox.com.

To set up BSL to use Dropbox:

1. File > Copy to Dropbox. If Dropbox is being used for the first time in BSL, or if not logged in to a Dropbox account, the following authorization dialog will appear.
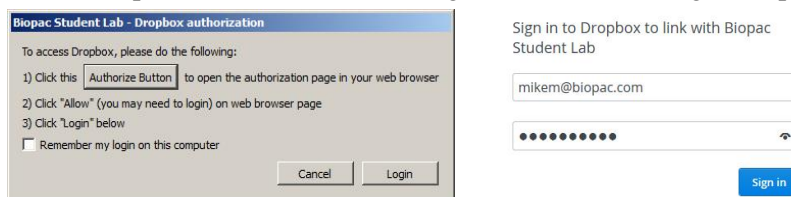
2. Click the "Authorize Button" and sign in to the Dropbox account.
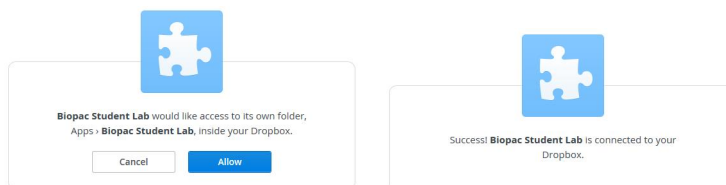
3. Click "Allow" to grant BSL permission to create a new Dropbox folder (above left).

4. A confirmation dialog will appear indicating BSL is successfully connected to Dropbox (above right). Close or minimize the Internet browser window.

5. Dimiss the Step 1 Dropbox authorization dialog by clicking "Login." As long as the user remains logged in to the Dropbox account, this setup procedure will not need to be repeated.

To Copy files to Dropbox:

1. File > Copy to Dropbox.
2. Accept the default filename or enter a new one and click OK.
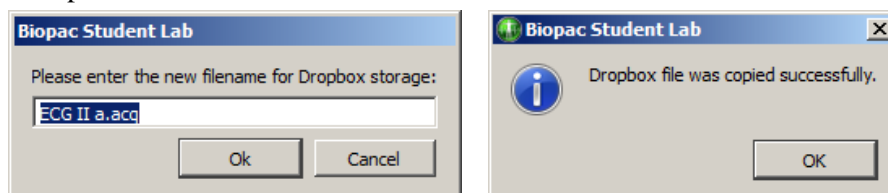
3. A confirmation dialog will appear indicating the file is stored on Dropbox.

To open files stored on Dropbox:

1. File > Open from Dropbox.
2. Select the desired file from the list of stored BSL files and click õOpen.ö
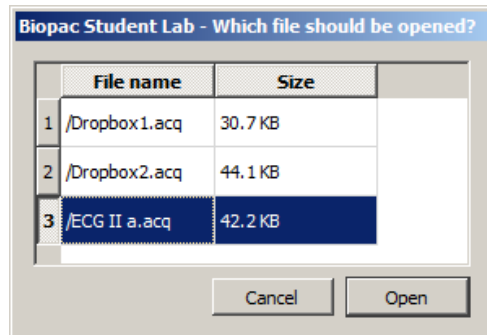
NOTES:

- If Dropbox is being used for the first time in BSL, or if are not logged in to a Dropbox account, the authorization dialog shown on the previous page will appear before a stored file can be accessed.
- More than one file can be opened from the list, but must be selected individually. Multiple selections are not supported.
- To log out of Dropbox from BSL, choose File > Logout from Dropbox.

Page Setup

Choosing File > Page Setup produces a standard printer setup dialog that allows setup for any available printers.

Event Divider

Toggle õDraw vertical divider at event locationsö to enable/disable this option. See Printing Events on page 204 for details.

Based on the range selection, the software will make appropriate adjustments before printing. For visible area, friendly grid scaling will be applied, and onscreen and printed precision will match, even if horizontal grids are unlocked. For selected area and entire area, onscreen and printed precision will not match when grids are unlocked because friendly grid scaling is applied on screen, but is not used during printing where the range is fixed to fill the entire page.

The automatic software adjustments before printing will set the horizontal scale as if it had been used to display the relevant data on the screen. When printing is completed, the scale and offset parameters of the graph will be restored to the previous settings.

Print

The File > Print menu that BSL *PRO* uses is similar to the standard computer print dialog; however, there are additional options available.

The Print menu is dynamic and corresponds to the type of file being printed, i.e. Print Graph, Print Journal.

Windows OS: Click print for more options.
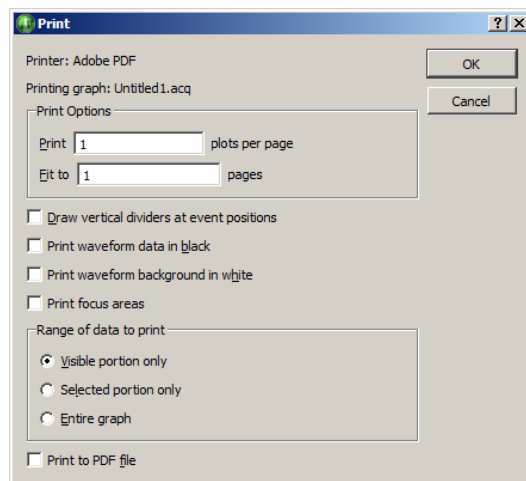
- Print Options
  - **Plots per page**ô Control how many plots appear per page when the file is printed. Printing more than one plot per page has the effect of õsnakingö graphs on a page much the same way text appears in a newspaper. For example, if this option was selected so that two plots were printed per page, BSL *PRO* would divide the amount of data to be printed on that page into two graphsô one graph printing at the top of the page, the second graph printing at the bottom of the page. This option allows records to be printed on considerably fewer pages than standard printouts, and is most effective when only a few channels of data are being printed.
  - **Fit to pages**ô Print the contents of a window across multiple pages. When a record is printed over multiple pages, the amount of data on the screen (the amount of data to be printed) is divided by the number of pages entered in the dialog. The graph on the screen is then printed across the number of pages specified in the Total pages box at the bottom of the File > Print dialog. These two options apply only to graph windows, and do not apply to Journals.
- **Draw vertical dividers** at event positions
- **Print waveform data in black**ô Waveforms will appear black when printed, regardless of selected colors in graph channels.
- **Print waveform background in white**ô Prints white background, regardless of selected background colors in graph channels.
- **Print focus areas**ô Turns focus areas on or off for the printout.
- Range Optionsô determine the range of data that will be included in the printout
  - **Visible portion only** synchronizes the range of data in the printout to match the range of data that is visible on the screen.
  - **Selected portion only** prints only the data that is selected in the graph. This option is disabled if there is no selection in the graph. When working with Journals, it is easy to generate large amounts of text content in the window. Only a portion of this information may actually be of interest and this feature allows for only portions of the text to be printed. If there is no selected text, the entire journal or modification log will be printed regardless of this setting.
  - **Entire graph** prints all of the data contained in the graph from zero to the maximum length channel.
- **Print to PDF file**ô generate a PDF file.

Quit

Select Quit from the File menu to exit BSL *PRO* software; a Save prompt will appear for open graph files that have been modified since last saved.

*Mac OS only*ô Use Quit under the BSL *PRO* menu (page 341) to exit the software.

Chapter 12   Edit Menu commands

Overview
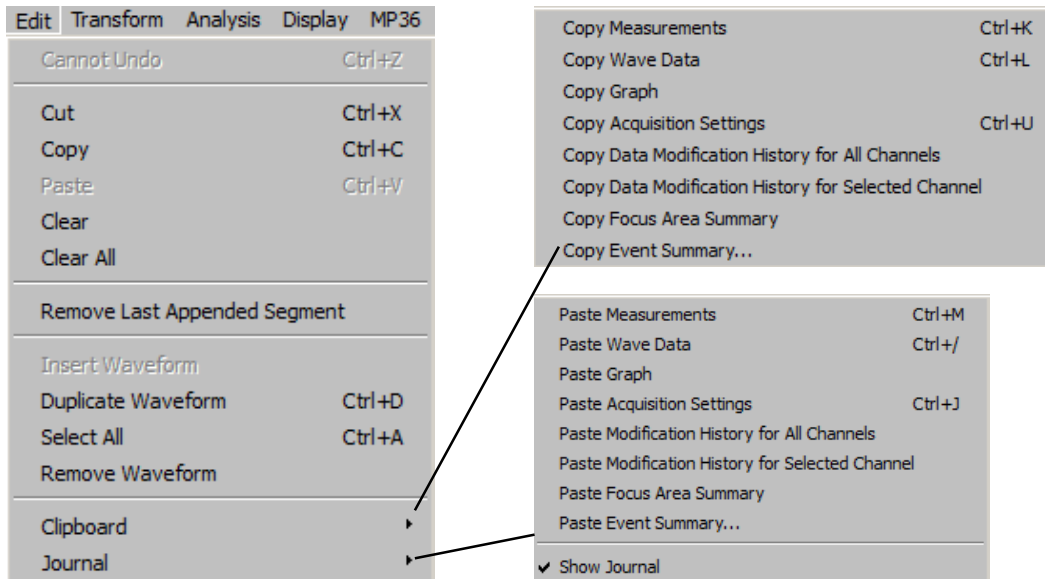
One of the most useful features in BSL *PRO* is the ability to edit and work with data by cutting sections and copying sections from one window to another. To select a section of data, use the editing tool to highlight an area. The selection tool is used for a variety of purposes including cutting and pasting waveform data, making measurements and determining which portion of a waveform to save as text values. To select the tool, click its icon in the lower right hand corner. Note that the cursor changes into the familiar õI-beamö tool moved within the graph area. Click the mouse and drag to select a portion of the waveform.

> **IMPORTANT**
> When multiple waveforms are present, the highlighted area appears to include all of the waveforms, but most modifications and transformations apply only to the selected channel.

Once a section of a waveform has been selected, many operations can be performed, such as editing, transformations, saving data to the journal, saving as text, and using the measurement functions. The cursor always selects at least one sample point; when there is no defined area, a single sample point will be selected, and the cursor will blink. Highlight a larger area by positioning the cursor over the first point of the area of interest by holding down the mouse button and dragging the cursor either left or right. This is similar to highlighting a series of letters or words in a document. Modify the selected area by placing the cursor anywhere on the graph, holding down the shift key and clicking the mouse. This feature is useful for fine-tuning the selected area. To fine tune, first coarsely select an area. By zooming in (with the zoom tool) on either edge, the shift key can be used to precisely align the edges of the selected area.

BSL *PRO* also allows selecting an area that spans multiple screens. To do this, first select an area that contains the leading edge of the area of interest in the graph. Next, use the horizontal scroll bar to scroll to the end of the area. Then place the mouse near the area of interest and click the button while holding down the shift key. While still depressing the mouse button, move the cursor to the exact position desired.

By using the selection tool to select areas of the waveform, the Cut, Copy, Paste and Clear functions are designed to work in much the same manner as a word processor. These functions operate only on areas selected by the selection tool.

TIP: For more precise selection of data, use the Selection Palette (Display > Show > Selection Palette). See page 323 for details.

Edit menu functionality during acquisition

The following Edit menu functions may move or alter memory and cannot be performed during acquisition: Undo, Cut, Clear, Clear All, Paste, Insert Waveform, Duplicate waveform, and Remove Waveform.

Undo / Can't undo

The Undo command allows data that was unintentionally deleted or modified to be restored. Undo applies to editing commands and transformations (such as digital filtering and mathematical operations).

There are some important exceptions to the Undo command.

First, neither Edit > Clear all nor Edit > Remove waveform can be undone. It is a good idea to make backup files before performing any editing, especially when using these commands.

Second, changes in the display options (i.e., changing the horizontal scale or changing the color of a waveform) cannot be undone, since they are easier to manipulate and less drastic than cutting data out of a waveform. When modifying the screen scale (or other display parameters) it's still possible to undo the latest data modification, which is much more difficult to recover than a screen parameter change.

> TIP: If a waveform has been accidentally removed or Clear All has been applied, one way to recover the data is to close the file without saving the changes. The data file can now be reopened, as it was when it was last saved; any changes made since it was last saved will be lost.

Perform multiple levels of undo on a per graph basis; Journal undo remains unchanged at one step. Complex data analysis in BSL *PRO* is rarely performed with a single transformation; multiple transformations are frequently cascaded together to produce a result. BSL *PRO* will "stack" the transformations and the user will be able to undo one step at a time until this stack is exhausted.

- Undo may move or alter memory and cannot be performed during acquisition.

- Undo operations may occupy large amounts of memory, particularly for transformations that affect entire waveforms or multiple events. Users without large amounts of RAM or working with large data sets may require the available computer memory for performing transformations. To accommodate these users, the maximum size of the undo stack can be limited using the *Levels of undo* Preference (Display > Preferences).
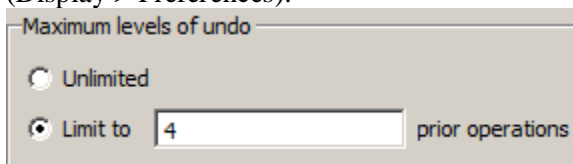
Cut

When Cut is selected from the Edit menu, the highlighted portion of the active window (Graph, Journal, entry prompt or dialog) is removed and copied to a clipboard, where it is available for pasting into other windows.

Cut may move or alter memory and cannot be performed during acquisition.

- When a selected area is removed from a waveform, the data will shift left to "fill in" the deleted area. So, if ten sample points are deleted, all data after the selected area will be shifted over ten sample points. Since this alters the relationship of events to the time base, it may be helpful to consider alternatives to cutting sections of data— such as using smoothing, digital filtering, or the connect endpoints functions to transform the section of data.

Area selected using the
editing tool →

Same data with selected
area Cut out →

*Note that the data
after the selected
area has shifted
forward in time.*
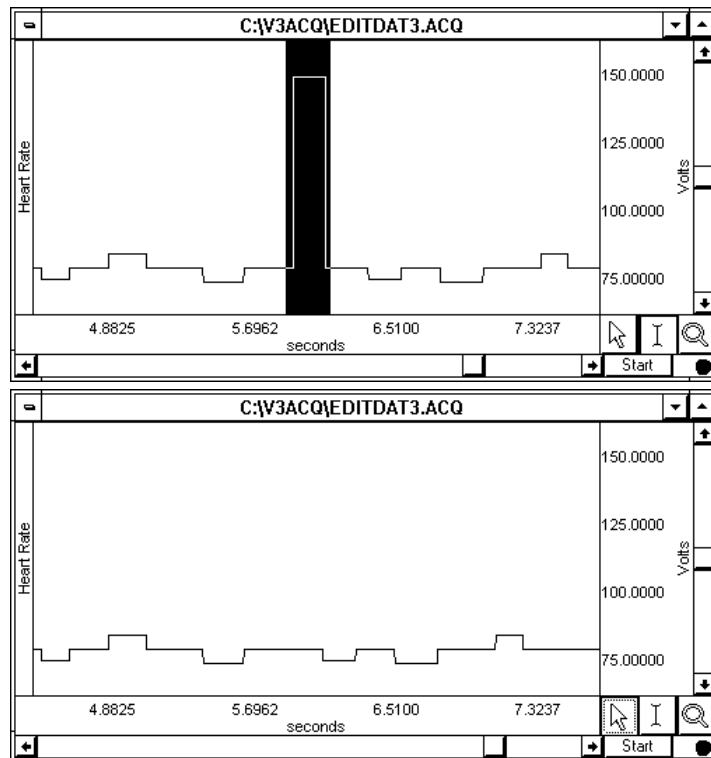
Copy

Choosing Edit > Copy will copy the selected area of the active window (Graph, Journal, entry prompt or dialog) to the clipboard without modifying the text/waveform on the screen.

- Once the area has been copied, it can be inserted in another window using the Edit > Paste command or, for waveforms, the Edit > Insert waveform command.
- To copy a waveform to another channel in the same graph window, choose the Edit > Duplicate waveform command.

Paste

The Edit > Paste command will take the contents of the clipboard and paste it into the currently selected area of the active window (Graph, Journal, entry prompt or dialog).

- If no area is selected, the data is pasted at the beginning of the waveform in a Graph window or the end of the text a Journal window

Note Copy/Paste operations require BSL *PRO* to allocate additional memory and then load the data into memory; when these operations are executed on large data files, the application may crash.

Clear

The Edit > Clear command works much the same way as the Cut command, with the key difference being that data is not copied to the clipboard. This function deletes the selected area from the selected channel only. If the entire waveform is selected (as with the Edit > Select all command), the clear command will delete all the waveform data and leave an empty channel.

Clear may move or alter memory and cannot be performed during acquisition.

- As with the cut command, the clear function operates on only one channel, and when a portion of the waveform is deleted, the remaining data will shift left. If multiple channels of data are present, one channel will be õshorterö than the others.
- To remove a selected area of data from multiple channels, use the Edit > Clear all command.

Clear all

Choosing Edit > Clear all will delete the selected area from *all* channels. This is similar to the clear function in that data is removed and is not copied to the clipboard. The Clear all command, however, removes a section of data from all waveforms, whereas the clear command applies only to the selected channel.

Clear All may move or alter memory and cannot be performed during acquisition.

- When Edit > Select all is chosen prior to performing the Clear all function, all waveform data for all channels will be deleted.
- The Edit > Undo command does not work for Clear all.

Select All

When Select all is chosen from the Edit menu, the entire selected channel becomes highlighted. For almost all commands, when a waveform is selected using Select all, subsequent operations apply to the selected channel only.

- The exception is when Edit > Clear all is chosen after Edit > Select all. When this occurs, all data from all waveforms will be deleted.

Insert waveform

The Edit > Insert waveform command is useful for copying a waveform (or a section of a waveform) from one window to another. To do this, select the area to be copied using the cursor and the õEdit > Copyö command. Next open the graph window the waveform is to be inserted into and choose õEdit > Insert waveform.ö

- Insert waveform cannot be performed during acquisition.
- This command cannot be undone directly, although selecting the inserted channel and choosing õEdit > Remove waveformö effectively undoes this operation.

Duplicate waveform

Choosing õEdit > Duplicateö waveform will create a new channel in a graph window and copy an entire waveform (or a selected area) to the new channel. When a portion of the waveform is selected, only the highlighted area will be duplicated.

- Duplicate waveform cannot be performed during acquisition.
- To duplicate the entire waveform, choose Edit > Select all and then select Duplicate from the Edit menu or click the right mouse button and select Duplicate from the pull-down menu.

Remove waveform

Deletes the entire selected waveform, regardless of what other options are selected. Remove waveform may move or alter memory and cannot be performed during acquisition.

- The Edit > Undo command does not work for Remove waveform.

Remove last appended segment

Removes the last appended segment. Equivalent to the Rewind toolbar icon.

- Edit > Undo does not work for Remove last appended segment.

Clipboard

Clipboard	▶	Copy Measurements	Ctrl+K
Journal	▶	Copy Wave Data	Ctrl+L
		Copy Graph	
		Copy Acquisition Settings	Ctrl+U
		Copy Data Modification History for All Channels	
		Copy Data Modification History for Selected Channel	
		Copy Focus Area Summary	
		Copy Event Summary...	
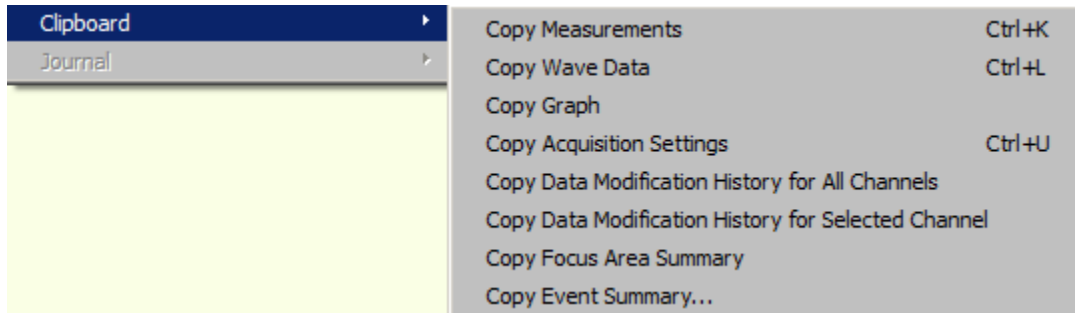
All of the clipboard commands involve copying data from BSL *PRO* to the standard Windows clipboard, where the contents of the clipboard are made available for other applications. Transferring data through the clipboard allows data to be copied from BSL *PRO* to other applications even after closing the graph window and/or quitting the application.

Data can be copied to the clipboard in two formats:

Text/Alphanumeric   Copy Measurement and Copy Wave Data save information to the clipboard in text/numeric format.

Graphic format   Copy Graph transfers the image in the window to the clipboard.

➢ Copy Measurements

Copies the contents of all visible measurement popup menus, along with the values associated with these windows. By default, three windows are displayed (on most monitors). This can be changed by increasing or decreasing the width of the window. Once the measurements have been copied, they can be pasted into any application that allows paste functions, including word processors, drawing packages, and page layout programs. A sample of measurements pasted from BSL *PRO* into a word processor follows:

BPM = 85.714 BPM   delta T = 0.700 sec   p-p = 0.8170 Volts

➢ Copy Wave Data

Copies the data (in numeric form) for all channels from the BSL *PRO* graph into the clipboard. When an area is selected, only the data in the highlighted area will be copied to the clipboard. As with the copy measurement command, once the data is stored in the clipboard, it can be pasted into virtually any application.

When multiple channels of data are copied to the clipboard, the data is stored in columns and rows, with data from each channel stored in a separate column. For a four-channel record, four columns of data will be copied to the clipboard. As with a text file, BSL *PRO* will insert a delimiter between each column of data. The default delimiter is a tab. The delimiter can be changed to either a space or tab in the in the File > Save as õOptionsö dialog. See page 224 for more detailed instructions on how to set the column delimiter. Transferring data through the clipboard performs essentially the same function as saving data as a text file (using the File > Save As command), with the obvious exception that transferring data through the clipboard does not save data to disk.

Note   Using Copy Wave Data on larger files may crash the application due to the excessive number of text lines generated (the problem is not the data size). For instance, one large file sample was 300,002 linesô a 3 MB text file.

➢ Copy graph

Copies the graph window as it appears on the screen to the clipboard, where it is stored in graphic format. The graphic can then be placed into a number of different formats, including word processors, drawing programs, and page layout programs. The JPEG graphic format are common to almost all applications, and images saved in these formats can be edited in most graphics packages and many word processors.

Using the copy graph function is similar to saving a graph window as a JPEG (using the File > Save As command), except that using the file save command writes a file to disk, whereas transferring data through the clipboard does not save a file.

➢ Copy Acquisition Settings

Creates a textual summary of the current acquisition settings and sends it to the clipboard, where it can be pasted into the journal via Edit > Journal > Paste Acquisition settings, or pasted to another program.

The summary includes sampling rates, channel configuration, calculation channel settings, triggering options, averaging options, and if any stimulator is active. This is useful for retaining records for acquisition parameters (and for technical support, if necessary). Use this feature to keep a textual record or printout of the configuration of the MP unit along with the data.

➢ Copy Data Modification Historyí

Copies the transformation history to the clipboard for all channels or the selected channel. Modification history includes the transformation name, channel (analog, calculation, or digital), date & time, and relevant transformation parameters, including starting and ending sample position.

Use Edit > Paste to move it from the clipboard to an active Journal window or other word processing application.
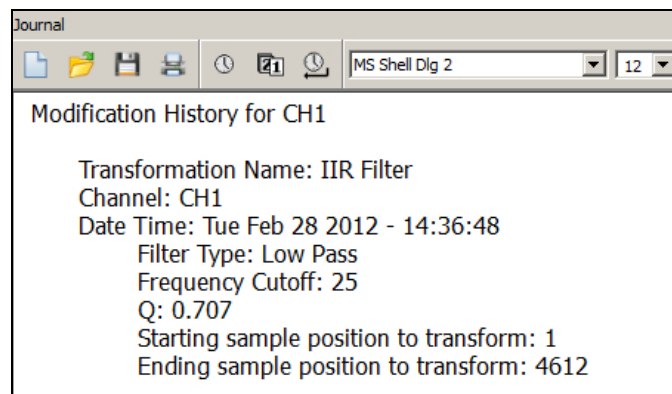
➢ Copy Focus Area Summary

Copies the starting and ending position of the focus area in horizontal axis units. Summary includes focus area label.

➢ Copy Event Summary

Copies a summary of graph events to the clipboard, including event type, position on horizontal axis, channel and label information. When this option is selected, a setup dialog containing searchable event criteria will appear. By default, all event types will be copied.
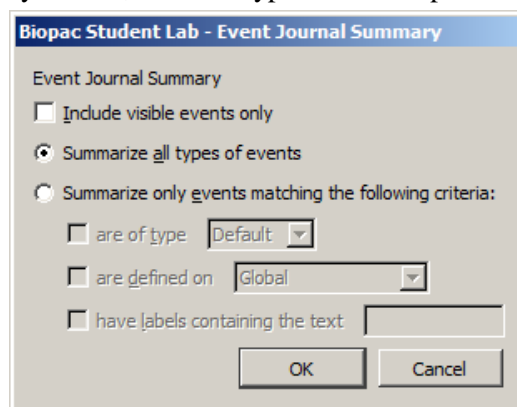
After copying, the events may be pasted to the Journal (via Journal > Paste), or pasted to an external text editor or spreadsheet.

Journal
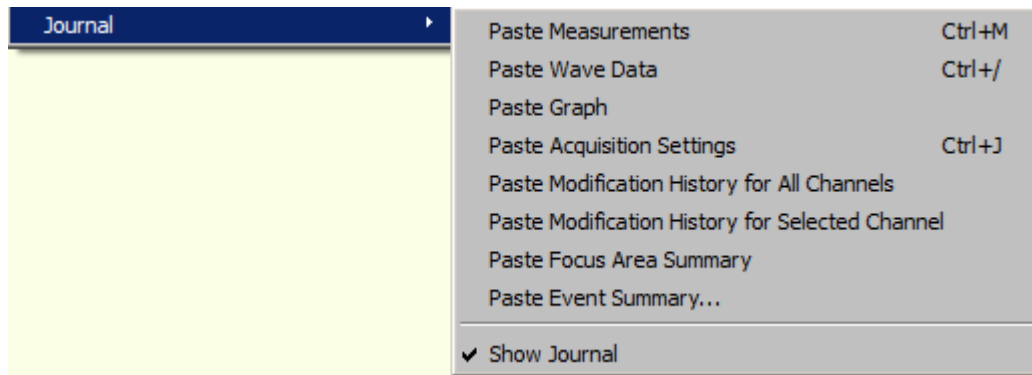
The Edit > Journal sub-menu options are similar to those found in the Edit > Clipboard menu. The key difference is that data (whether measurements or raw data) is pasted directly into the journal rather than copied to the clipboard.

➢ Paste Measurements

Choosing Paste Measurements from the Edit > Journal menu will cause all visible measurement windows to be pasted into the journal. Each time this is selected, the measurements and values are pasted into the journal using the precision specified in the Display > Preferences dialog. The number of measurements displayed is customizable. Use the Preferences menu (see page 329) to change the number of measurement rows or the measurement precision displayed on the screen.

Paste Measurement shortcuts:

Keyboard: Ctrl + M

Mouse: Right-click in the Journal and choose õPaste Measurementö

➢ Paste Wave Data

Converts the selected area of the waveform to numeric format and paste it into the journal in standard text file format. As with the copy wave data command (in the Edit > Clipboard submenu) this will paste the selected area from all channels, not just the selected channel, and will place a delimiter between the columns when two or more channels are being pasted to the journal. By default, tab characters are used to separate columns; this can be changed to comma or space delimiters in the File > Save As > Options dialog. See the Save As section on page 230 for more information on how to change the column delimiter.

Paste Acquisition Settings

Pastes the acquisition settings to the Journal as they were copied via Edit > Clipboard > Copy Acquisition settings.

➢ Paste Modification Historyí

Use after Copy Data Modification Historyí to paste the transformation history from the clipboard for all channels or for the selected channel to an active Journal window or other word processing application. Modification history includes the transformation name, channel (analog, calc, or digital), date & time, and relevant transformation parameters, including starting and ending sample position.
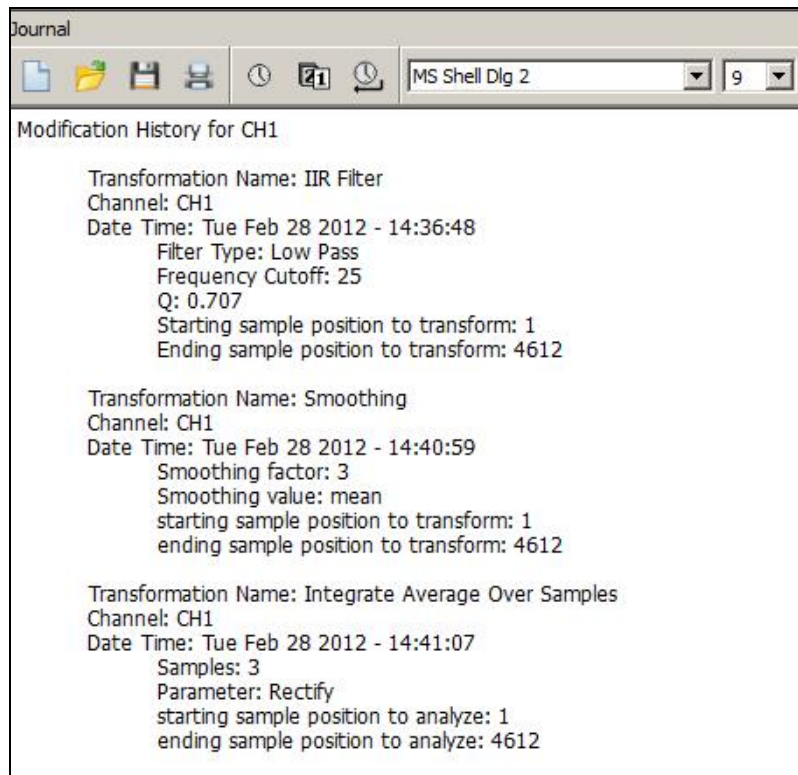
- ➢ Paste Focus Area Summary

  Use after Copy Focus Area Summary to paste the summary from the clipboard to the Journal.

- ➢ Paste Event Summary

  Use after Copy Event Summary to paste the selected event criteria from the clipboard to the Journal.

- ➢ Manage PDFs

  Use this option to select and import (embed) PDF files into the Journal as tabbed windows. Multiple PDFs may be imported and each PDF appears under its own tab heading. Choose Edit > Journal > Manage PDFs, or right-click in the Journal and choose Manage PDFs. The following dialog will appear:
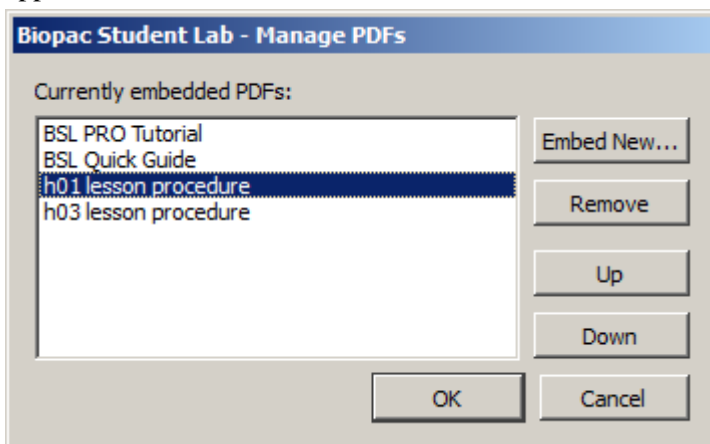
Control	Description
Embed New	Launches a %File > Open+dialog for navigating to the directory containing the PDFs to be embedded.
Remove	Removes a PDF from the list. (The actual PDF is not deleted.)
Up	Moves the selected PDF up the list and determines its tab order in the Journal.
Down	Moves the selected PDF down the list and determines its tab order in the Journal.
OK	Imports the embedded PDFs into the Journal

Multiple embedded PDFs may be toggled by clicking the tabs. Clicking the Journal tab will activate the Journal window. Saved Journal content is not affected by embedded PDFs.

- The Journal formatting tools are not available when a PDF is actively displayed.
- The Manage PDFs option is only available when the Journal is displayed (Show > Journal).
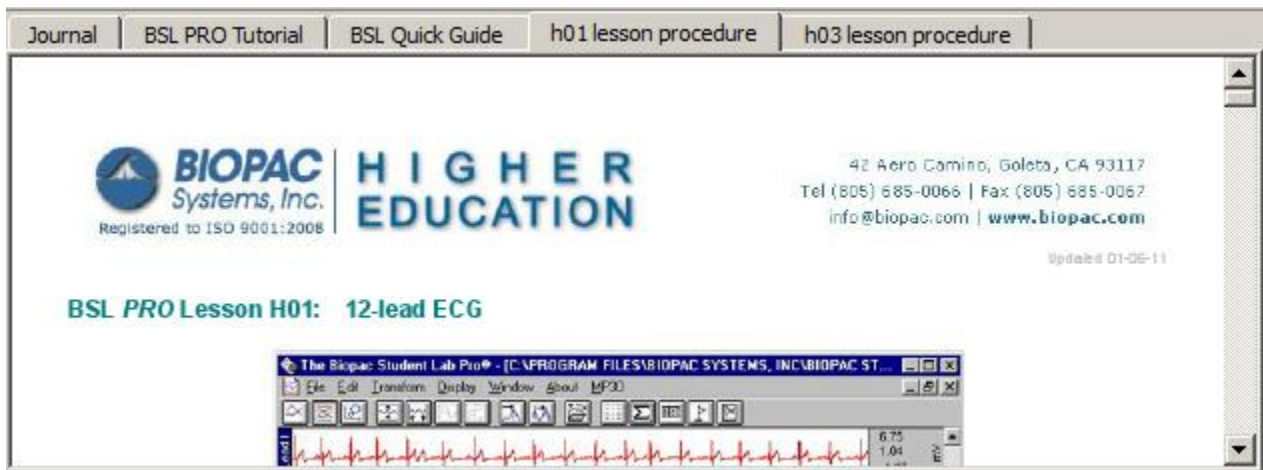
➢ Show Journal

Toggle to display/hide the Journal window.

Chapter 13   Transform Menu Commands

Overview
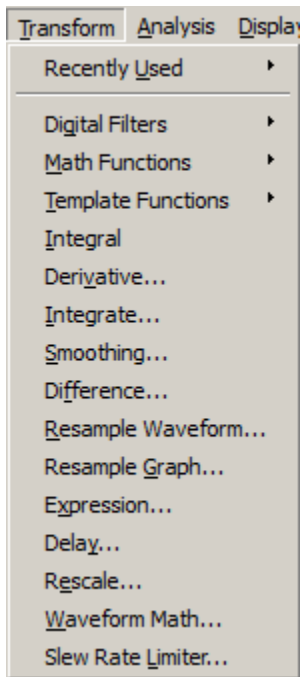
The Transform menu contains operations that primarily modify the data in the graph.

BSL *PRO* provides a number of options for post-acquisition analysis and transformations. These transformations perform a range of operations on data, from digital filtering and Fourier analysis to math functions. These options are found under the Transform menu (disabled while an acquisition is in progress.) Unless otherwise noted, all transformations described here apply to the selected channel only. Some options (such as the expression and math functions) allows a channel to be specified for applying the transformation.

It is important to remember that BSL *PRO* is always selecting at least one point, and the cursor will flash whenever only one point is selected. Some of the transformation functions (e.g., math function, waveform math) can operate on a single sample point, and will transform a single sample point when only one is selected.

There are two ways to apply a transformation to an entire waveform.

a) For transformations that generate a dialog, check the õtransform entire waveformö box (usually located toward the bottom of each dialog). This will transform the entire waveform, regardless of whether a single point, area, or the entire waveform is selected.

b) For transformations that do not generate a dialog, use the Edit > Select all command prior to selecting the transformation. This will transform the entire waveform for all of the transformation functions.

- Edit > Select All is not necessary when only a single point is selected prior to selecting the transformation because BSL *PRO* will automatically apply the transformation to the entire waveform since it is not possible to perform these transformations on a single point.
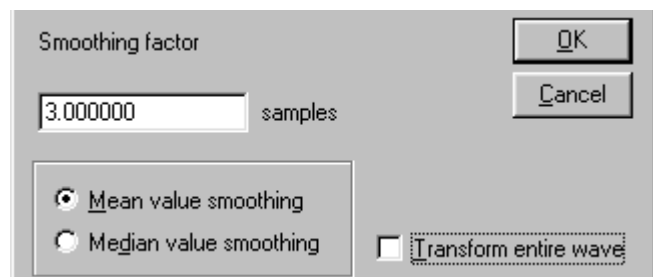
Note   Transformations require BSL *PRO* to allocate additional memory and then load the data into memory; when transformations are executed on large data files, the application may crash.

Recently Used Transformations

The Transform > Recently Used submenu allows quick access to a user's most recently used transformations and analysis commands. The Recently Used submenu also appears at the top of the Transform submenu available from the context menus of waveforms.

The submenu lists a default of five of the most recently used transformations, with the most recently executed at the top of the menu. To adjust the number of recent transformations displayed, select Display > Preferences.

Transformation--Recently Used Menu

List 10   most recent transformations
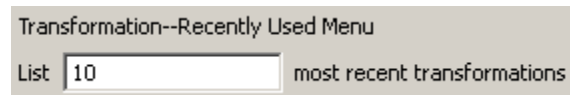
The recently used transformation listing is saved and restored across subsequent launches of BSL *PRO*. It also is application wide: Executing a transformation in any graph will add that transformation onto the recently used list. The recently used list is independent for each user account.

Open Recent	▶	Gail-L02	Ctrl+1
Open for Playback...		Batch 3 - Heart Sounds 1.acq	Ctrl+2
Close	Ctrl+W	Batch 2 - EMG 1.acq	Ctrl+3
		Batch 1 - ECG Lead II 1.acq	Ctrl+4
Save	Ctrl+S	Batch 2 - EMG.acq	Ctrl+5
Save As...		Batch 3 - Heart Sounds.acq	Ctrl+6
Save Selection As...		Batch 1 - ECG Lead II.acq	Ctrl+7
Save Journal Text As...		Heart Sounds.gtl	Ctrl+8
Send E-Mail Attachment		EMG.gtl	Ctrl+9
		ECG Lead II.gtl	
Page Setup...			
Print...	Ctrl+P	Clear Menu	
Quit	Ctrl+Q		

The recently used transformations can also be launched by the keystroke combinations appearing in the menu.

Digital Filters

Digital Filters	▶	FIR	▶
Fourier Linear Combiners	▶	IIR	▶
Math Functions	▶		
Template Functions	▶	Adaptive...	
Integral		Comb Band Stop...	
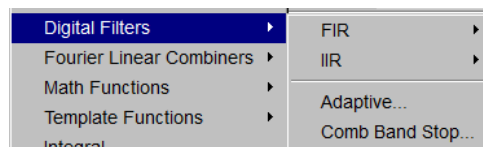
FIR filters are linear phase filters, which mean that there is no phase distortion between the original signal and filtered waveforms.

IIR filters are not phase linear filters, but are much more efficient than FIR filters in processing data. The IIR filters are useful for approximating the results of standard biquadric filters of the form:

$$(as^2 + bs + c) / (xs^2 + ys + z)$$

These types of filters are commonly implemented in electronic analog circuitry. IIR filters are also used for online filtering (discussed on page 133).

➢ See Appendix B for more information about the differences between these types of filters.

Adaptive filtering is a signal processing technique that processes two different signals in relation to one another; see page 257 for details.

To understand how digital filters work, it is important to understand the nature of analog signals and their frequency components. All analog signals are comprised of signals of various frequencies. A commonly used analogy is that of the color spectra. Just as white light is made up of a variety of colors that have different wavelengths (frequencies), physiological signals are comprised of specific signals with unique frequency signatures.

For example, an electroencephalogram (EEG) recording is comprised of several different types of signals, each of which has a different frequency signature. Alpha waves (one of the most studied EEG signals) have a frequency range of about 8 Hz to 13 Hz. This means that alpha waves go through a complete cycle (from peak to peak or trough to trough) anywhere from eight to 13 times a second.

There are, of course, signals that have other frequency signatures in EEG data. Most types of physiological data have a number of different frequency signatures present in the overall signal. In addition, frequency components besides the signal(s) of interest are often present. In the U.S., it is not uncommon for 60 Hz electrical noise to be acquired along with physiological signals (in other countries, AC interference is present at either 60 Hz or 50 Hz).

Use digital filtering to retain only the frequency components of interest and remove other data (whether it is õnoiseö or merely physiological signals outside the range of interest).

It is important to note that the way in which data is filtered depends in large part on the sampling rate at which the original data was acquired. For instance, if data was collected at 50 samples per second (50 Hz), it is not possible to filter out 60 Hz signals.

In fact, data must be sampled at a rate equal to at least twice the frequency of the signal to be removed. So, if data is to be collected and the information between 80 Hz and 120 Hz is to be removed, the data must be sampled at 120 Hz*2, or 240 samples per second (or faster). Also, each channel of data is filtered separately, so removing one type of data from one channel will not affect any other channels.

Digital filters can be divided into four general classes:

>   low pass   band pass   high pass   band stop

Descriptions of these four classes of filters follow, with visual examples of how these filters work. In each of the four examples, a single channel of data containing frequency components in three ranges (low frequency, mid-range, and high frequency) is acquired.

- Low frequency data, by definition, has slowly changing values, much like respiration patterns or core temperature variations.

- High frequency data, compared to low frequency data, is noticeably more õspiked,ö much like an EMG signal. Observe that the high frequency wave repeats itself about five times in the time it takes the low frequency wave to repeat once.

- Mid-range data falls somewhere in between these two extremes.

In the examples that follow, one possible way that these data could have been collected is if respiration were measured, but the measurement was contaminated with high-frequency muscle movement and mid-frequency signal coming from AC interference. The data is then passed through a filter, where some of the frequency components are removed.

Low pass filtering

In the example below, a low pass filter attenuates the data above a given threshold, allowing only lower frequency data to õpassö through the filter.

High Pass Filtering

In the example below, a high pass filter removes the low and middle range data, but allows the high frequency data to pass through the filter.
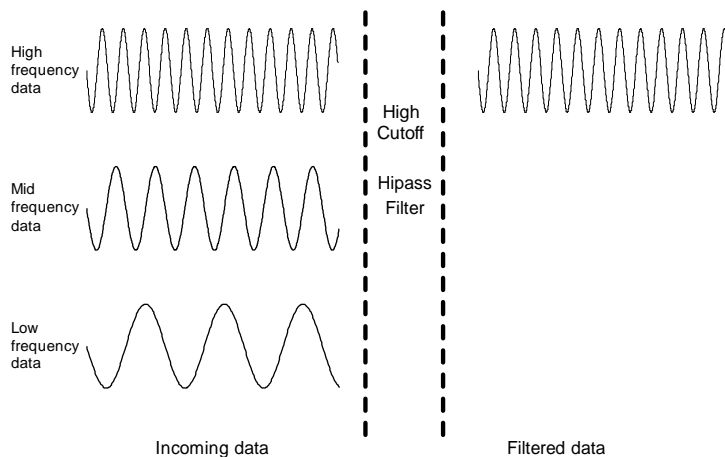
Whereas the low pass and high pass filters retain data either above or below a given threshold, the next two types of filters work with a range, or band, of data.

Band pass filter

The band pass filter, allows only the data within the specified range to pass through the filter. A band pass filter is useful for retaining only specific waves from an EEG record. For example, to retain alpha waves, the filer can be set the filter to only pass data between 8 Hz and 13 Hz.
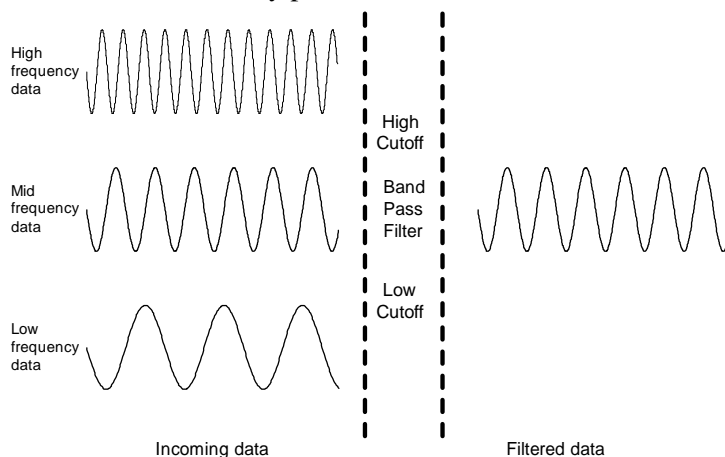
Band stop filter

The band stop filter allows data to pass above and below the specified range. This type of filter is typically applied to remove extraneous 60 Hz or 50 Hz noise from a data record.

FIR Filters

Digital Filters ▶ | FIR ▶
Fourier Linear Combiners ▶ | IIR ▶
Math Functions ▶ | Adaptive...
Template Functions ▶ | Comb Band Stop...
Integral
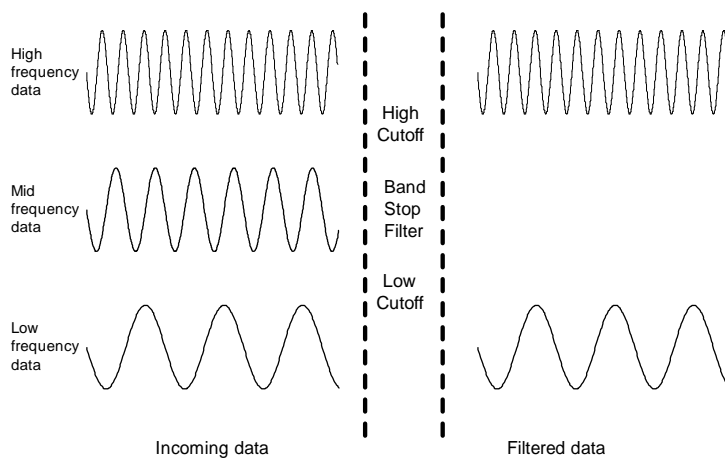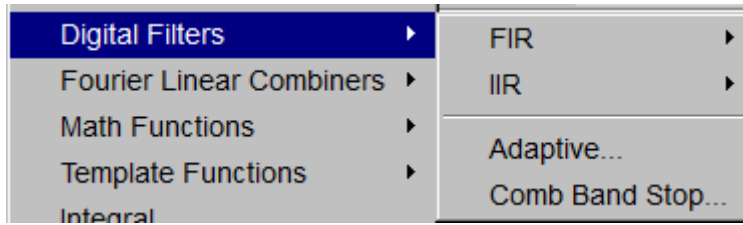
Digital filter dialog

When selecting an FIR filter type, the corresponding Digital Filter dialog will be displayed, allowing access to a range of filtering options.

1. Window. The Window popup menu contains a variety of filtering algorithms. The filter default is set to a õBlackmanö type. These different Windows (described in detail in Appendix D) allow fine tuning of the filter response.

2. Cutoff Frequency (Hz) (or threshold). Enter a fixed value or set to a fraction of the sampling rate or to line frequency.

    Sampling rateô frequency is set to a fraction of the sampling rate and automatically updates when the sample rate is modified.

    Line frequencyô frequency is set to the line frequency at which the data was recorded.

    Fixed at ô Fixed value guidelines are as follows:

    *   *Low Pass Filter*ô data with frequency components below the cutoff will pass through the filter, whereas frequency components above the threshold will be removed. For low pass filters, the default cutoff frequency is the waveform sampling rate divided by eight and can be set to any value between 0.000001Hz and 0.5 times the sampling rate.

    *   *High Pass Filter*—data with frequency components above the cutoff will pass through the filter, whereas frequency components below the threshold will be removed. For high pass filters, the default threshold is the waveform sampling rate divided by four and can be set to any value between 0.000001Hz and 0.5 times the sampling rate.

    *   *Band-type Filters*ô a low threshold and a high threshold must be specified to define the band of data (the frequency range) that is either passed or stopped, depending on whether it is a Band Pass or Band Stop filter. In either case, the default for the low threshold is the waveform sampling rate divided by eight and the default for the high threshold is the waveform sampling rate divided by four. The threshold settings can take on any value from 0.000001Hz and 0.5 times the sampling rate, but the two thresholds cannot be set to the same value and the high threshold must be greater than the low threshold.

3. Number of Coefficients. Enter a fixed value or enable the optimize option.

    *   Fixed atô This determines how well the filter will match the desired cutoff frequency (or range). The minimum number of coefficients is 3 and the maximum must be less than the total number of sample points in the selected area. The software will truncate the maximum number of coefficients to the highest odd number less than the total.

    *   Optimize for sample rate and cutoffô the number of coefficients is set as four times the sampling rate divided by the cutoff frequency of the filter. Optimize does not necessarily produce the best quality filter, but it takes less time.

    The recommended number of coefficients is

    4 x (waveform sampling rate/lowest frequency cutoff for the filter)
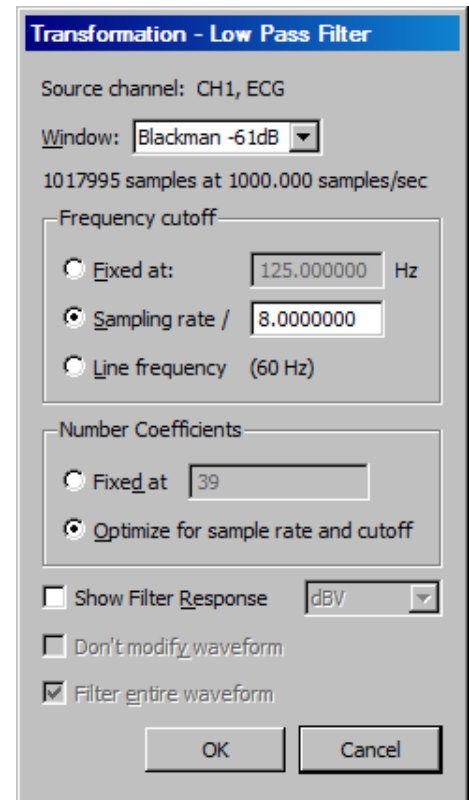
For every filter except the band pass, the lowest frequency cutoff is equal to the specified cutoff frequency for the filter; for the band pass filter, the lowest frequency cutoff is the low frequency cutoff setting. Filters that use a small number of coefficients tend to be less accurate than filters that use a large number of coefficients. Larger coefficients increase filter accuracy, but also increase the processing time required to filter the data.

To see how changing the number of coefficients affects the way data is filtered, it can be useful to examine the filter response patterns. In the example below, data was collected at 500 Hz and the band stop filter was designed to remove 60 Hz noise using a low cutoff of 55Hz and a high cutoff of 65Hz. The same data was band stop filtered using 39 coefficients (upper waveform) and then 250 coefficients (lower waveform).
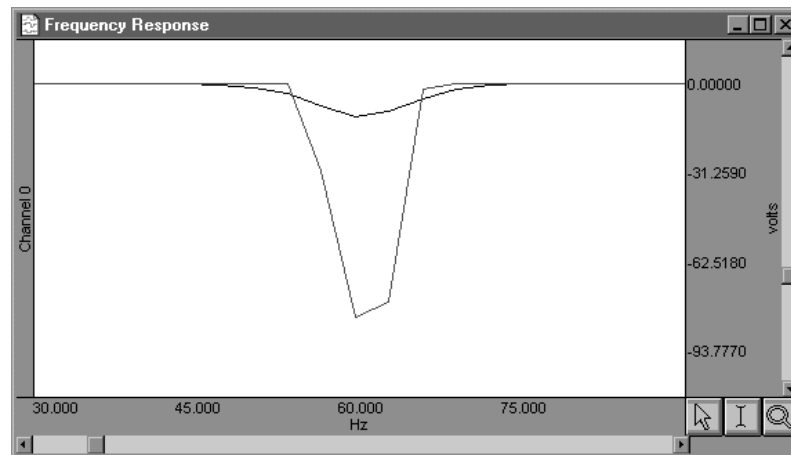
Along the horizontal axis, the units are scaled in terms of frequency, with lower frequencies at the left of the screen. The values along the vertical axis are scaled in terms of dB/V and indicate the extent to which various frequencies have been attenuated.

In both filter response waveforms, there is a downward-pointing spike that is centered on 60 Hz. The baseline of the filter response corresponds to a value of approximately 0 on the vertical axis, indicating that the signals significantly above or below 60 Hz were not attenuated to any measurable extent. Observe that the filter does not õchopö the data at either 55 Hz or 65 Hz, but gradually attenuates the data as it approaches 60 Hz.

For example, the upper waveform in the filter response plot represents data that was filtered using a value of 39 coefficients. The slope is relatively shallow when compared to the lower waveform, which represents a filter response performed with 250 coefficients. Although the filter that used 250 coefficients took slightly longer to transform the data, the filter response pattern indicates that the data around 60 Hz is attenuated to a greater degree. Also, the 250-coefficient filter started to attenuate data considerably closer to the 55 Hz and 65 Hz cutoffs, whereas the default filter began to attenuate data below 55 Hz and above 65 Hz.

> TIP: A good rule of thumb is to use a number of coefficients greater than or equal to two times the sampling rate divided by the lowest cutoff frequency specified. For example, if running a low pass filter at 1 Hz on data sampled at 100 Hz, choose at least (2 x 100/1) or 200 coefficients in the filter. Additional coefficients will improve the response.

4. Show Filter Response. When checked, this option generates a plot of the filter response in a new window, labeled õFrequency Responseö (see example above).

    ▪ Units: Select linear units or dBV.

5. Donøt modify waveform. This option is useful in conjunction with the õShow Filter Responseö option. When both boxes are checked, BSL *PRO* will produce a plot showing the filter response, but will not modify the waveform. This allows different filter options to be applied (without modifying the waveform) until the desired frequency response is achieved.
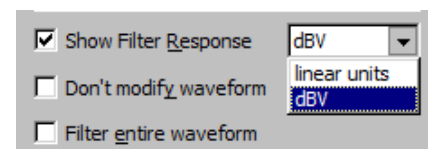
6. Filter entire wave. If this option is checked, BSL *PRO* will filter the entire wave and replace the original. To keep the original, duplicate it prior to filtering.

IIR Filters

To access the IIR filter dialog, click the Transform menu, scroll to select Digital Filters, drag right to IIR and drag right again for the filter options. For all filter types, the software will limit the frequency setting so it cannot exceed one-half the channel sampling rate. For real-time filter options, see page 133.

IIR ▶	Low Pass...
Adaptive...	High Pass...
Comb Band Stop...	Band Pass Low+High...
	Band Pass...
	Band Stop...

Low Pass IIR filter

17812 samples at 500.000 samples/sec

Cutoff Frequency: ○ Fixed at [   ] Hz
● Sampling rate / [8.0000000]
○ Line frequency (60 Hz)
Q [0.707000]

☑ Filter entire wave   (Cancel) (Ok)
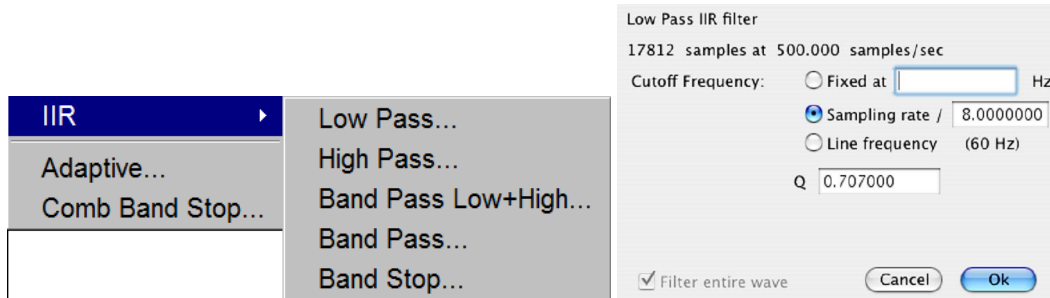
Low Pass and High pass	Pass data that falls below or above the specified standard. The Low Pass default is waveform sample rate/8; the High pass default is waveform sample rate/4.
Band Pass (low + high)	Pass a variable range of data. Specify a low frequency cutoff and a high frequency cutoff to define the range or õbandö of data that will pass through the filter; frequencies outside this range are attenuated. For the Band Pass Low + High filter, the low default is waveform sample rate/8 and the high default is waveform sample rate/4.
	▪ This filter is best suited for applications where a fairly broad range of data is to be passed through the filter. For example, apply to EEG data to retain only alpha wave activity.
Band Pass (single freq)	Requires only a single frequency setting, which specifies the center frequency of the band to be passed through the filter. The õwidthö of the band is determined by the Q setting of the filter (discussed in detail below). Larger Q values result in narrower bandwidths, whereas smaller Q values are associated with a wider band of data that will be passed through the filter. This filter has a bandwidth equal to Fo/Q, so the bandwidth of this filter centered on 50 Hz (with the default Q=5) would be 10 Hz. Although functionally equivalent to the Band Pass (low + high) filter, this filter is most effective when passing a single frequency or narrow band of data, and to attenuate data around this center frequency. The Band Pass (single frequency) default is waveform sample rate/8.
Band Stop (single freq)	Defines a range (or band) of data and attenuates data within that band (the opposite function of a band pass). This filter is implemented in much the same way as the standard Band Pass, whereby a center frequency is defined and the Q value determines the width of the band of frequencies that will be attenuated. The Band Stop (single frequency) default is waveform sample rate/8.
Q coefficient	The online filters are implemented as IIR (Infinite Impulse Response) filters, which have a variable Q coefficient. The Q value entered in the filter setup box determines, in part, the frequency response of the filter. This value ranges from zero to infinity, and the õoptimalö (critically damped) value is 0.707 for the Low Pass, High pass and Band Pass filters. A Q of .707 for any of these filters will result in a second order Butterworth response. The Q is set to a default of 5.000 for the single frequency Band Pass and Band stop filters. For more details about the Q setting, see the Appendix.
Sampling rate	Sets the Frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.
Line frequency	Sets the Frequency to the line frequency at which the data was recorded.

Adaptive Filtering

Adaptive filtering is a signal processing technique that processes two different signals in relation to one another and can be used for noise estimation, noise reduction, general-purpose filtering, and signal separation. Adaptive filtering creates efficient high-quality filters with a minimal number of terms, which can be very useful in blocking mains interferences or other known periodic disturbances.

- Useful for noise filtering where it is possible to acquire a signal that is correlated to the noise (similar to the way noise-cancelling headphones detect and remove outside noise). Applications include removing EMG from ECG or EOG from EEG.

⮑ See the Adaptive Filtering Calculation Channel on page 147.

The weights within an adaptive filter are modified on a step-by-step basis. BSL *PRO* uses the N-tap FIR adaptive filter, with coefficients updated using least means squares (gradient) feedback.

Source signal

  The source channel will be replaced by the adaptive filter results.

Noise signal

  The noise channel is the signal that is correlated with the noise to be eliminated from the Source; it is not modified by adaptive filtering.

  Source and Noise channels must have the same sampling rate.

Order

  Specify a positive integer for the number of terms to be used in the internal FIR filter.

Step size

  Provides *mu*, the rate of adaptation of the coefficients within the FIR filter.

Comb Band Stop Filter

Comb Band Stop filters out a fundamental frequency and its overharmonics (integer multiples of the base). Resonance, aliasing, and other effects may generate interference at multiples of a base frequency. The Comb Band Stop filter combines all the required filters instead of requiring a separate filter for each interfering overharmonic.
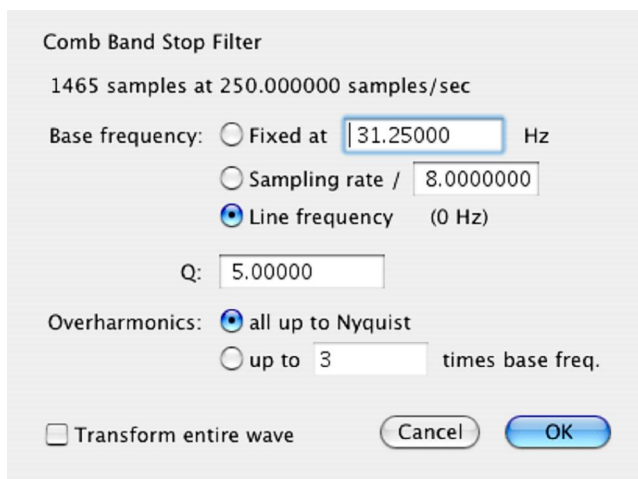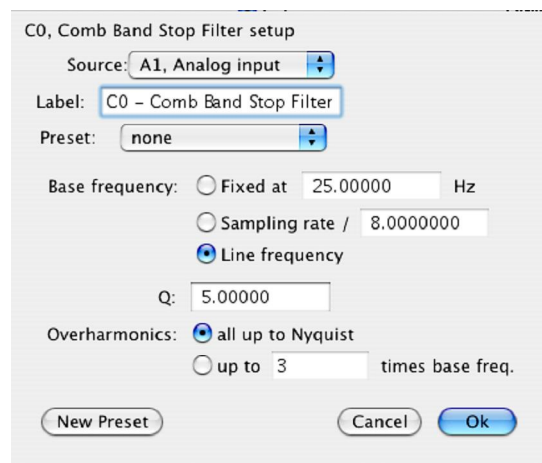
Transformation Dialog	Calculation Channel Dialog

Resonance, aliasing, and other effects may generate interference at multiples of a base frequency. The Comb Band Stop filter combines all the required filters instead of requiring a separate filter for each interfering overharmonic. Comb Band Stop filters remove a fundamental frequency and its overharmonics (e.g., integer multiples of the base frequency) from a signal, and are useful for removing noise. BSL *PRO* approximates a Comb Band Stop filter by cascading a series of IIR Band Stop filters, and is limited to removing frequencies and overharmonics. The number of filters used can be fixed at a particular number (e.g., limiting the number of harmonics to filter out) or configured to automatically remove all possible harmonics for any given sampling rate.

- Mac OS ô Use the "Comb Band Stop Filter" Automator action to integrate Comb Band Stop filters into Workflows.

For a given base frequency ω and quality factor Q, the comb filter approximation will be given by the set of following formulas:

$$y = \left(F_\omega \circ F_{2\omega} \circ F_{3\omega} \cdots \circ F_{k\omega} \right)(x)$$

where F_ω represents a standard two-tap IIR band stop filter for the frequency ω with coefficients computed using the quality factor Q.

The number of overharmonics of the base frequency to be removed is given by the integer value k. The maximum allowable number of overharmonics may be automatically determined given the sampling frequency f_s:

$$k_{max} = \left\lfloor \frac{f_s}{2\omega} \right\rfloor$$

This limits the maximum overharmonic frequency to be less than the Nyquist of the sampling frequency.

After the first comb filter is performed, the most recently used settings for the comb filter will be displayed, (except for õTransform entire wave,ö which will be reset each time the dialog is opened).

Textual export will include the source channel, base frequency, quality factor, and number of harmonics.

Comb Band Stop Filter Dialog

number of samples	Width of the selection.
@ samples/sec	Waveform sampling rate of the source channel.
	• The channel sampling rate of the calculation channel can not exceed the channel sampling rate of the source channel. Downsampling will be applied to the source channel prior to comb filter processing, if required, and all Nyquist frequency restrictions will be determined from the calculation channel sampling rate.
Frequency	Fixedô The comb filter will remove this base frequency and integer multiples of this frequency.
	• Must be positive and less than the Nyquist frequency (half the sampling rate).
	Sampling rateô Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.
	Line frequencyô Uses the line frequency at which the data was recorded.
Q	Quality factor used when computing the coefficients of the IIR notch filters.
	• Must be positive.
all up to Nyquist	Removes all integer multiples of the base frequency. This will include all multiples of the base frequency that are less than the Nyquist frequency.
Harmonics	Removes the base frequency and integer multiples of the base frequency up to and including the multiple contained in the edit field
	• Must be an integer greater than 0 and must not exceed k max
	• The final multiple must be less than the Nyquist frequency. If it is not, the input will need to be corrected before the comb filter can be applied.
OK	If the settings are valid, executes the comb filter transformation. Verification of certain calculation channel parameters does not occur until the start of acquisition as sampling rates may be changed after calculation channels are configured.
	Prior to the start of acquisition, the following will be checked:
	• source channel to ensure it is still being acquired.
	• base frequency of the comb filter to ensure it is less than the Nyquist frequency of the channel sampling rate.
	• if the user has manually specified that a fixed number of overharmonics should be used, the number of overharmonics to ensure the highest used overharmonic does not exceed the Nyquist frequency of the channel sampling rate.
	If any of the parameters are invalid, a prompt will be displayed indicating which settings are incorrect and must be fixed for the acquisition to be started.
Cancel	Quits without modifying any data.
Source	All enabled analog, digital, and lower-index calculation channels.
Label	When the calculation type of a channel is changed to comb filter, the title of the channel will be replaced with the default label õC*n* óFilterö where *n* is the index of the calculation channel.
	• Must be 40 characters or less.
Preset	Displays the title of any Calculation Preset currently applied to the calculation channel.

Math Functions

BSL *PRO* supports a wide range of mathematical and computational post-acquisition transformations. Unless otherwise noted, each of these functions applies only to the selected area of the selected channel. If no area is selected (i.e., a single data point is selected), the cursor will blink and BSL *PRO* will transform the entire wave. If a math function attempts to divide by zero, a zero will be returned.

For complex transformations involving multiple functions, it may be more helpful to use the Expression/ Equation Generator (see page 272 for details).

The following table describes the commands available in the Transform > Math functions menu:

Transform > Math	Explanation of Command
Abs (Absolute Value)	Computes the absolute value of the data. All negative data values are made positive, with no change in magnitude. This function can be used to rectify data.
Atan (Arc Tangent)	Returns the arc tangent of each data point in radians. This rescales the data such that the range is from $-\pi/2$ to $\pi/2$.
Connect endpoints (Connect the endpoints)	Draws a line from the first selected sample point to the last selected sample point and interpolates the values on this line to replace the original data. The *connect endpoints* function is useful for removing artifacts in the data or in generating waveforms. In the example below, the "noise spike" in the data is an undesired measurement artifact that should be removed. The Cut operation will remove data, but the subsequent data will be shifted to the left. Connect endpoint preserves the time series of data on the horizontal axis by connecting the edges of the selected area.. *Area selected before (top) and after (bottom) connect endpoints function*
Exp (Exponential)	Computes the function e^x, where x is the waveform data and e is 2.718281828. This is the base of the natural logarithms.

Transform > Math	Explanation of Command
Limit (Limit data values)	%Clips+data outside the range specified by the set of boundaries in the limit dialog. This operation prompts the user for an upper and lower limit. Any data values outside these limits will be clipped. To limit only one boundary (high or low), set one edge to the desire level and the second boundary beyond the Max/Min value of the data within the selected area. For example to set all negative values to zero and leave the positive values unchanged: set the lower limit to zero and the upper limit to a value greater than max for the selected area.
Ln (Natural Logarithm)	Computes the natural logarithm of the selected section. The inverse of this function is the exponential function, *Exp*.
Log (Base 10 Logarithm)	Computes the base 10 logarithm of the selected section. In order to perform the inverse of this function, which would be 10^X, use the Waveform Math power operator with the constant k=10 as the first operand and the waveform data as the second operand.
Noise	Converts the selected section into random data values between . 1.0 and +1.0. This is mainly useful for creating stimulus signals and other waveforms.
Sin (Sine)	Calculates the sine of the selected section. The data is assumed to be in radians.
Sqrt (Square Root)	Takes the square root ($\sqrt{}$) of each data point in the selected section.
Threshold (Threshold data values).	Transforms all data points above the threshold to +1 units, and converts all values below the lower threshold to 0 units. Once the data crosses a threshold it will continue to be set to +1 for the upper cutoff and 0 for the lower cutoff, until it crosses the opposite threshold. The most common application of this function is to serve as a simple peak detector, the results of which can be used in rate or phase calculations. Threshold Algorithm Assume a domain variable $t \in \{t_{start}, t_{start}+1, t_{start}+2, \text{К }\}$ with t_{start} being an integer, a real-valued signal y(t) defined for all t, and two real valued levels y_{low} and y_{max} satisfying the relation $y_{low} \le y_{high}$. Define the threshold function thresh(t) function such that: $$thresh(t_{start}) = \begin{cases} 1 & y(t_{start}) \ge y_{low} \\ 0 & y(t_{start}) < y_{low} \end{cases}$$ $$thresh(t) = \begin{cases} 0 & y(t) < y_{low} \\ 1 & y(t) > y_{high} \\ thresh(t-1) & y_{low} \le y(t) \le y_{high} \end{cases}$$

Template Functions

Set Template
Remove Mean
Correlation
Convolution
Mean Square Error
Inverse Mean Square Error

The Template Functions are useful for comparing waveforms. Technically, the template functions provide correlation, convolution and mean square error transformations of a template waveform against another waveform. To activate the full template menu, select an area and then select set template.

Set Template

Use the following ECG waveform as an example and contains an abnormality. After detecting an abnormality, this operation can detect whether there are other (similar) abnormalities in the recording. To do that, it's necessary to select the pattern to search for, and then compare that pattern to other data sets in the file.

Selecting a section of a wave to be used as a template:

1) Highlight the section to be used as a pattern.
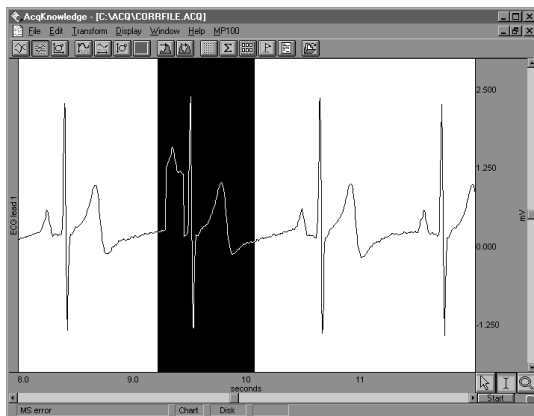
2) Click the Transform menu and choose Set template from the Template functions submenu. This copies the selected portion into a buffer for subsequent template functions

3) Select the waveform and position the cursor at the beginning of the data.

4) Choose Correlation from the Template functions submenu. The center waveform in the graph below shows the result of the correlation.

Note the higher amplitude peaks where the template data more closely matches the waveform. The lower waveform illustrates the mean square error function, which is similar to the correlation function.

This indicates that there are two abnormal beats in the record. The first one appears at about 3 seconds and is the one used as a template; the second one appears at about 11 seconds.
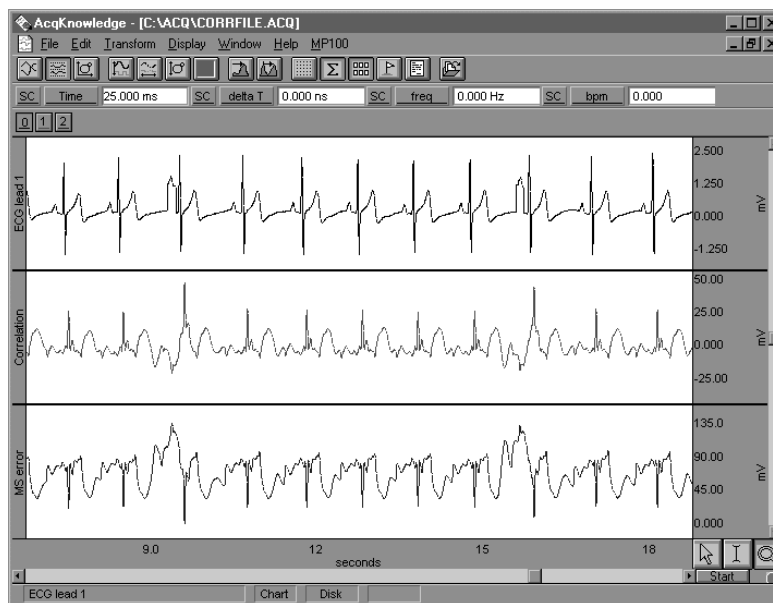
Result of correlation and mean square error functions

5) Use the zoom tool to inspect the abnormalities more closely.

Remove mean

A drifting baseline can be problematic when comparing waveforms. The effectiveness of a comparison of a template or waveform with a slowly drifting baseline will be increased by applying the Remove mean template function. The remove mean option causes the mean amplitude value of the template and the compared section of the waveform to be subtracted from each other before the sections are compared. This way, a large baseline offset will have very little effect on the comparison. This option is toggled every time it is selected and is enabled when a check mark is present.

For example, the following graph shows the original waveform at the top, the correlated waveform with mean removal in the middle, and the same correlation without mean removal at the bottom. Note how the mean removal effectively compensates for the drifting baseline in the original waveform.
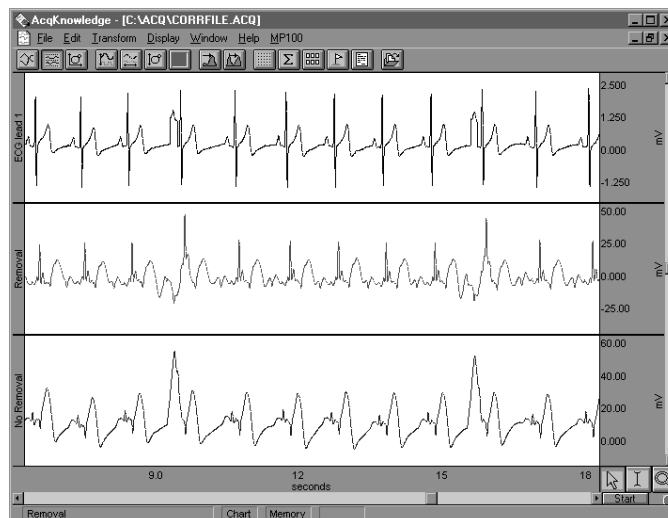
Correlation with and without mean removal

Template algorithms

The template functions are: correlation, convolution, mean square error and inverse mean square error.

a) Correlation is a simple multiplication and sum operation. The template is first positioned at the cursor position in the waveform to be correlated. Each point in the template waveform is multiplied by the corresponding point in the data waveform (the waveform to be correlated) and summed to produce the resulting data point. The template is then moved one data sample forward and the operation is repeated to produce the next resulting data point. The resulting data points replace the waveform to be correlated.

The correlation function algorithm can be expressed by the following formula, where $f_{output}(n)$ is the resulting data point, $f_{template}(k)$ is the template waveform data points, and K is the number of data points in the template:

$$f_{output}(n) = \sum_{k=1}^{K} f_{template}(k) * f_{waveform}(n)$$

b) Convolution is identical to the correlation function except that the template waveform is reversed during the operation. This function is not generally useful by itself, but can be used as a building block for more sophisticated transformations. The convolution function algorithm can be expressed by the following formula, where $f_{output}(n)$ is the resulting data point, $f_{template}(k)$ is the template waveform data points, and N is the number of data points in the template:

$$f_{output}(n) = \sum_{k=-N/2}^{N/2-1} f_{template}(-k) * f_{waveform}(n+k)$$

c) Mean square error positions the template at the cursor position in the waveform to be compared. Each point in the template waveform is subtracted from the corresponding point in the waveform to be compared. The result is squared and summed to produce the resulting data point. The template is then moved one data sample forward and the operation is repeated to produce the next resulting data point. The resulting data points replace the waveform.

The mean square error function tends to amplify the error (or difference) between the template and the waveform, which makes it useful when looking for an extremely close match rather than a general comparison. When a match is found, the mean square error algorithm returns a value close to zero.

The mean square error function algorithm can be expressed by the following formula, where $f_{output}(n)$ is the resulting data point, $f_{template}(k)$ is the template waveform data points, and K is the number of data points in the template:

$$f_{output}(n) = \sum_{k=1}^{K} [f_{template}(k) - f_{waveform}(n)]^2$$

d) Inverse Mean square error simply inverts the result of the mean square error algorithm. Accordingly, when this algorithm finds a match between the template and the data, the algorithm returns the inverse of a value close to zero and, typically, a large positive spike will occur at the point of the match.

Integral

Integral is essentially a running summation of the data. Each point of the integral is equal to the sum of all the points up to that point in time, exclusive of the endpoints, which are weighted by half. The exact formula is below, where f( ) is the data values and ΔTs is the horizontal sampling interval:

$$f_{output}(n) \; = \; \sum_{k=1}^{n-1} f_{input}(k) + [[f_{input}(n-1) \; + \; f_{input}(n)]/2]*\Delta Ts$$

The units will be (amplitude units Éhorizontal units). The integral function can be used to compute the area under the curve in a continuous fashion. For example, in data acquired by an accelerometer, the integral of the data would be the velocity, and the integral of the velocity would be the distance. As with all transformations, this function can be applied to either a selected area or to the entire waveform.
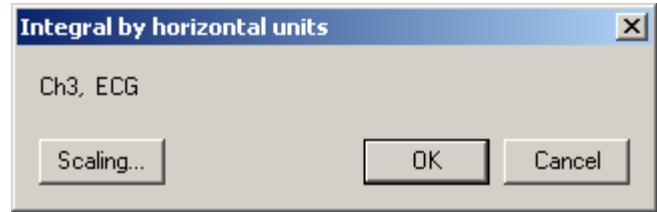
Derivative
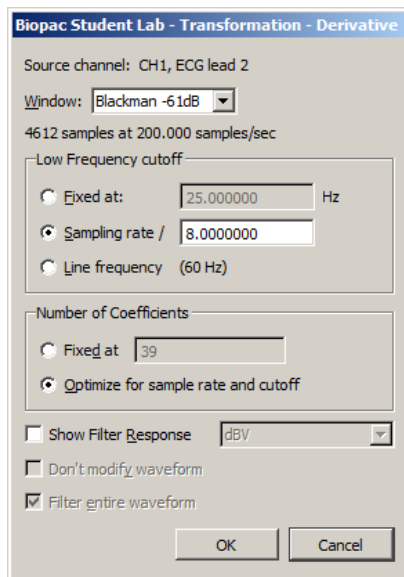
Derivative calculates the derivative of the selected area of a waveform. Since high frequency components return nonsensical results in a derivative, a low pass filtering function is included in the Derivative function (see page 252 for more information on low pass filters). Derivative is based on an FIR filter implementation.

The Filter Response for a Derivative transformation will be displayed in linear units or in dBv. The Derivative FIR filter frequency response will appear as a linearly increasing magnitude up to the point of the specified cutoff frequency, at which point, the filter magnitude will drop off sharply.
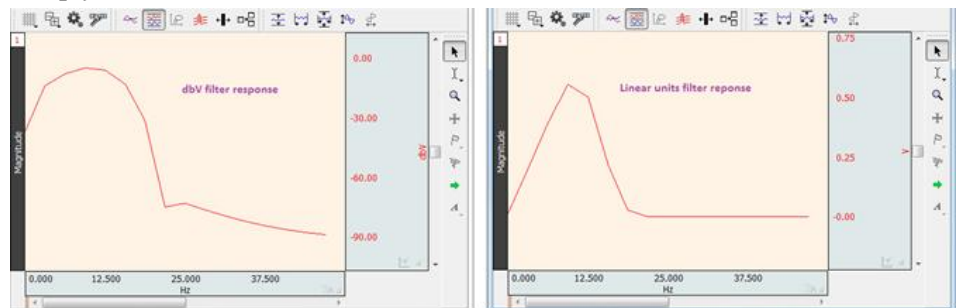
Derivative can provide a more meaningful result than Difference if high frequency noise is present in the signal.

Cutoff Frequency	The value entered in the cutoff frequency box should be roughly equivalent to the highest frequency component of interest present in the time series data. The default cutoff frequency is 0.125 times the waveform sampling rate.
	Sampling rateô Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.
	Line frequencyô Uses the line frequency at which the data was recorded.
# of Coefficients	Fixedô The default number of coefficients is (4 x waveform sampling rate)/Cutoff Frequency. As the number of coefficients (Q) increases, the Derivative becomes more accurate. Fixed can produce better filters but may take longer to execute.
	Optimize for sample rate and cutoffô Estimate the number of coefficients as four times the sampling rate divided by the cutoff frequency of the filter. Optimize does not necessarily produce the best quality filter, but takes less time.

Units   Select linear units or dbV.

> **TIP:** A good rule of thumb is to use a number of coefficients greater than or equal to two times the sampling rate divided by the lowest cutoff frequency specified. For example, if running a low pass filter at 1Hz on data sampled at 100 Hz, choose at least (2 x 100/1) or 200 coefficients in the filter. Additional coefficients will improve the response.

Integrate
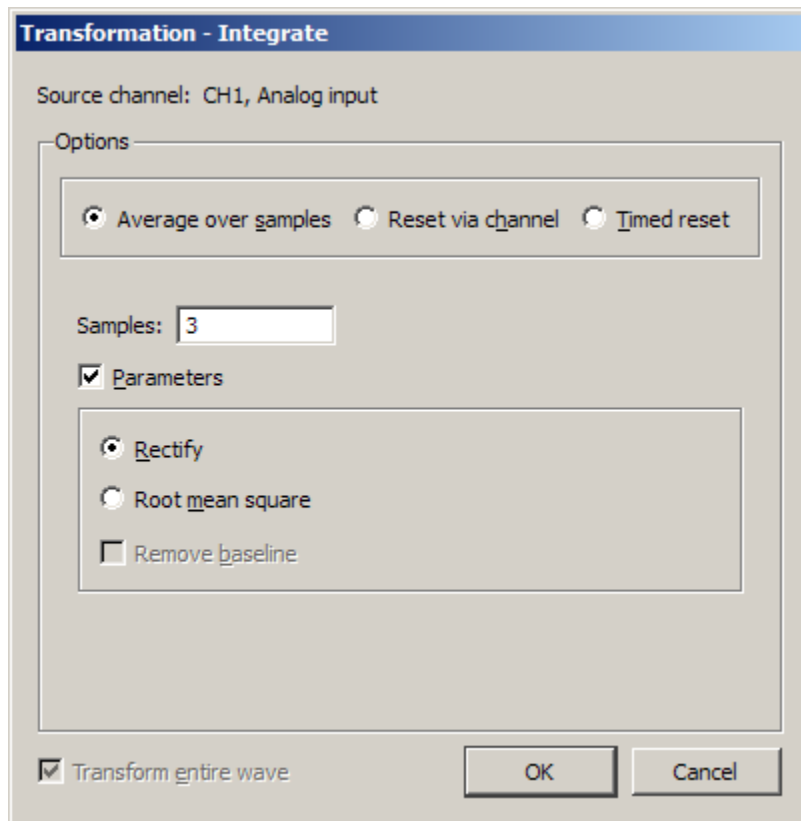
The Integrate transformation operates the same as the Integrate calculation– see page 122, except it does not have a Max Cycle option, which is not relevant post-acquisition, and Reset via channel with mean subtraction enabled functions differently online and offline.

Root mean square is implemented as:
$$\text{Sqrt(sum(}x^2\text{)/(}n\text{))}$$

Reset

Online   Mean subtraction causes the online version to be delayed by the mean cycle length. It waits for that period of time to pass so it can determine a mean value for the initial cycle, and it then tries to re-compute this mean for each cycle. If the resets are too short or too long, the window expires and the processing halts again until a new mean can be recomputed. Online processing may reset from threshold crossing in the control channel or window expiration when it loses mean tracking.

Offline   Since all the data is available, the mean is computed from the data in the channel and doesn't delay the signal. Also, since it isn∅t doing windowed means, there are no window expiration events that are inserted. Offline processing may reset from threshold crossing in the control channel.

Output Reset

Enable the checkbox option to create an Event at each signal reset.
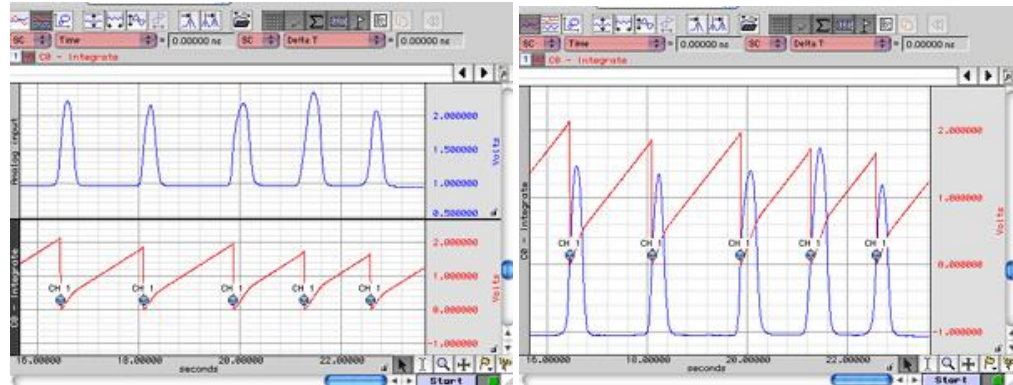
The Integrate formula is the same in the calculation (online, real-time) mode and the transformation (off-line, post-processing) mode; it varies only based on the parameters selected.

Notes

- For the first points, value of index *"i"* will be *less than or equal to zero;* it means that for summation the result will only contain values beginning with $f(x_1)$.
    - For the first point for summation: $f(x_{-1}), f(x_0), f(x_1)$.

      $f(x_{-1})$ and $f(x_0)$ - don¢t exist, resulting in: $f(x_1)$.
    - For the second point for summation: $f(x_0), f(x_1), f(x_2)$.

      $f(x_0)$ - doesn¢t exist, resulting in: $f(x_1) + f(x_2)$.
- The Integrate formula is implemented as a Standard Deviation formula (see mathworld.wolffram.com > Wolfram Research > equation 5 at http://mathworld.wolfram.com/StandardDeviation.html).

- The Root Mean Square formula is identical to the Standard Deviation formula, but without mean removal; this is the *n-1* definition.
    - For a window size *n*, to convert from the *n-1* definition to the *n* definition, use $\sqrt{(n-1)/n}$

- The formulas to calculate RMS are optimal for data with a zero mean (typical for biopotential data). Data with a non-zero mean can be rescaled with the Transform option Rescale. Choose Transform > Rescale, and then enter the following parameters:

Input value (Scale) value	Map
10	7.07107
-10	-7.07107
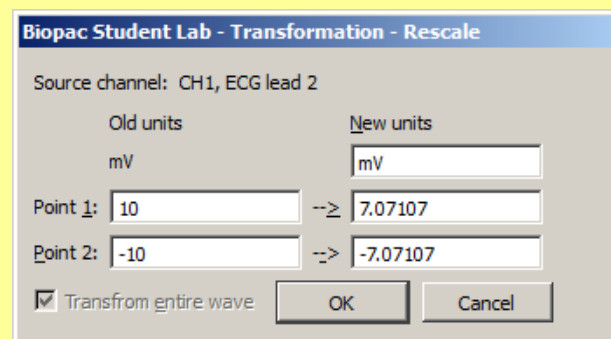
1. Via samples, no extra parameters selected

$$F(x_j) = \sum_{i=j-s+1}^{j} f(x_i) * \Delta x$$

Where:
i - index for source values (***the real range is 1..j);
j - index for destination values (1..n);
n - number of samples;

x_i, x_j - values of points at horizontal axis;

$f(x_i)$ - values of points of a curve;

$F(x_j)$ - integrated values of points of a curve;

s ó number of samples to average across;

$\Delta x = \dfrac{x_n - x_1}{n-1}$ - horizontal sample interval;

x_n, x_1 - values at horizontal axis at the endpoints of selected area.

Integrate formulas, continuedí   ➡ See *Notes* on page 267

2. Via samples, rectify

$$F(x_j) = \sum_{i=j-s+1}^{j} ABS(f(x_i)) * \Delta x$$

Where:
i - index for source values (***the real range is 1..j);
j - index for destination values (1..n);
n - number of samples;
x_i, x_j - values of points at horizontal axis;

$f(x_i)$ - values of points of a curve;

$F(x_j)$ - integrated values of points of a curve;

s - number of samples to average across;

$\Delta x = \dfrac{x_n - x_1}{n-1}$ - horizontal sample interval;

x_n, x_1 - values at horizontal axis at the endpoints of selected area.

3. Via Samples, root mean square (RMS)

$$F(x_j) = \sqrt{\dfrac{\sum_{i=j-s+1}^{j} (f(x_i))^2}{s-1}}$$

Where:
i - index for source values (***the real range is 1..j);
j - index for destination values (1..n);
n - number of samples;
x_i, x_j - values of points at horizontal axis;

$f(x_i)$ - values of points of a curve;

$F(x_j)$ - integrated values of points of a curve;

s - number of samples to average across.

4. Via samples, root mean square, remove baseline

$$F(x_j) = \sqrt{\dfrac{\sum_{i=j-s+1}^{j}\left[f(x_i) - \dfrac{\sum_{m=j-s+1}^{j} f(x_m)}{k} \right]^2}{s-1}}$$

Where:
i and *m* - indexes for source values (***the real range is 1..j);
j - index for destination values (1..n);
n - number of samples;
x_i, x_j - values of points at horizontal axis;

$f(x_i)$ - values of points of a curve;

$F(x_j)$- integrate values of points of a curve;

s - number of samples to average across.

k - coefficient: for the first few points that have index j < s k=j,

for the other points with j > =s   k=s

Smoothing
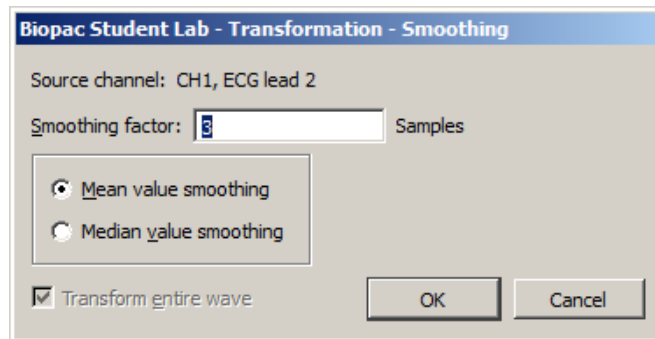
The smoothing function is a transformation that computes the moving average of a series of data points and replaces each value with the mean or median value of the moving average õwindow.ö This has the same effect as a crude low pass filter, the advantage being that there is less change to the shape and amplitude of the original waveform.

Samples   BSL *PRO* allows the user to set the width of the moving average window (the number of sample points used to compute the mean) to any value larger than three. By default, this is set to three samples, meaning that BSL *PRO* will compute the average of three adjacent samples and replace the value of each sample with the mean before moving on to the next sample. For data acquired at relatively high sampling rates, it is recommended to set the smoothing factor to a higher value, since smoothing three sample points when data is collected at 1000 Hz will only average across three milliseconds of data, and will typically do little to filter out noise. To set the size of the window, enter a value in the Transform > Smoothing dialog.

This function is most effective on data with slowly changing values (e.g., respiration, heart rate, GSR) when there is noise apparent in the data record.

Mean value   Mean value smoothing is the default and should be uses when noise appears in a Gaussian distribution around the mean of the signal. The Mean value smoothing formula is shown below, where õmö is the number of points in the window and õnö is the sample number:

$$f_{output}(n) = \sum_{k=n-(m/2)}^{k=n+[m-1)/2]} f_{input}(k) / m$$

Median value Use Median value smoothing if some data points appear completely aberrant and seem to be õwild flyersö in the data set.

The Median value smoothing formula is shown below, where õmö is the number of points in the window and õnö is the sample number:

$$f_{output}(n) = median(n - [m/2]; n + [m/2])$$

Scaling   Generates the Scaling Parameters dialog.

Difference
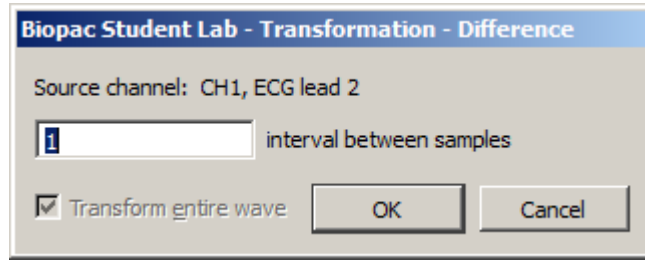
The Difference function measures the difference (in amplitude) of two sample points separated by an arbitrary number of intervals. The difference is then divided by the total interval between the first selected sample and the last selected sample.

When the difference transformation is selected, a difference interval dialog will be generated and the number of intervals between samples can be entered (default of 1).

For data with no high frequency components, a 1-interval difference transformation approximates a differentiator.

The formula for the difference transformation is shown below, where õmö is the number of intervals difference, [ ] rounds the integer down, õnö is the sample number, and ΔTs is the horizontal sampling interval:

$$f_{output}(n) = \frac{f_{input}(n + [m/2])ô\ f_{input}(nô\ [(m+1)/2])}{(\Delta Ts * m)}$$

Example for boundary values when m = 3:

$$f_{output}(0) = (f_{input}(1)ô\ f_{input}(0)) / (\Delta Ts * m)$$
$$f_{output}(1) = (f_{input}(2)ô\ f_{input}(0)) / (\Delta Ts * m)$$
$$f_{output}(2) = (f_{input}(3)ô\ f_{input}(0)) / (\Delta Ts * m)$$

When entering an odd number (K = odd):

$$f_{output}(K) = (f_{input}(K+1)ô\ f_{input}(K\ ó2)) / (\Delta Ts * m)$$

When entering an even number (K = even):

$$f_{output}(K) = (f_{input}(K+2)ô\ f_{input}(K\ ó2)) / (\Delta Ts * m)$$

Note: The online (real-time) Difference calculation is calculated differently because projected values are not available. The online Difference formula is:

$$f_{output}(n) = f_{input}(n\ óm)ô\ f_{input}(n) / (\Delta Ts * m)$$

Using the default difference setting of 1 interval will produce a õΔP/ΔTö waveform when the transformation is applied to a blood pressure or similar waveform.

Resample
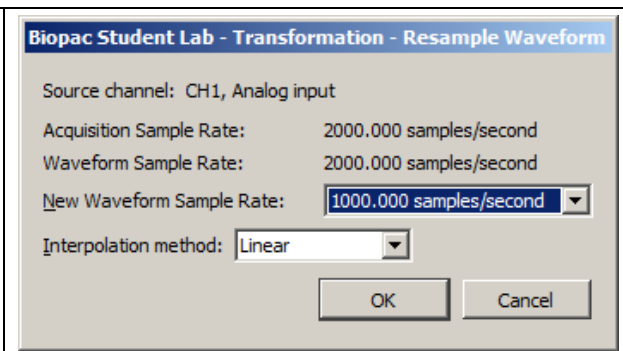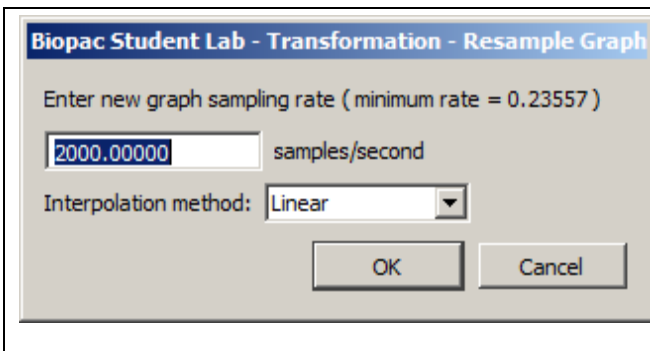
Variable sampling rate and the flexible acquisition speeds of MP units can create data sets that are at different sampling rates. For some types of data analysis, the data must be resampled to a common sampling rate. BSL *PRO* has resampling facilities with Transform > Resample Graph, and Pasting between graph windows of different sample rates when the õInterpolate pastings between graphsö Preference is enabled (via Display > Preferences, page 334).

BSL *PRO* provides three interpolation methods for resampling data. Any changes made to the interpolated pastings between windows Preference and the interpolation method used in the Preferences dialog will be retained across launches of the software.

Paddingô Padding will use the closest original value of the waveform to the left of the new sample position for the value, constructing a padded square save as the data is resampled. Padding is desirable when it is imperative no new data or data approximations get introduced into an analysis.

Linearô Linear interpolation is the default; previous software versions generated any missing data via linear interpolation. This method uses the sample points of the old waveform as the endpoints of a line. Missing data points are approximated from points lying on this linear segment.

Cubic splineô Cubic spline interpolation will construct a spline for the entire data set and use the values of this spline as the new waveform values. A natural fit spline is used that keeps zero second derivative at the endpoints of the fit. Cubic splines are useful when the analysis requires data with a smooth derivative.

Resample Graph

Apply an arbitrary, user-defined sample rate to all waveforms in the file.

- This option will adjust as needed the channel sampling rate as well as the acquisition sampling rate.

Resample Waveform

Resamples the active channel to a different rate. Resampling data maintains the same time scale but changes the number of samples per second. This option can be used to increase the number of sample points per interval (usually samples per second). When this is done, BSL *PRO* will interpolate between sample points to adjust to the new rate. This will add data points, although not necessarily more information.

- Resampling to a lower sampling rate will õcompressö a data file and information will be lost.
  - For example, a 4-channel data file sampled at 250 samples per second for 15 minutes requires about 1.8 MB of disk space. If these channels are resampled to 100 samples per second, the size of the file on disk is about 720 KB, a considerable reduction.
- The highest rate a channel can be resampled to is the file acquisition rate (Hardware menu > Set Up Acquisition).
- If data is resampled to a lower rate and then resampled again at a higher rate, the waveform will maintain the resolution of the lower sampling rate, only with more data points.

Expression
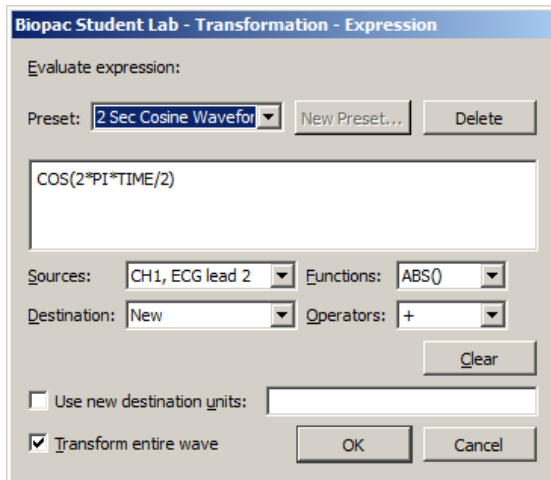
See the tables starting on page 139 for descriptions of sources, operators and functions for the Expression dialog.

The post-acquisition Expression transformation is available for performing computations more complex than available with the Math and Function calculations. The post-acquisition version Expression transformation includes all the same features as the online version described on page 135. The Expression transformation will symbolically evaluate complex equations involving multiple channels and multiple operations. Unlike the Math and Function calculations, which can only operate on one or two channels at a time, the Expression transformation can combine data from analog or digital channels, as well as calculation channels with a lower number Also, computations performed by the Expression transformation eliminate the need for õchainingö multiple channels together to produce a single output channel.

To have BSL *PRO* solve an equation/expression and save the result to a new channel, choose Transform > Expression. A dialog will be generated. For each equation/expression, specify a source channel (or channels), the function(s) to be performed, any operators to be used, and a destination for the result. The different components of each equation/expression can be entered either by double-clicking items from the pop-up menus (sources, functions, and operators) or by typing mathematical commands directly into the expression box.

Any expression can be assigned a specific name and saved as a custom preset. A pop-up menu of recently used expressions is also available in the Preset menu, along with a pre-loaded list of commonly used expressions.

The Expression transformation can reference past and future points.

Delay

The Delay transformation allows the addition of time delays in post-processing (similar to the Delay calculation channel that can be used to add time delays to signals). The time delay can be added by introducing zero-valued samples at the start of the area to be delayed. The length of the waveform will remain the same; an amount of data at the end of the wave prior to the delay will be lost, with the length equal to the delay. The delay can be applied by using the Transform > Delay menu item.
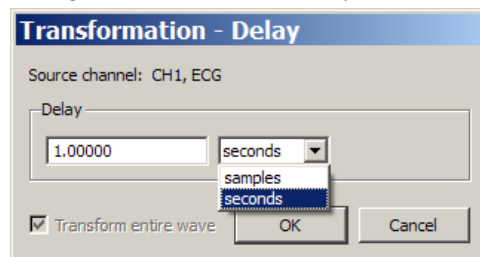
When inputting the delay amount, the units can be changed between **seconds** and **samples**.

- **Delay by samples** is applied according to the acquisition sampling rate, not the channel sampling rate. Delay specifies the units of acquisition and graph sampling rate for samples.

The Automator action allows Delay to be used in Automator workflows.

Rescale

The Rescale transformation operates the same as the Rescale calculationô see page 148.
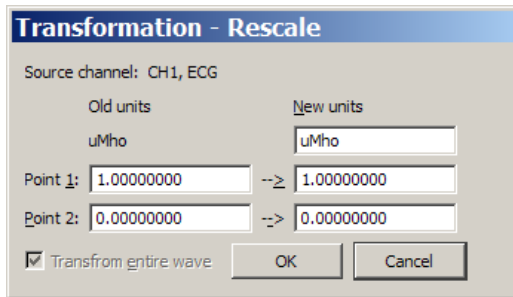
Waveform math
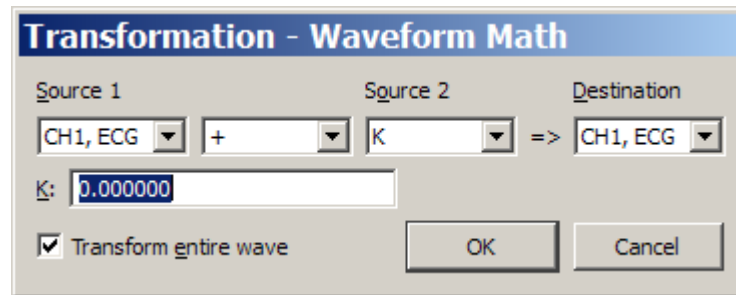
The Waveform math transformation allows arithmetic manipulation of waveforms. Waveforms can be added together, subtracted, multiplied, divided or raised to a power. These operations can be performed using either two waveforms or one waveform and an arbitrarily defined constant. Operate on the entire waveform by choosing Transform entire wave, or operate on portions of the waveform that have been selected using the cursor tool. If there is no selected area, only one sample point (the one selected by the cursor) will be transformed.

All of the main components of a waveform math calculation can be selected from pop-up menus in the Waveform Arithmetic dialog.

Source   The channels to be used in the transformation are referred to as source channels (Source 1 and Source 2), and can be combined using any of the operators in the pop-up menu. Source channels allow selection of any existing channels in the current window, or a constant (defined by K).

Constant   The õConstant =ö entry box is activated when a Source is set to õK, Constant.ö

Operand   The pop-up menu allows selection of addition, subtraction, multiplication, division or power functions.

Destination   Save the results to an existing channel or create a new channel. Choose an existing channel from the pop-up menu or select the õNewö option, which will create a new channel (using the next available channel).

Waveform math can be used many ways. As one example, two waveforms can be added together. The following screen shows a sine wave in channel 14 and a triangle wave in channel 16.

BSL *PRO* Manual
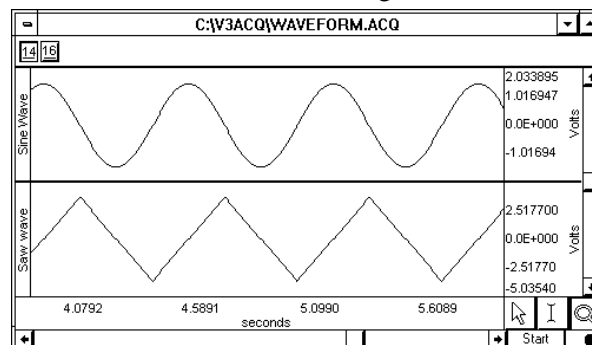
To add these two waves, select Transform > Waveform Math and set source 1 to channel 14, the operator to addition õ+ö, source 2 to channel 16, and destination to New as shown here:
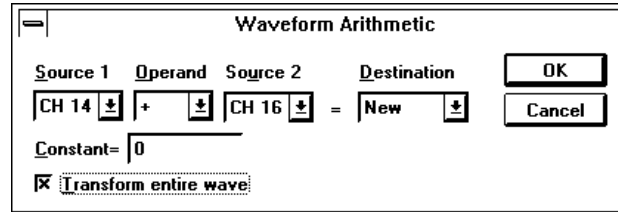
Click OK to perform the transformation. The following screen shows the sum of CH14 and CH16 on a new channel.
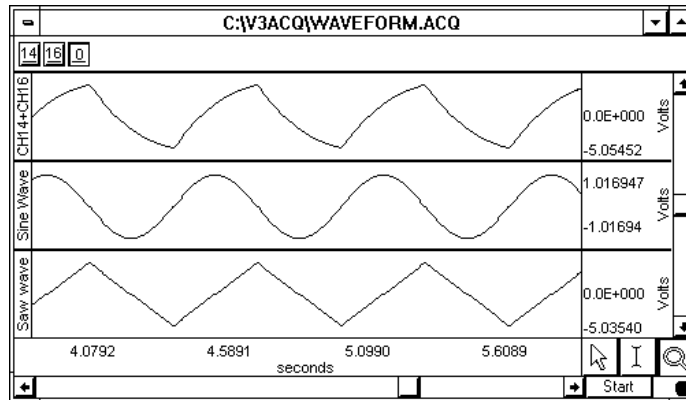
> NOTE*:* When selecting two waveforms of unequal length as sources, the length of the resulting waveform will be equal to that of the shortest one. Likewise, if one of the source waveforms extends only into a portion of the selected area, the resultant waveform will only be as long as the shortest source portion. If waveform math is performed on a selected area and output to an existing waveform that does not extend into the selected area, the resultant waveform is appended to the destination waveform.

Slew Rate Limiter
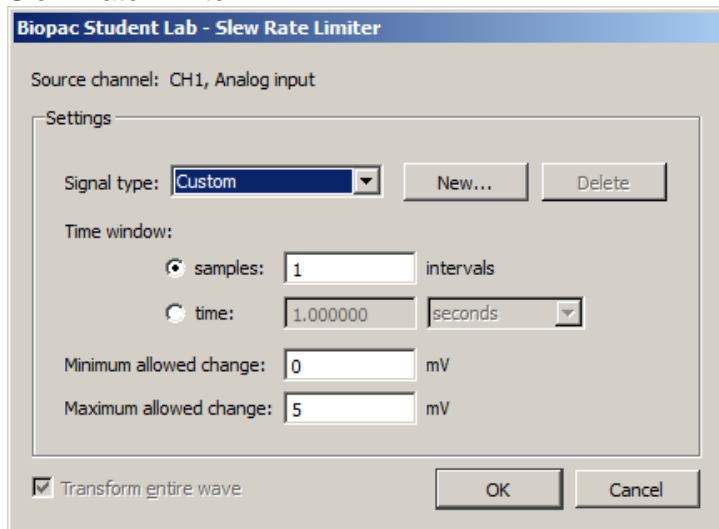
The Slew Rate Limiter transformation is used for denoising and removing motion artifact during and after recording. The allowable amount of motion artifact over a given time/sample window can be precisely adjusted from a minimum allowable change to a maximum allowable change, thereby eliminating artifacts that exceed the selected amplitude range within a given time period.

Tailor the range for a given type of artifact by modifying the Time window and Minimum/Maximum allowed change parameters. Parameters for various levels of artifact detection can be permanently stored by clicking õNewí ö and saving the signal type as a custom preset.

To apply the slew rate limiter transformation in BSL *PRO*:

1. Select the desired source channel in the data.
2. Transform > Slew Rate Limiter.
3. Select the time window using a sample interval or a time value.
4. Set the desired minimum allowed change value.
5. Set the desired maximum allowed change value.
6. Click OK.

Any artifact that falls outside the boundaries of the maximum/minimum allowed change setting will be eliminated from the data.

See also: Slew Rate Limiter online calculation channel on page 149.

▶ Watch the BIOPAC Slew Rate Limiter tutorial video for a detailed demonstration of this feature.

Chapter 14   Analysis Menu Commands

Overview

The Analysis menu contains operations that derive data and measurements from the graph.

Histogram
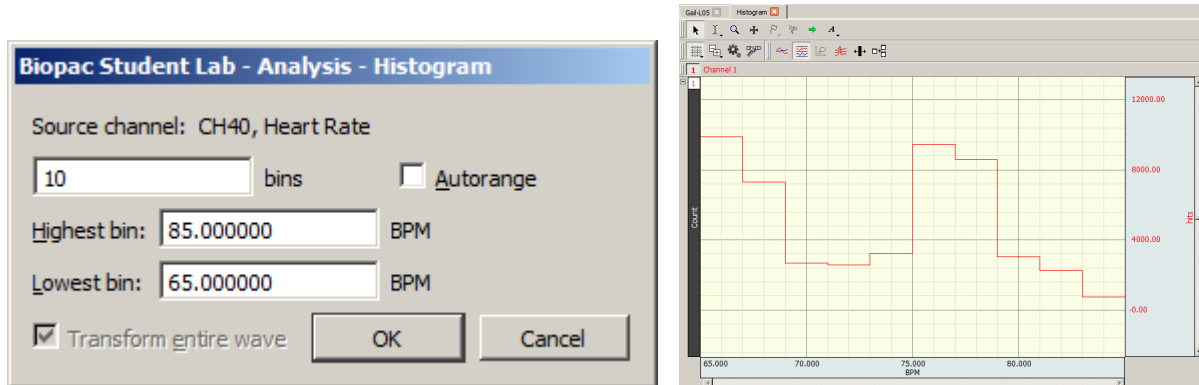
The Histogram function produces a histogram plot of the selected area. When a histogram is created, the sample points are sorted into õbinsö along the horizontal axis that contain ranges of amplitude values. These bins divide the range of amplitude values into equal intervals (by default, ten bins) and the individual sample points are sorted into the appropriate bin based on their amplitude value.

For instance, if a waveform had a range from 65 BPM to 85 BPM, the lowest bin would contain all data points with a value from 65 BPM to 67 BPM. The second lowest bin would hold all data points between 67 BPM and 69 BPM, and so on, until the tenth bin was created. BSL *PRO* then counts the number of õhitsö (the number of data points) in each bin and plots this number on the vertical axis.

Analysis > Histogram Options:

bins   Determines how many bins the data will be divided into; the default is ten bins.

Autorange   Fits all the data selected into a bin; the bin sizes are determined by the extent of the data and the desired number of lines. Automatically sets the center of the lowest bin equal to the minimum value of the waveform (or the selected area, if a section is highlighted), and centers the highest bin on the maximum value of the waveform (or selected area, if any).

              Disable to fix the bin sizes and enter values for Highest Bin and Lowest Bin.

After clicking OK, a histogram plot will be generated in a new window. By default, BSL *PRO* displays the frequency of occurrence for each bin on the vertical axis. To calculate the cumulative frequency, select the entire histogram waveform and choose Integrate from the Transform menu.

Since the histogram function sorts sample points into a relatively small number of categories, the histogram window is likely to display a large number of õhitsö in each bin, especially if data was collected at a relatively fast sampling rate. If this is the case, it may be helpful to resample the data at a lower rate (using the Transform > Resample function). The caveat to this is that resampling the data may cause a bias, unless the data was filtered to remove all frequency components that are more than 0.5 the resampling rate.

Power Spectral Density
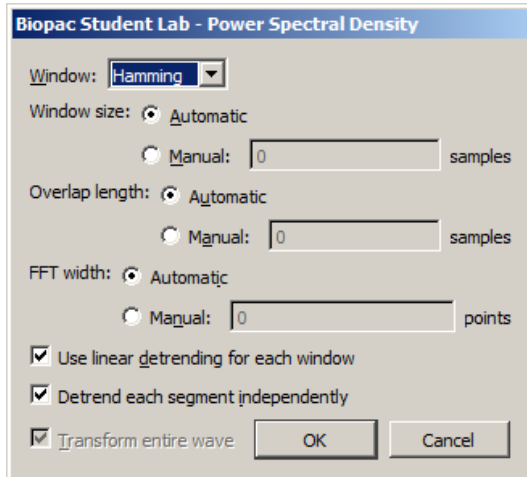
The Power Spectral Density (PSD) function extracts the power present at different frequencies within a signal and is useful for EMG analysis. The PSD transformation approximates the same result as squaring the linear FFT magnitude. PSD is not available when the horizontal units of the source graph are set to Frequency.

BSL *PRO* uses the Welsh approximation algorithm to average signal time-sliced portions of the signal and reduce noise effect, and generates a two dimensional graph displaying the wattage of a particular frequency component in a signal. Windowing options are Hanning, Hamming, or Blackman. The graph is plotted as horizontal frequency vs. vertical (units)^2/Hz, where *units* are the vertical axis units of the source data.

Use linear detrending for each windowô when enabled, linear regression detrending is applied for each individual segment prior to the FFT computation; when disabled, windowing only is applied.

Detrend each segment independentlyô becomes available when õUse linear detrendingö is enabled. When this option is enabled, detrending is applied independently for each segment; when disabled, detrending from the previous segment will be incorporated into the next segment.

FFT Fast Fourier Transformation
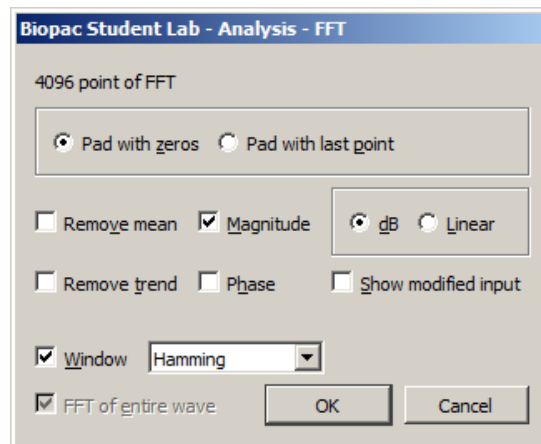
The FFT algorithm requires that the length of the data be an exact power of two (i.e., 256 points, 512 points, 1024 points, and so on).

The Fast Fourier Transformation (FFT) is an algorithm that produces a description of time series data in terms of its frequency components. This is related to the *frequency spectrum*. The FFT displays the magnitude and phase of the time series data selected and displays only the DC and positive frequency components; the FFT does not display negative frequency components. To reconstruct a signal from additive sines or cosines, itøs necessary to include both the positive and negative frequency components. Since itøs not physically possible to generate a negative frequency signal, itøs necessary to double the amplitude of the corresponding positive frequency component.

The output from an FFT appears in a graph window with magnitude (vertical axis) plotted against various frequencies (horizontal axis). A large component for a given frequency appears as a positive (upward-pointing) peak. The range of frequencies plotted is from 0 Hz to 1/2 the sampling frequency. Thus, if data was collected at 200 samples per seconds, BSL *PRO* will plot the frequency components from 0 Hz to 100 Hz.

Fourier analysis can yield important information about the frequency components in a data set, and can be useful in making determinations regarding appropriate data cleaning techniques (e.g., digital filtering). The FFT algorithm assumes that data is an infinitely repeating periodic signal with the end points wrapping around. Thus, to the extent that the amplitude of the first point differs from the last point, the resulting frequency spectrum is likely to be distorted as result of this start point to end point discontinuity. This can be overcome by õwindowingö the data during the transformation. For more information on the windowing feature, see the window section that follows.

The FFT transformation cannot be performed in real time (i.e., during an acquisition). To emulate an online spectral analysis, use online filters and the Input Values window. See page 206 for more information about real-time frequency information.

Pad	If a section of data is selected that is not a power of two, BSL *PRO* will always õpadö data up to the next power of two, filling in the remaining data point with either
	Pad with zeros: a zero
	Pad with endpoint: the last data point in the selected area
	In other words, if 511 data points are selected, BSL *PRO* will use a modified version of the waveform as input. The modified waveform will have 512 points, and the last point in the modified wave will be either a zero or equal to the 511th point of the original data.
Show Mod.	To view the modified waveform being used as input for the FFT, check the Show modified input box. Whenever possible, it is best to use an input waveform (select an area) that is an exact power of two. The waveform is modified by applying the windowing and padding options. Window functions diminish the discontinuities that occur at either end of the wave.
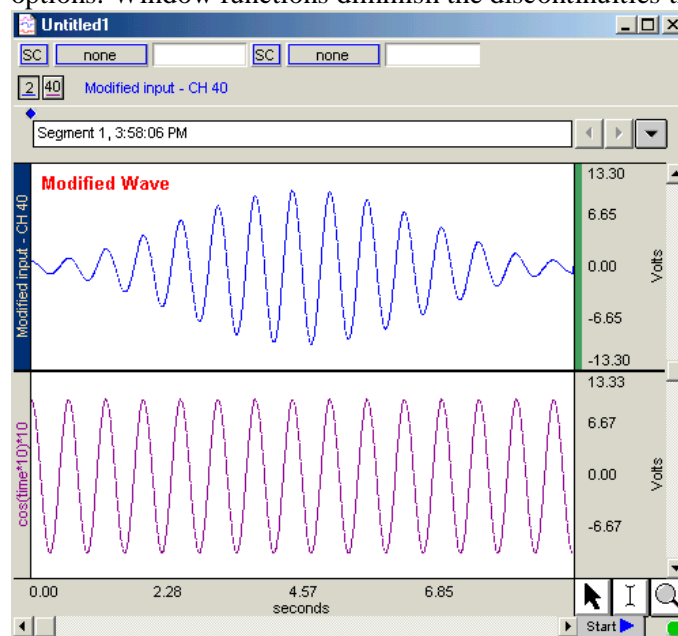
Window	The FFT algorithm treats the data as an infinitely repeating signal with a period equal to the length of the waveform. Therefore, if the endpoint values are unequal, the resulting frequency spectrum will contain larger than expected high frequency components due to the discontinuity. Windowing these data minimizes this phenomenon. For example, to apply a window transformation to a sine wave whose endpoints do not match up, check the box next to Window and choose a type of window from the pop-up menu. Each of the windows has slightly different characteristics, although in practice each provides similar results within measurement error.
	As shown below, the frequency spectra of the windowed and non-windowed data differ significantly when the endpoints are unequal. When data are not windowed, the very low and very high frequencies are not attenuated to the same extent as when windowed.
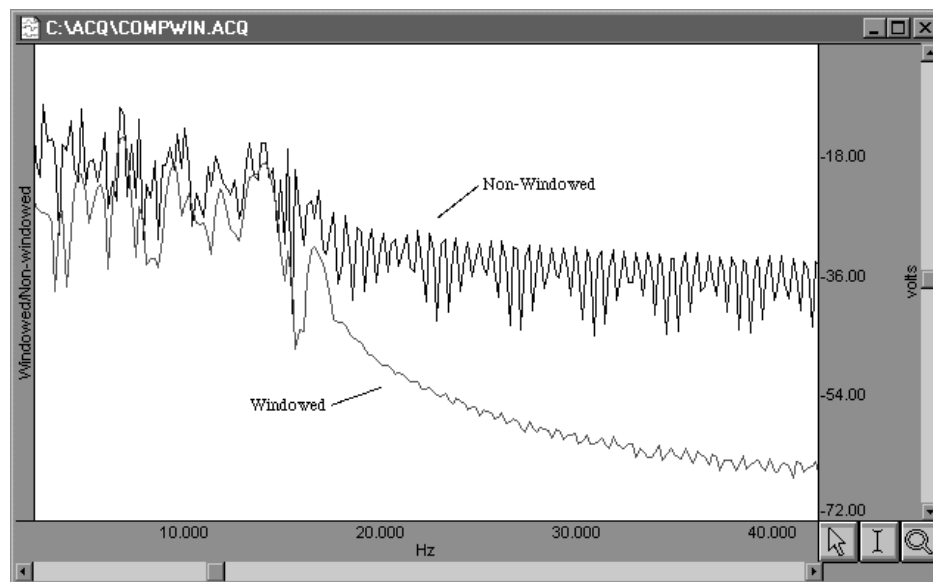
Remove Trend
Sometimes, data contains a positive or negative trend that can cause extraneous frequency components to õleakö into the frequency spectrum. In this case, select remove trend when performing the FFT, which will draw a line through the endpoints, and then subtract the trend from the waveform.

For example, the following sine wave has an upward trend through the data (positive trend component). The lower graph shows FFTs of the skewed sine wave data with and without the trend removed.

Note that the spectrum of the data without the trend removal has gradually decreasing frequency components, while the data with the trend removed has far fewer frequency components except for the single spike due to the sine wave.
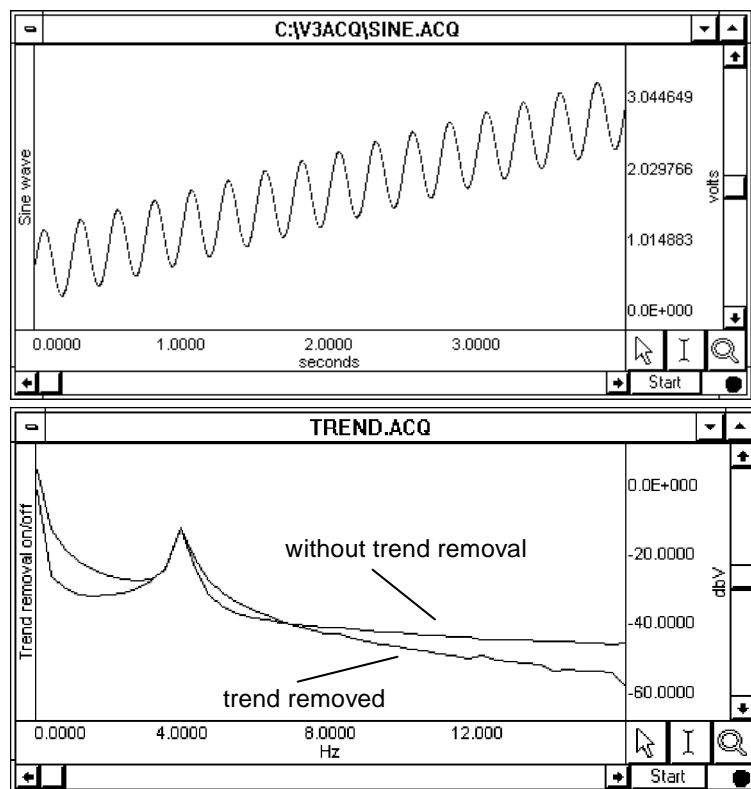
Remove Mean
Remove mean calculates the mean of all the points in the selected area and then subtracts it from the waveform. This is generally useful for windowing a waveform that has a large DC offset.

As an example, start with a sine wave with a 10-volt DC offset (with a little noise added to broaden the spectrum), and perform spectral analysis with and without mean removal:
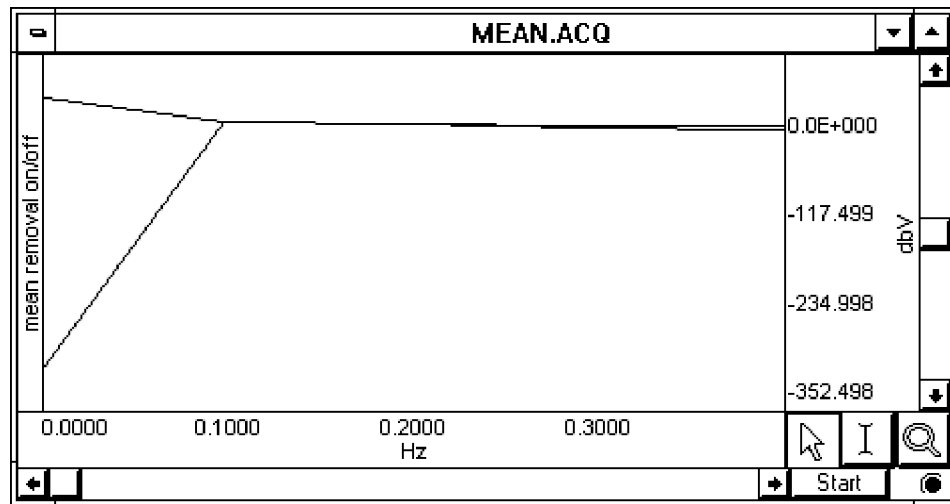
Note the large spectral components at the beginning of the top plot, without mean removal. This is due to the offset of the original data. The bottom plot is with mean removal.

Since the offset of the waveform is often an artifact of the way it was generated, the remove mean option provides a more accurate indication of the true spectral components. This is especially true for applications where low frequency components are of interest. If the data has a large DC offset and needs to be windowed, a more meaningful spectrum will result if the mean is removed prior to windowing (which is the same order the FFT uses).

Linear   By default, the FFT output is described in terms of frequency along the horizontal axis and dBV on the vertical axis. The Bell scale (from which dB are derived) is logarithmic, and in some cases it may be useful to have the output scaled in linear units. To do this, click the button next to linear and check OK. The other options in the dialog work as they normally do when the dB scaling option is selected. The relationship between log and linear units is: $dBV_{out} = 20 \log VIN$.

Phase   The standard FFT produces a plot with frequency on the horizontal axis and either dB/V or linear units (usually Volts) on the vertical axis. In some cases, it may be useful to obtain phase plots of the waveform (as opposed to the default magnitude plots). Phase plots display frequency along the horizontal axis, and the phase of the waveform (scaled in degrees) on the vertical axis. This option functions exclusive of the magnitude optionô they can be checked independently, or checking both, two plots will be produced (a magnitude plot and a phase plot).

Inverse FFT
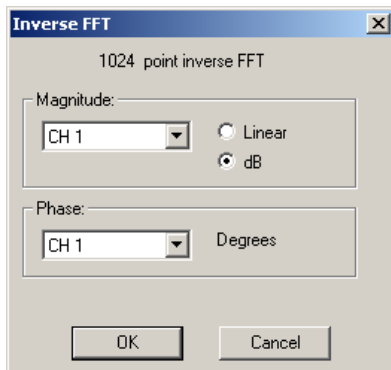
The Transform > IFFT menu option is generated after an FFT is performed. An Inverse FFT (Transform > IFFT) converts spectral values back to a time series waveform to reverse the FFT transformation. Any modifications to the original data (such as windowing or padding) will be shown in the resulting time series data.

To obtain a meaningful IFFT result, a graph window must be open with at least one magnitude channel and at least one phase channel. With the window open, choose IFFT from the Transform menu to generate the Inverse FFT dialog.

To accurately recreate the time series waveform

    1.   Select the source channels for the inverse FFT in the Magnitude and Phase pull-down menus.

2. Select whether to express Magnitude in linear units or dB logarithmic units (decibels). To determine this setting, check the vertical axis units of the magnitude channel; this should correspond to the Magnitude scaling choice that was used when performing the forward FFT.

   ▪ The Phase waveform must be in degrees.

3. Click OK to perform the IFFT.

   ▪ The result is generated in a new time domain window, labeled õIFFT of Spectralí ö

To perform an FFT, it may be helpful to start with an electroencephalogram (EEG) signal acquired when the subject alternated between eyes open and eyes closed. Typical results suggest that higher levels of alpha activity (activity with frequency components between 8Hz and 13Hz) are to be expected when a subjectøs eyes are closed.

1. The raw data, prior to FFT, is shown here:
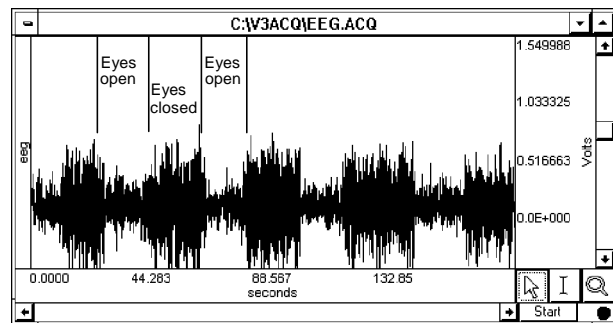
2. Select Transform > FFT from the menu.

   The FFT Parameters dialog will be generated; in this example, the Window function chosen is Kaiser Bessel:
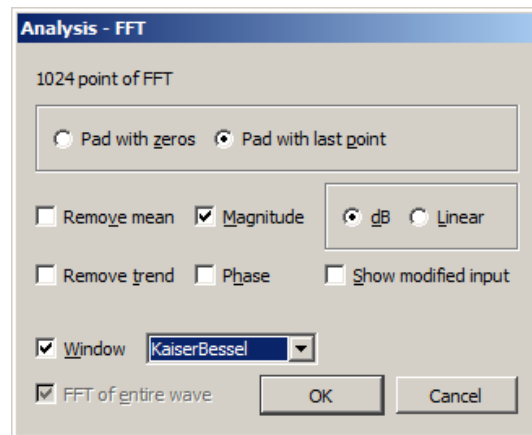
3. Click OK.

   A frequency domain window (a graph window which places frequency along the horizontal axis rather than time) will be created and displayed, showing the spectrum of the input data.

   The window is named %Spectral of (the original window name)+and ends with the channel number, as shown here:
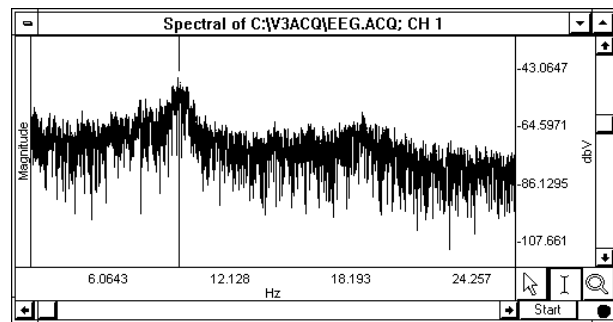
   The resulting magnitude value for each component is equal to the peak value of the sine wave contributing to that component. The entire pattern of frequency components is known as the frequency spectrum of the data. The somewhat erratic appearance of the spectrum is usually due to small-scale variations in the original waveform.

4. *Optional·* This %noise+can be removed by applying a smoothing transformation to the FFT output. In the graph shown, there is a pronounced frequency component centered on 8Hz, which corresponds to the alpha wave frequency band (8Hz· 13Hz). The frequency spectrum (0-20 Hz shown) used 20-point smoothing.
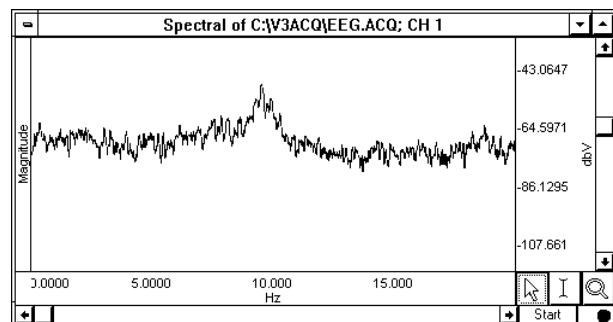
Find Cycle (Cycle/Peak Detector)

Overview

The advanced Cycle/Peak Detector combines with the powerful new Event Marking System. Use it to perform amplitude, time, or event-based measurements. New output options for measurements, averaging, events, and 3D surface (cycle data, histogram, and FFT).

The Find Cycle detector uses three tabbed settings panels to define and automate cycle/peak detection:

<p align="center">Cycles/Peaks   Selection   Output</p>

Cycle detector settings are graph-independent, which means that find cycle/peak operations can be performed in multiple graphs without needing to re-enter graph-specific settings for each run. By using multiple data views, different find cycle/peak operation can be performed on the same set of data without losing settings between õFind Next Cycle/Peakö operations.

When the Cycle/Peak Detector is first opened for a graph, the dialog will be filled with the values from the last successfully executed find Cycle/Peak operation. Subsequently, changes to the settings will be applied only to that graph.

> **TIP**   If running the cycle/peak detector multiple times and itøs necessary to put the edge back at the beginning of the waveform for the next pass, use the keyboard shortcuts Home, End, Page Up, and Page Down to quickly change edge location (see page 61).

Cycles/Peaks tab
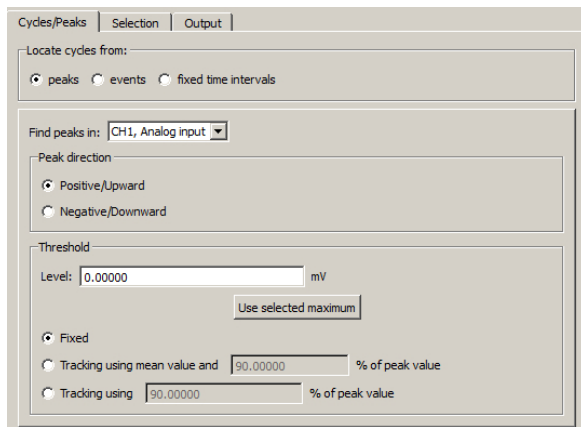
<p align="center">Peaks</p>
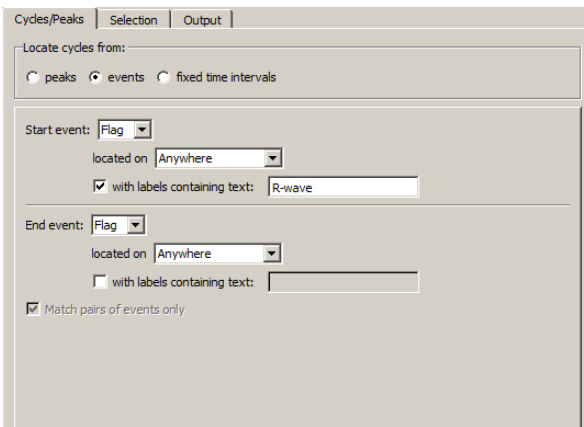
<p align="center">Events</p>

<p align="center">Fixed Interval</p>
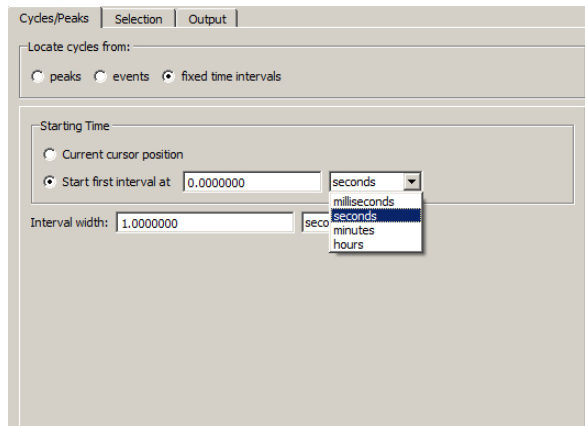
Find in Selected Area	Find All in Focus Areas	Find All in Graph	Find First Cycle
Preview		OK	Cancel

Find Cycle controls available at bottom of dialog

Find Next Cycle

When selected from the Analysis menu (or select the toolbar icon or Ctrl+E), both edges will move one peak to the right while staying above the threshold.

Find All Cycles in Graph

When selected from the Analysis menu, Find Cycle setup dialog or selecting Ctrl+R,, the software will find all cycles/peaks through the end of the file. If the data file is very large, it may take some time to find all the cycles since BSL *PRO* loads data from disk while it scans for the cycles.

Find in Selected Area

When selected from the Analysis menu or in the Find Cycle setup dialog, only cycles within a selected area will be detected, all others will be ignored.

Find All Cycles in Focus Areas

If the graph contains defined focus areas, this option will limit cycle detection to focus areas only. If no focus areas are defined, this option will not be available. This is selectable via the Analysis menu or in the Find Cycle setup dialog.

Find First Cycle

Use this option to apply changes to the Find Cycle setup and locate the first cycle. This is selectable via the Analysis menu or in the Find Cycle setup dialog.

About Find Cycle Preview

Sometimes it can be difficult to predict exactly where cycles will be located as the detection parameters are changed. The Preview functionality offers an advance view of these selected areas via a separate resizable graph window. The overlay in the Preview updates dynamically as parameters in the Cycle Detector dialog are changed, and illustrates how the selected cycles would be modified during the actual Find Cycles operation. An additional thumbnail preview window can also be found under the Selection tab.
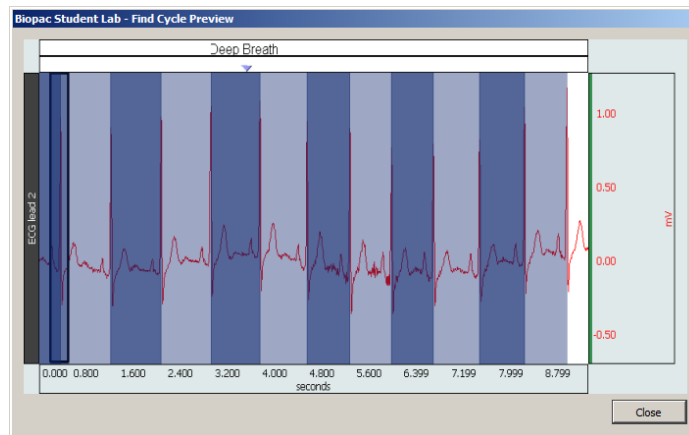
Find Cycle Preview window

Find Cycle definitions

The Cycles/Peaks tab offers three general methods for establishing cycle parameters:

- Peaks: Data driven maximum and minimum
- Events
- User-defined fixed time intervals
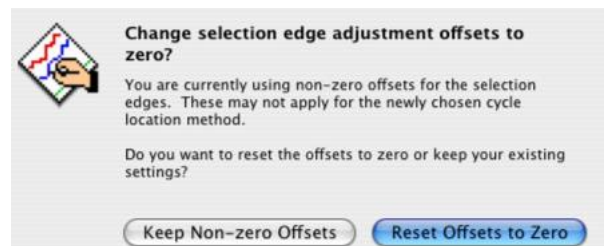
When the cycle location mode is switched on the õCycles/Peaksö tab, the edge selection offsets will be checked. If they are non-zero, a prompt will generated to warn that that the edge adjustment offsets may not apply for the new cycle location mode. The user can reset the offsets to zero (default) or retain the (non-zero) settings used in the previous cycle location mode.

Peaks

Peak direction   See the Peak definitions.

Level   *Important usage note*ô Level is not set automatically when the Cycle/Peak detector is generated. (Automatic Level is used in previous versions of BSL *PRO* for Mac and current version for Windows.)

Use selected...   To optimize the threshold detection level for the selected area of data in the graph, click the õUse selected maximum/minimumö button underneath the level. If changing the source channel or peak direction, this option can be used to re-compute the recommended level based upon the new settings.

Threshold   **Fixed**ô Keeps the threshold voltage level constant.

   Tracking   The Tracking threshold mode modifies the threshold after it finds a peak, depending upon the value of the new peak, and will compensate for a slowly drifting baseline.

   Hints regarding the use of Tracking Threshold Options

   - If data has a very consistent cyclical nature, either Tracking Option will work.
   - If data has spurious positive or negative peak values present, the Means Reference Tracking Option is probably a better choice.
   - If data has an erratic baseline, but consistently sized, positive and negative peaks, the Peaks Reference Tracking Option is probably a better choice.

   Tracking using mean value and % of peak valueô Adjusts the threshold voltage level after each peak based on the average of the last cycleøs data and the specified percentage of the current peak voltage. The Means reference option will cause the software to determine the Mean Value of all the data, from peak to peak. This Mean Value establishes a variable reference upon which the tracking threshold operates. The software will determine the new threshold (NT) as follows:

   For Positive Peaks

   NT = Mean Value + (Positive Peak Value - Mean Value) x (% factor)

   For Negative Peaks

   NT = Mean Value - (Mean Value - Negative Peak Value) x (% factor)

   Tracking using % of peak valueô Adjusts the threshold voltage level dynamically based on the specified percentage of the value of the most currently found peak. The Peaks reference option will cause the software to determine the Positive Peak Value and Negative Peak Value of all the data, from peak to peak. The Positive and Negative Peak Values establish a variable reference upon which the tracking threshold operates. The software will determine the new threshold (NT) as follows:

   For Positive Peaks

   NT = Neg. Peak Value + (Pos. Peak Valueô Neg. Peak Value) x (% factor)

   For Negative Peaks

   NT = Pos. Peak Value - (Pos. Peak Valueô Neg. Peak Value) x (% factor)

Events

Event-based cycle location can extract information from events or define events based upon the output of the peak detector.

Start / End Define the event; any of the predefined event types can be explicitly matched. To use only one event to define each cycle select the exact same event type for both õStart eventö and End event,ö and see the õMatch Pairsö discussion below.

Match pairs õMatch pairs of events onlyö may be unchecked only when the Start event and End event are identical. Under this condition, if the box is checked, two such events are used to define one cycle. If the box is unchecked, then each event defines a cycle by itself. This is useful for adjusting a selection relative to an event, such as locating the first second prior to each event of a specific type. This option makes it possible to hit time periods for each event since each cycle consumes two events.

Located on Specify the channel when the event must be defined, either its actual channel or õGlobalö for events not associated with any channel. Select õAnywhereö to search for events of specific types across channels.

With Labels Toggle the õWith labels containing textö checkbox to set this option.
optional
When checked, the matching eventøs label must contain the text in the edit box to the right of the checkbox.

▪ The text search is not case sensitive. The search must be non-empty for cycles to be located properly.

When unchecked, the matching event can have any label, including none.

The Cycle detector uses the following algorithm to search for cycles in the graph:

1. From the starting point, find the first event matching the criteria of the Start event. This will be defined as the *left event*. If no event matches the Start criteria, no more cycles are in the file.

2. If the Start event criteria match the Ending event criteria and zero width cycles are allowed (e.g. õMatch pairs of events onlyö is unchecked), define the right event as identical to the left event and go to step 5.

3. From the location of the left event, find the closest event matching the criteria of the End event. This will be defined as the *right event*. If no event matches the End criteria, no more cycles are present in the graph.

4. Within the time region between the left and right events, search for any events that match the Start criteria. If such an event occurs, redefine the left event to be this matching event and repeat the step. If no event is located, then the closest pair of events has been located.

▪ This step is useful for working with data that has missing portions of the sequence, as can come out of some classifiers. For example, if two event types A and B are used as the endpoints, a sequence of three events AAB will match the last two events as the cycle. This is logical in the case of physiological data where, if B should occur periodically in the signal, AA is an indicator of an abnormality or missed classification.

5. Set the selected area to the time interval whose endpoints are the left and right events.

6. Perform selection adjustment and output as indicated by the settings on the õSelectionö and õOutputö tabs.

7. If õFind All Cyclesö is being performed, return to step 1 and use the ending event location as the new starting point to find any remaining cycles in the graph.

Fixed Interval

See the interval definitions.

Selection tab

Use the Selection tab to adjust the range of data that will be analyzed to generate any output. By default, the data range is set to be the entire cycle as located by the settings on the Cycle/Peak tab, but it can be adjusted to analyze only specific portions of the cycle.

The controls on the Selection tab vary based on the settings on the Cycle/Peak tab

Peak   When the Cycles/Peaks location method is õPeaks,ö the Selection can be adjusted based on the times of the peaks in the data or the times of the threshold crossings prior to the peaks.
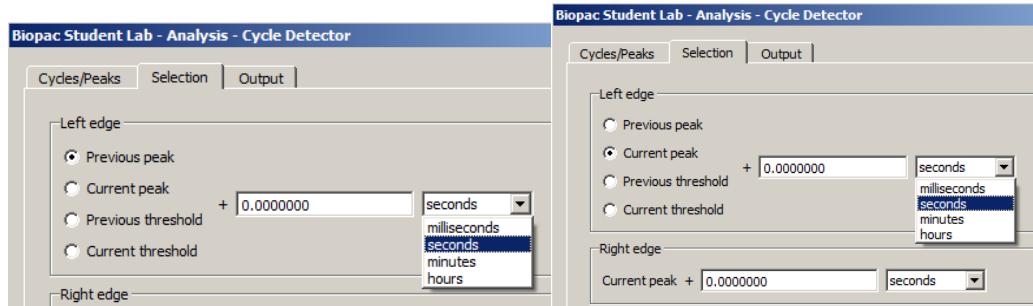
To perform analysis on the entire data within each cycle, the selection should be from the õprevious peakö to the õcurrent peak.ö To examine fixed-width time windows located at each peak, use the õcurrent peakö to õcurrent peakö settings and adjust the two time offsets accordingly. Note that the settings must place the left edge earlier in time than the right edge for the peak detection to succeed properly.

õMove Cursor To Originö (at bottom left of screen) sets the graph data selection back to the first sample. Use this to reset the cursor in order to find all of the data in the graph.

Event   When the Cycles/Peaks location method is õEvents,ö the Selection can be adjusted based on the locations of the events that define the boundaries of a cycle.

For a specific cycle, the starting event will be the event at the left boundary of the cycle and the ending event will be the event at the right boundary of the cycle. The starting event will never be located after the ending event in time.
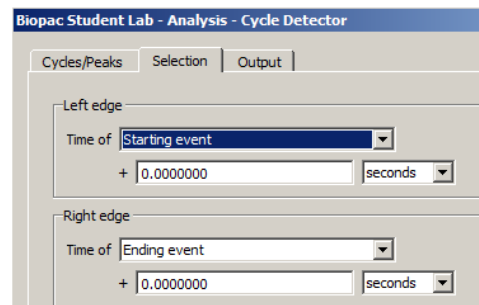
To analyze data over each entire cycle, use the õstarting eventö to õending eventö setting. To examine fixed-width time windows occurring within each cycle, set the left edge and the right edge to the same event (e.g. õstarting eventö to õstarting eventö for time windows at the beginning of each cycle) and adjust the offsets accordingly. Note that the settings must place the left edge earlier in time than the right edge for the peak detection to succeed properly.

Fixed   When the Cycles/Peaks location method is õFixed time intervals,ö adjust the Selection based on the endpoints of the time interval.

To analyze the data over each entire interval, use the õprevious intervalö to õcurrent intervalö setting.

To examine fixed-width time windows within each interval or only a sub-portion of each interval, use the õcurrent intervalö to õcurrent intervalö setting and adjust the time offsets accordingly. Note that the settings must place the left edge earlier in time than the right edge for the peak detection to succeed properly.
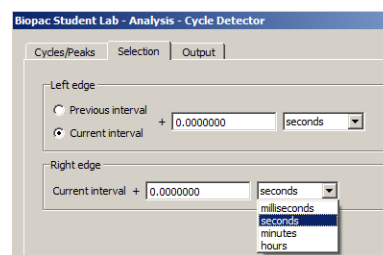
Output tab
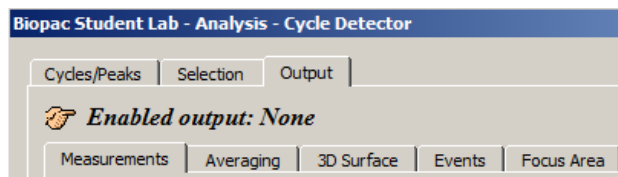
The Cycle/Peak Detector includes five Output options, which can be independently enabled: Measurements, Averaging, 3D Surface, Events and Focus Area. The selected output, if any, is listed at the top of the Output tab as Enabled output.

Output Measurements
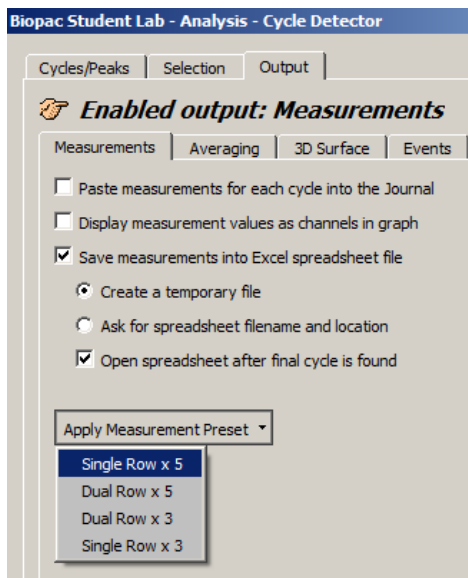
Toggle each checkbox to enable/disable the option:

- Paste measurements for each cycle to the Journal
- Plot measurement results; display measurement values as channels in graph.
- Save measurements to Excel spreadsheet file, plus output options. In order for spreadsheet output to be generated, a õFind All Cyclesö operation is required.
- Apply Measurement Preset ó this option replaces the current measurement configuration with any of these selectable presets.

NOTE: If the horizontal axis is in world time (HH:MM:ss), any time measurement exported to Excel will be reported in standard time units, such as seconds or minutes.

Output: Averaging—Offline
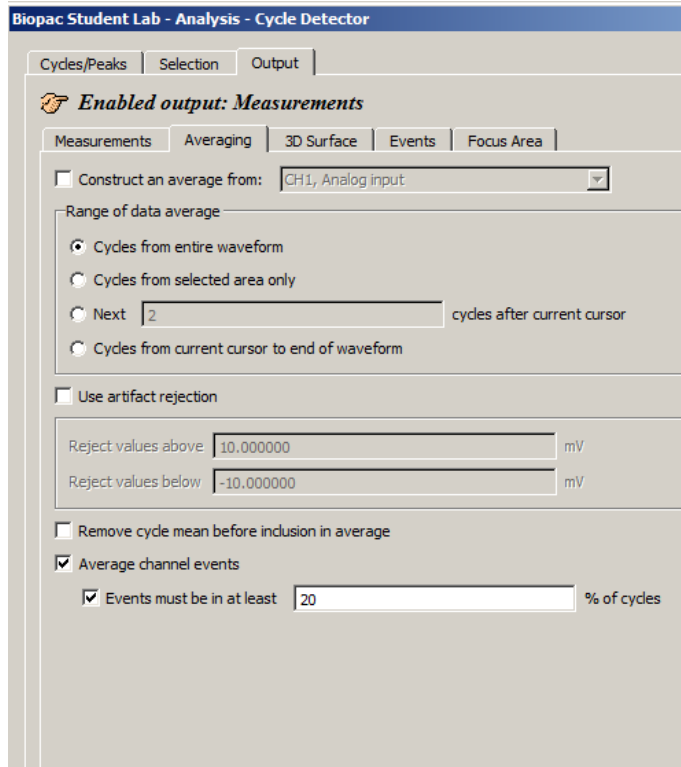
Use Averaging Outputö to perform offline ensemble averaging of source data or ensemble averaging of event locations. Specify the channel where the cycles/peaks are to be located in the õCycles/Peaksö tab and specify the channel whose data should be ensemble averaged in the õAverageö controls on the õOutputö tab.

Toggle the õAverage channel events checkbox near the bottom of the tab to turn event averaging on and off.

õRange of data averageö is used to select the portions of data from which the averages are taken.

Offline averaging can produce average locations of events within the defined cycle along with the average data. When a cycle is found, any events in that cycle will be noted. Events that are on the channel of data being averaged will be examined for inclusion in the average.

Rejection Toggle the õEvents must be iní ö checkbox to turn rejection on and off, and specify a percentage for the relative number of cycles an event must appear in to be considered valid.

Remove… When mean removal is enabled, the mean value of the data within each cycle is subtracted prior to including it in the overall signal average. This mean removal option is useful for:

- o Extracting signals that are õridingö on top of other signals with high DC offset (e.g., MRI artifact on top of skin temperature)
- o Compensating for baseline drift where there are not enough cycles present in the data for the baseline variation to completely cancel itself out.

Output 3D Surface
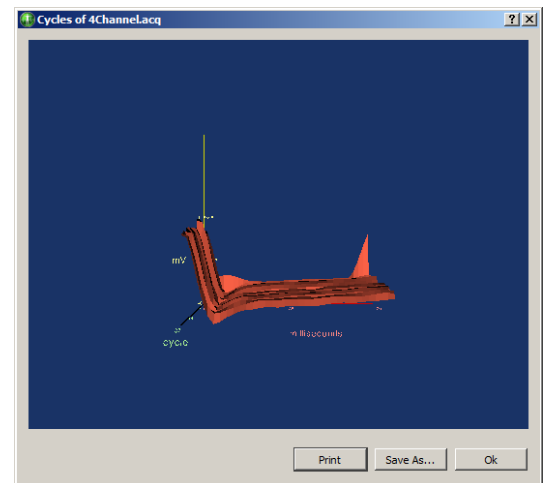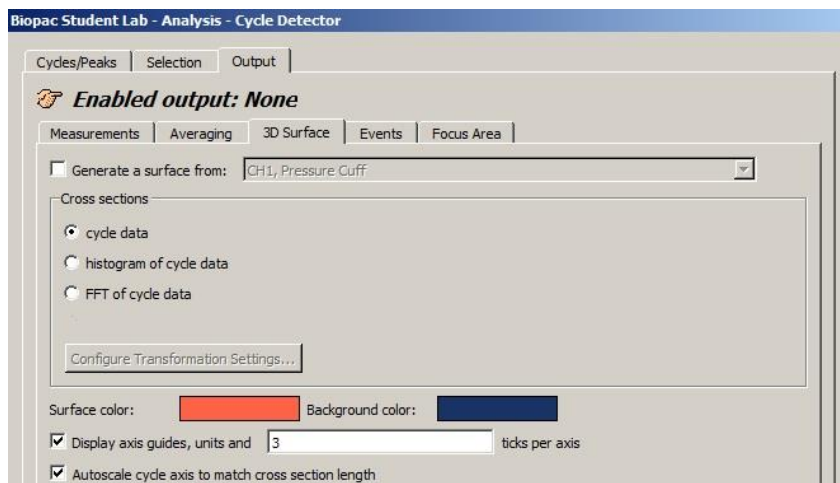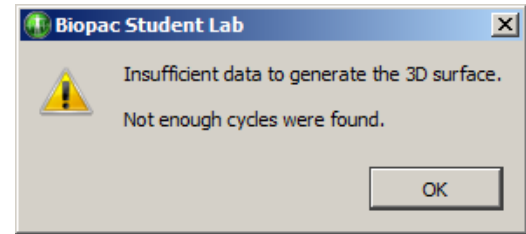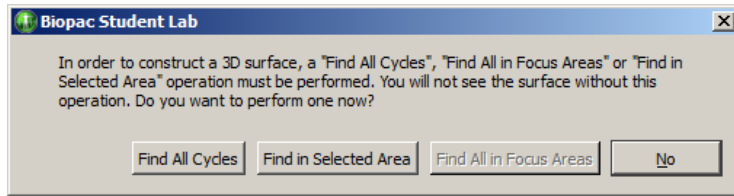
Toggle the õGenerate a surfaceö checkbox at the top of the 3D tab to turn Surface Output on and off.

1) Choose a channel to generate a 3D surface from.

2) Confirm or establish the cycle period of interest on the channel.
   - Use the *Cycles/Peaks* tab and the *Selection* tab to adjust the threshold and cursor positions for the cycle period for 3D output.

3) Choose a cross-section output format for the cycle data: cycle data, histogram, or FFT.
   - For histogram or FFT, click õConfigure Transformationö to change the settings.

4) Select surface and background colors.

5) Set axis options.

6) Click OK.

Use the cursor to rotate the 3D image; the magnitude of display response increases as the cursor moves from the center of the screen (keep cursor close to center for slow response/display control).

3D Output Example   Compare ECG cycles in 3D Output. The following example shows how to BSL *PRO* will generate a 3D image using each cross section of ECG.

a) Cycles/Peaks tab: set the threshold level to identify each R-wave.

b) Selection tab: set the edges to

   Current Peak
   Left edge -.5 seconds
   Right edge .5 seconds

c) On the Output tab

   Enable 3D Output

   Specify the channel to generate a surface from.

   Choose õcycle dataö for the cross-section format.

d) Click Find All Cycles.

Output Events
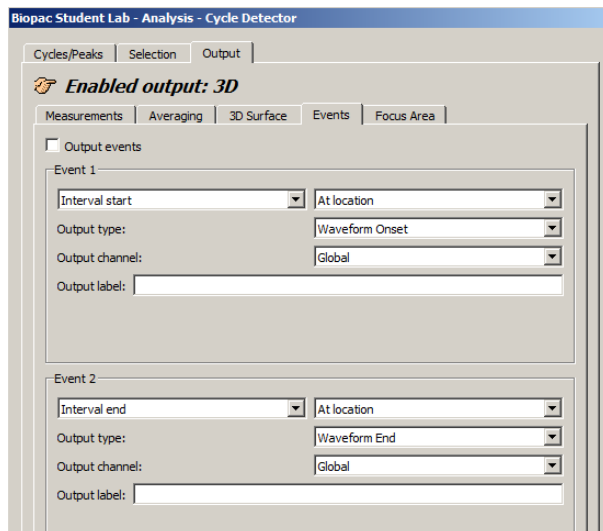
Toggle the õOutput eventsö checkbox at the top of the Events tab to turn Event Output on and off.

The Cycle/Peak Detector Output mode can define events at specific locations; a maximum of two events per cycle can be inserted with Event Output. After the Peak Detector has located a cycle and adjusted the selection, the data within that cycle can be analyzed and used to create new events in the graph (data-driven or time specific).

Event definition
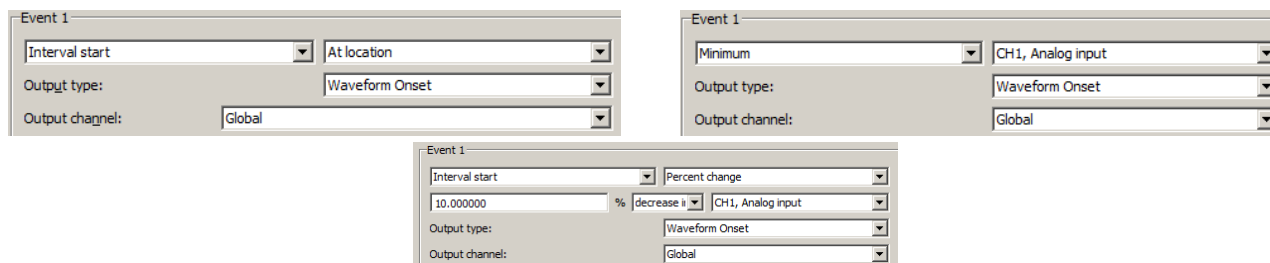
Insertion method & channel selection	Brief definitions follow, see the Event Location table on page 291 for details:
	At edge place the event directly at the specified edge (left or right). See Edge Adjustment on page 290.
	Percent change looks for a crossing based on a percentage of the value of the signal at the corresponding edge and places the event when a signal increases or decreases in value from the edge.
	% peak to peak change looks for a point where the signal's value has changed by a percentage of the maximum peak-to-peak amplitude distance over the selected area and places the event when a signal increases or decreases in value from the edge
	Minimum place events at the minimum of a specific channel's data within the selection.
	Maximum place events at the minimum of a specific channel's data within the selection
	The channel whose data should be examined is specified in the pull-down menu directly to the right of the insertion method pull-down menu:
Output type	For each insertion method, the õOutput typeö pull-down menu adjusts the event type of the inserted event.
Output channel	Sets the channel where the event is inserted, either õGlobalö for defining global events or specific channels.

- ▪ Noneô disables any insertion for that event and all of the other controls will be hidden except the insertion method pull-down menu.
- ▪ Interval start / Interval endô a pull-down menu is displayed to be used to change between the different offset methods
- ▪ Minimum / Maximum

Output label	Use this edit field to type in specific label text. Each event that is inserted will have its label set to this text. By default, it is empty (inserted events will not be labeled).
Edge Adjustment	When an õAt locationö method is used, options will be generated to fine-tune event placement relative to that (right or left) edge of the selection.
Offset	Underneath the insertion method pull-down menu, a set of controls will be added that allow the user to specify the percentage, choose whether to search for an increase or decrease, and choose the channel whose signal should be examined.
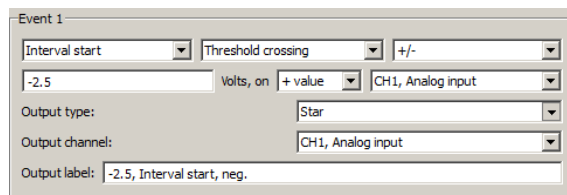
When the offset method is õThreshold crossing,ö the event will be placed when the signal on a channel crosses a threshold.

There are a number of possible ways to configure the threshold crossing:

- ▪ Fixedô The edit field may contain a specific voltage level for the threshold.

In this configuration, an event will be placed if the value of the channel specified in the next pull-down menu crosses this fixed voltage value.

- + valueô The edit field may specify an offset from the value of the channel at an edge. The threshold voltage level is the value of the chosen source channel plus the offset from the edit field. To specify a threshold lower then the value of the channel at the edge, a negative sign can be placed before the offset.

Direction of crossing   The direction of the crossing can be specified.

- + (positive crossing)ô the signal must approach the threshold from below and cross to above the threshold before an event is inserted.
- - (negative crossing)ô the signal must approach the threshold from above and cross to below the threshold before an event is inserted.
- ± (mixed threshold)ô an event will be inserted at the first positive or negative crossing that is encountered.

Event Location Table

Insertion Method	*Location Process*
Interval, at location	Place an event at the left or right boundary of the selected area, as specified.
Interval +/- percent offset	Given a particular channel, place an event at the specified time within the selection when the signal increases or decreases by a specific percentage.
	Interval start + Place at the time closest to the left boundary of the selection. The percentage is calculated from the value of the signal at the left boundary of the selected area.
	Interval end - Place at the time closest to the right boundary of the selection. The distance between the event and the right edge of the selection will have an amplitude difference equal to the indicated percentage of the right edgeøs value.
	If the signal does not increase or decrease by that percentage within the selection, no event will be inserted.
Interval +/- percent peak to peak offset	Given a particular channel, place an event at the specified time within the selection when the signal increases or decreases by a specific percentage of the peak to peak delta of the selected area.
	Interval start + Place at the time closest to the left boundary of the selection. The percentage is calculated from the result of subtracting the minimum value of the signal over the selected interval from its maximum.
	Interval end - Place at the time closest to the right boundary. The distance between the event and the interval end of the selection will have an amplitude difference equal to the indicated percentage of the minimum value of the signal over the selected interval subtracted from its maximum.
	If the signal does not increase or decrease by that percentage within the selection, no event will be inserted.

Interval +/- threshold crossing	Starting at the specified boundary of the selection, determine a threshold value. This threshold voltage may be:
	    ▪ fixed voltage level
	    ▪ value of signal at the specified edge + offset
	    ▪ mean value in selected area + offset

       Interval start + Search for the first location where the signal on a particular channel crosses the threshold.

       Interval end -   Examining data from right to left, search for the rightmost location where the signal on a particular channel crosses the threshold.

If the direction of the threshold crossing matches the user specified direction, then an event is inserted. If it does not, then the next threshold crossing is located and the process repeats. If the threshold is never crossed within the selected area in the user-specified direction, no event is inserted.

Minimum	The event will be placed at the time location corresponding to a specific channelø minimum value within the selected area.
Maximum	The event will be placed at the time location corresponding to a specific channelø maximum value within the selected area.

Output Focus Area

Use this tool to define and highlight focus areas within the graph and include them in the Find Cycle output.

Biopac Student Lab - Analysis - Cycle Detector

Cycles/Peaks | Selection | Output

☞ *Enabled output: 3D, Focus Area*

Measurements | Averaging | 3D Surface | Events | Focus Area

☑ Define focus areas at selection boundaries

Label basename: | Cycle
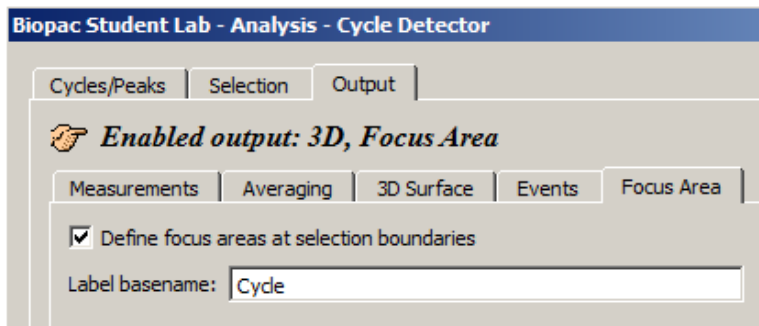
Define focus areas at selection boundaries

When checked, focus area output is enabled. Focus area selection boundaries will be defined as determined in the Find Cycle selection setup.

Label basename

Use to assign a name or label to the cycles located in the focus area. The defined basename will appear in the focus area section of the graph, along with incremented numbers for each subsequent cycle. (See below)
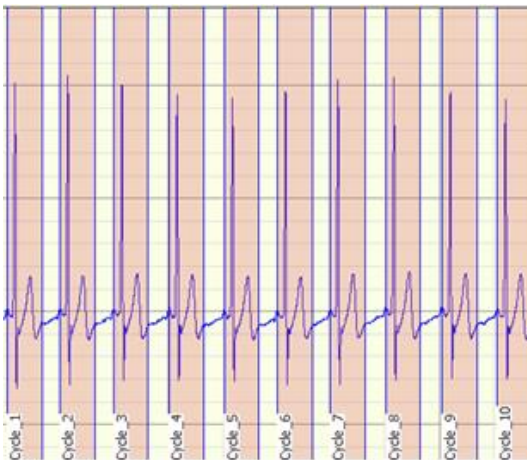
The following example details how to detect the positive spike in the QRS complex·   a typical use of the Find Cycle (peak detection) function.

Analysis > Find Cycle, Find next cycle, Find all cycles   Icons: Find Cycle   Find Next Cycle

1. Select the area around a typical peak.
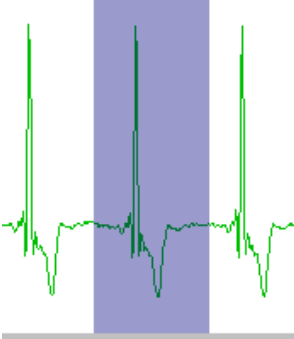
2. Select Find Cycle. (Locate cycles from peaks).

3. Enable õUse selected maximumö on the Cycles/Peaks tab to automatically set an appropriate threshold value based on the amplitude of the cycle detector.

4. Click the Output tab and choose the desired option(s), such as paste measurement controls to update the journal with the measurement values from the new peak.

5. Click a Find button.

- Find first cycle ó the cursor will blink at the first cycle point
  - To manually move through the file, click Find next
  - Or, select an area and choose Find all or Find in selected area.
  - Or, place the cursor in the data and Find all will detect cycles from that point forward.

- Find all cycles will find all cycles from the beginning of the selected area to the end of the waveform.

- Find in selected area will only find cycles in the selected area.

To use an offset

Use the Selection controls to set a time window around the selected cycle; previous peak controls the left edge, Current peak has options to control the left and right edges.

1. Use steps 1-4 above.

2. Click the Selection tab.

3. Set the desired edge values.

- For example, to set the time window 0.5 seconds *prior* to the previous peak.
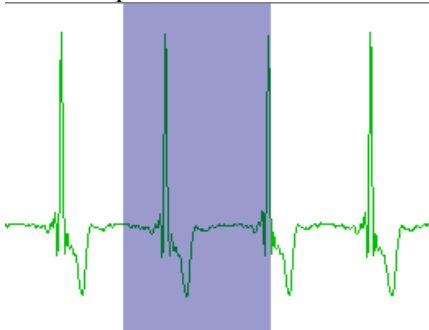
To control the left and right edges, select current peak and enter the appropriate time window to define an interval around the cycle.

Find Rate
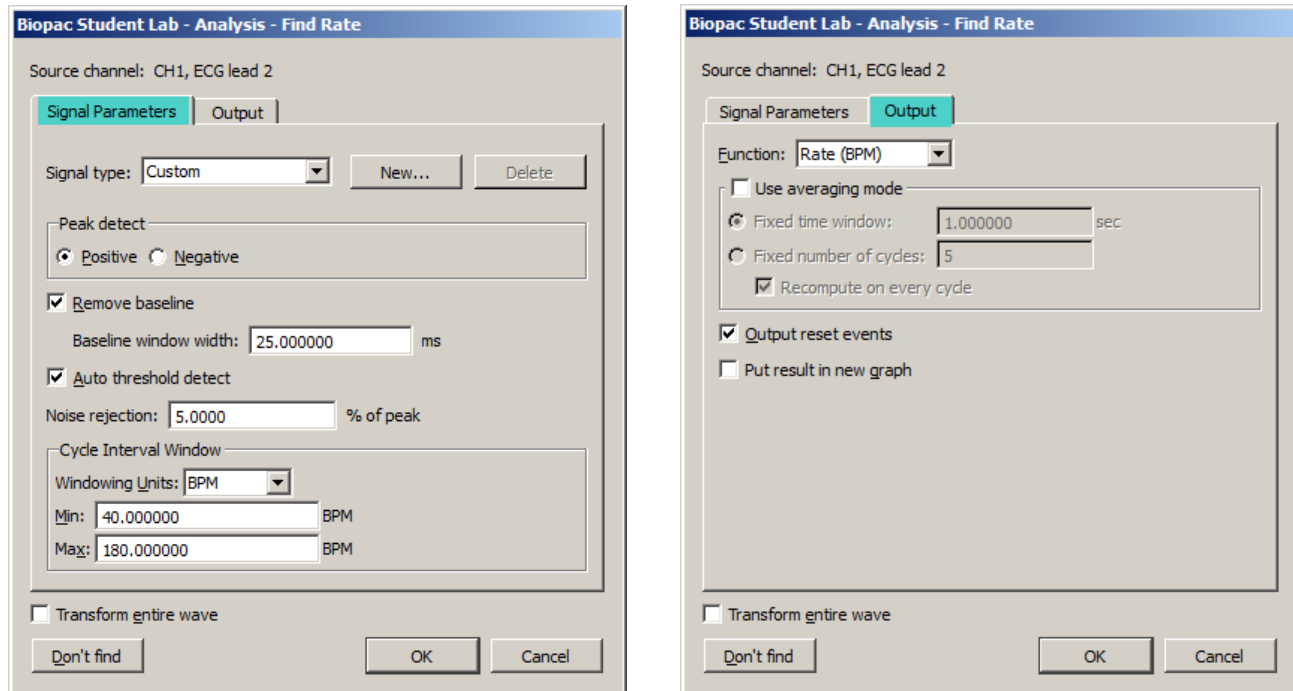
The Rate Detector is critical to BSL *PRO*'s ability to extract information from physiological data that has a degree of periodicity. Physiological data that can be investigated using the BSL *PRO* Rate Detector includes:

- ECG (e.g. Heart Rate or Inter-Beat-Interval recording)
- Blood Pressure (e.g. Systolic, Diastolic, Mean, dP/dt Max, dP/dt Min)
- Respiration (Respiration Rate measurement)
- EMG (Zero Crossing or Mean Frequency analysis)

The Find Rate function allows rate calculations (including BPM) to be computed for data that has already been collected. Although this function uses the same algorithm as the online rate detector (which uses a Calculation channel), it can be advantageous to perform rate calculations after the data has been acquired. One benefit is that off-line rate computations do not require that a separate channel (i.e., a Calculation channel) be acquired. Since the number of acquired channels is reduced, other data can be collected and/or data can be sampled at a higher rate.

Rate detector settings are graph-independent, which means that find rate operations can be performed in multiple graphs without needing to re-enter graph-specific settings for each run. By using multiple data views, different find rate operations can be performed on the same set of data without losing settings between õFind Rateö operations. When the Rate Detector is first opened for a graph, the dialog will be filled with the values from the last successfully executed Find Rate operation. Subsequently, changes to the settings will be applied only to that graph.

Modes of Operation

The Rate Detector incorporates a significant amount of flexibility to optimize performance when extracting data from periodic physiological waveforms. There are three basic modes of operation for the Rate Detector:

1) Fixed threshold detect mode
2) Auto threshold detect mode (enables Noise rejection)
3) Remove baseline and Auto threshold detect mode

The Rate Detector will eliminate certain options when selecting different modes of operation.

- The Remove baseline function always uses the Auto threshold detect mode.
- Any cyclic measurement relating to amplitude (e.g. Peak-Peak, Maximum, Minimum, Area, Mean) automatically turns off the Remove baseline function.
- If the measurement pertains directly to time (e.g. Hz, BPM, Interval, Peak Time, Count Peaks) the Remove baseline and Auto threshold detect modes are both operational.

Generally, it's best to use the simplest Rate Detector mode that is suitable for the current application. If the simplest mode doesn't work, add layers of sophistication, one at a time. For example:

- If the Fixed threshold mode can't or will not work, use the Auto threshold detect mode.
- If the Auto threshold detect mode is similarly unavailable, adjust the Noise rejection or add the Remove baseline option (if possible).
- If the Auto threshold detect mode is similarly unavailable, adjust the Noise rejection or add the Remove baseline option.

If the Auto threshold detect mode is similarly unavailable, adjust the Noise rejection or add the Remove baseline option.

1) Fixed threshold detect mode:

Fixed threshold detect mode is the simplest mode of operation for the Rate Detector. As shown here, the Threshold Level has been set to 0.00 Volts. If the waveform crosses 0 Volts, the Detector will begin to look for Positive or Negative peaks (based on the Peak detect setting).

Not available in Fixed mode:

- Noise rejection
- Windowing options
- Output reset events

2) Auto threshold detect mode:

Auto threshold detect mode is a more advanced and flexible mode of operation for the Rate Detector. In this case, the Rate Detector will create a variable threshold defined as:

Positive peak search
0.75 É(Old Peak Maximum - Old Peak Minimum)

Negative peak search
0.25 É(Old Peak Maximum - Old Peak Minimum)

Furthermore, the Rate Detector will construct a moving file of data points defined by 1.5 times the number of samples that can be placed in the largest rate window size (defined by the Window settings). If the Rate Detector loses sync (no trigger event inside the window), the threshold is changed to the mean value of the moving file of data points. This operation permits successful recovery in the event of spurious waveform data values.

The Noise rejection setting creates Hysteresis around the variable threshold. The Hysteresis level is defined as:

Hysteresis = Noise rejection (%) É(Old Peak Maximum - Old Peak Minimum)
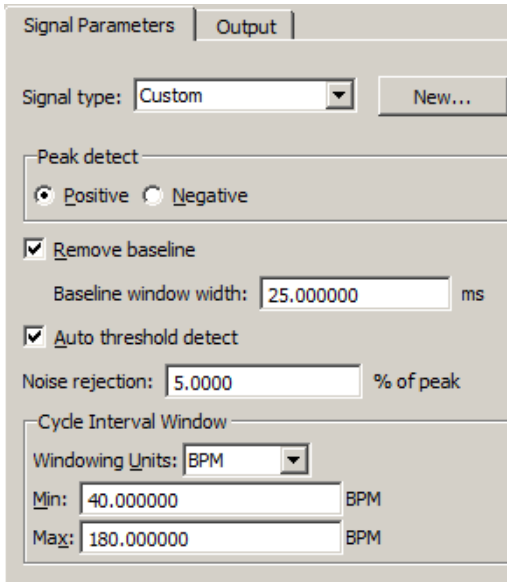
3) Remove baseline and Auto threshold detect mode:

Remove baseline and Auto threshold detect mode is an advanced and flexible mode of operation for the Rate Detector. Primarily, the Rate Detector performs an automatic (and hidden) moving difference function on the waveform data. The difference function is performed over a variable number of samples defined by:

# of points over which difference is performed =
  0.025 ÉSampling Rate

This difference waveform is then passed through the variable threshold:

Positive peak search =
0.75 É(Old Peak Maximum - Old Peak Minimum)

Negative peak search =
0.25 É(Old Peak Max - Old Peak Min)

Furthermore, the Rate Detector will construct a moving file of data points defined by 1.5 times the number of samples that can be placed in the largest rate window size (defined by the Window settings). If the Rate Detector loses sync (no trigger event inside the window), the threshold is changed to the mean value of the moving file of data points. This operation permits successful recovery in the event of spurious waveform data values.

FIND RATE OPERATIONAL SUGGESTIONS	
Option	Waveform Characteristics
Fixed threshold option	• waveform data has clearly defined positive or negative peaks (like respiratory or air flow data), which are consistently higher (in magnitude) than the rest of the waveform. • waveform data has clearly defined zero-crossings (like EMG), and itøs necessary to determine the rate of these crossings
Auto threshold detect option	• waveform data has a moving baseline, but the peaks are otherwise larger in magnitude than other parts of the waveform (blood pressure). *It may be necessary to adjust the Noise rejection (Hysteresis) to optimize performance.*
Remove baseline *and* Auto threshold detect options	• waveform data has high narrow peaks (like most ECG leads), which may or may not be larger in magnitude than other (slow moving) parts of the waveform. *It may be necessary to adjust the Noise rejection (Hysteresis) to optimize performance.*

Signal type

The Signal type menu contains parameters for specific human and animal waveform morphologies. All pre-defined and custom signal types are common to both calculation channel Rate (online) and analysis Rate (offline) dialogs. Signal type modifications affect settings in the Signal Parameters tab only, and do not affect the Output tab settings.

Select from six pre-configured signal types or click õNewö to create, name and save custom setups. This allows quick access to frequently used Rate detection signals without the need to recreate modified settings. Custom Rate signal types may be added or deleted in the same manner that channel presets are in other areas of the BSL *PRO* application.
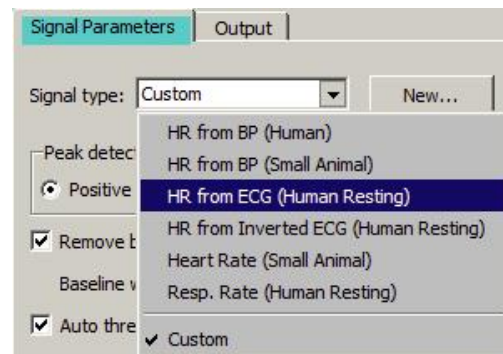
Peak detect

By default, the Peak Detector searches for Positive peaks (upward pointing, such as the R-wave of an ECG signal) to calculate the rate of a waveform. In some instances, however, it may be necessary to base the rate calculation on negative peaks (downward pointing). To do this, select Negative peak.

Remove baseline

The Remove baseline option applies the optimal high pass filter based on the other settings. This option is useful when signals have a slowly fluctuating baseline.

Auto Threshold Detect

When the Auto threshold detect box is selected in the Find Rate dialog, BSL *PRO* automatically computes the threshold value using an algorithm that accentuates peaks and uses information about the previous peak to estimate when and where the next peak is likely to occur. This threshold detector is typically more accurate than a simple absolute value rate calculation function, and is able to compute a rate from data with a drifting baseline and when noise is present in the signal. (For a detailed description of how the calculation is performed, contact BIOPAC Systems, Inc. for the complete Application Note.)

▪ When Auto threshold detect is enabled, the Noise rejection and Window options are enabled.

Threshold level

This option (activated when õAuto threshold detectö is *not* selected) allows entry of a threshold level to be used for a simple absolute value rate calculation function.

▪ The Auto threshold detect option is typically more accurate.
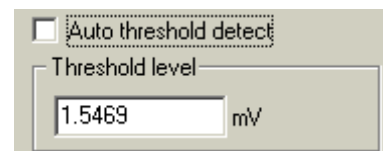
Noise Rejection

Noise rejection (activated when õAuto threshold detectö is enabled) constructs an interval around the threshold level. The size of the interval is equal to the value in the õNoise rejectionö text box. Checking this option helps prevent noise õspikesö from being counted as peaks.

▪ The default is equal to 5% of the peak-to-peak range.
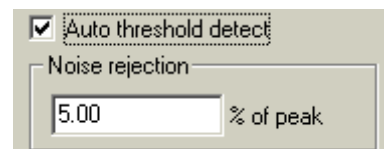
Cycle Interval Window (Peak Interval)

Window is used to specify an upper and lower limit for the Rate calculation. Window is activated when õAuto threshold detectö is enabled; the Windowing Units pull-down menu is only activated when the selected Function can have variable units.

Setting the upper and lower bounds for the õwindowö tells BSL *PRO* when to start looking for a peak.

BSL *PRO* will try to locate a peak that matches the automatic threshold criteria within the specified window. If no peak is found, the area outside the envelope will be searched and the criteria (in terms of peak value) will be relaxed until the next peak is found.

For instance, once the first peak is found, BSL *PRO* will look for the next peak in an interval that corresponds to the range set by the upper and lower bounds of the window. The interval associated with the upper band of 180 BPM is 0.33 seconds (60 seconds ÷ 180 BPM), and the interval for the lower band is 1.5 seconds (1 minute ÷ 40 BPM). If a second peak is not found between .33 seconds and 1.5 seconds after the first peak, then BSL *PRO* will look in the area after 1.5 seconds for a õsmallerö peak (i.e., one of lesser amplitude).

For those rate functions that require a window interval in seconds, it may be necessary to enter numbers like .33 seconds and 1.5 seconds (which correspond to the BPM defaults of 40 and 180). These numbers will be suitable for detecting the heart rate of an average subject.
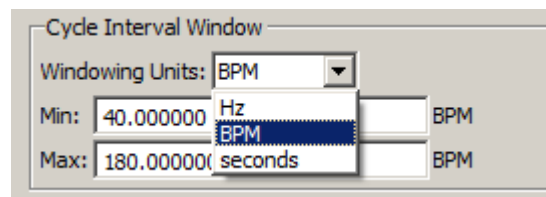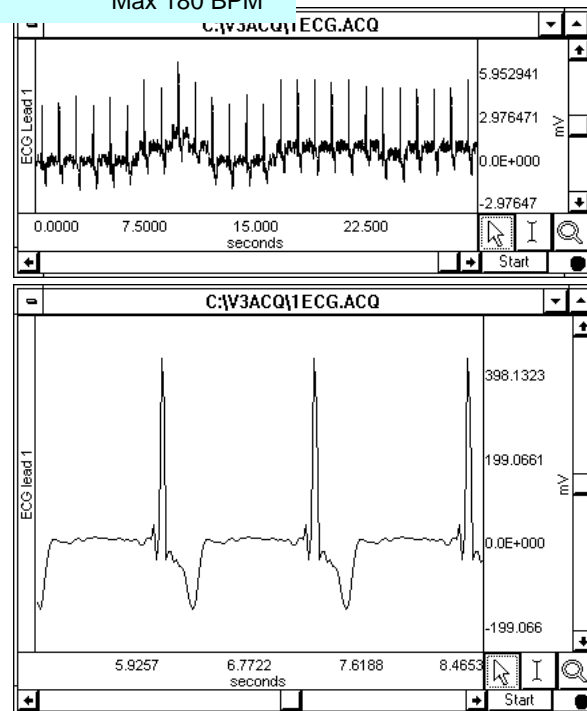
A simple peak detector uses what is called a *threshold-crossing algorithm*, whereby each time the amplitude (vertical scale) value exceeds a given value, the peak detector õremembersö that point and begins searching for the next event where the channel crosses the threshold. The interval between the two occurrences is then computed and usually rescaled in terms of BPM or Hz. This is how the BSL *PRO* rate Calculation functions when all options are unchecked.

In the sample waveform shown here, the threshold was set to 390 mV to detect the peaks of the waveform and provide an accurate rate calculation. Since it only recognizes signals greater than 390 mV as a peak, this 390-mV threshold is referred to as an õabsolute threshold.ö Most waveforms are not so well behaved, however, and artifact can be introduced as a result of movement, electrical interference, and so forth. Combined with actual variability in the signal of interest, this can result in õnoiseö being included with the signal, as well as baseline õdriftö which can render absolute threshold algorithms useless.

Additional Find Rate Dialog Settings, Output Tab
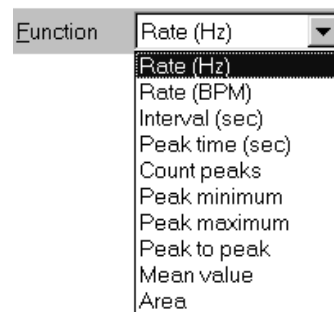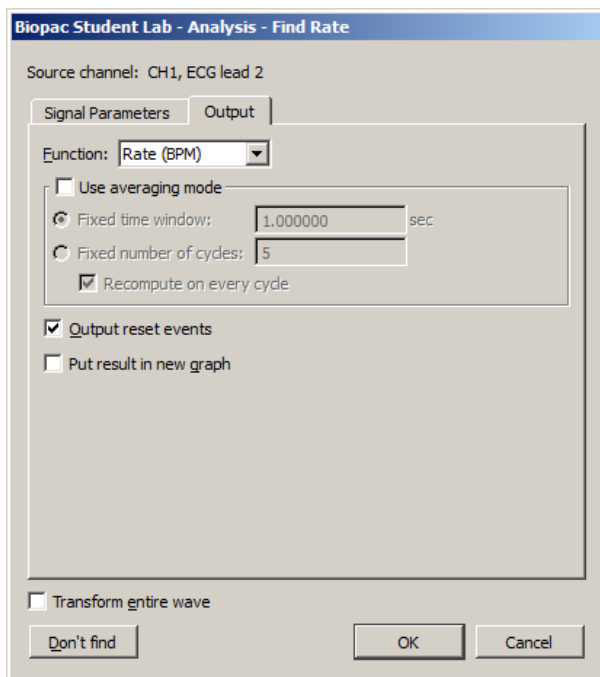
Function

The Rate Detector Function menu lists a variety of calculations, which are discussed below.

Rate (Hz), Rate (BPM), Interval (sec)

The most commonly used function is the Rate (BPM) option, which calculates a rate in terms of beats per minute or BPM. Rate calculations can also be performed that return a rate value scaled in terms of frequency (Hz) or time interval (sec). When rate is reflected in terms of a time interval, the time difference (delta T) between the two peaks is returned. This is sometimes referred to as the *inter-beat interval* (IBI). The frequency calculation returns the rate in Hertz (Hz), which is computed by dividing 1 by delta T. These measurements are perfectly correlated with the BPM calculation, since BPM is equal to 60 times the frequency calculation, or 60 divided by delta T.

Peak time

Returns the time (in seconds) at which the peak occurred. Like the other Rate functions (e.g., BPM and Hz), the value of the last peak time will be plotted until a subsequent peak is detected. The resulting plot will resemble a monotonically increasing õstaircaseö plot.

Count peaks

Produces a plot of the number of peaks (on the vertical axis) vs. time on the horizontal axis. When used with the delta measurements (in the measurement windows), this is a convenient way to calculate how many peaks occur within a selected area.

Peak maximum/minimum

Tracks the maximum value of the peak (the ECG R-wave). This correlates to the systolic pressure in blood pressure readings. To search for minimum peak values, select negative from the Peak detect section of the dialog.

Peak-to-peak

Looks at the vertical difference between the maximum and minimum values of the waveform on a cyclical basisô useful for determining the amplitude of the pulsatile signal.

Mean value

Computes the mean of a pulsatile signal on a cycle-by-cycle basis between two peaks; produces a staircase plot.

Area

Computes the area of the signal between two peaks, on a cycle-by-cycle basis.

Use Averaging Mode

Use this option to average the output of the selected function using values based upon a fixed time window or a fixed number of cycles. If the average is taken from a fixed number of cycles, there is an additional option to recompute on every cycle. When unchecked, the output will be reset after the selected number of cycles are detected and remain fixed until the next group cycles are detected. When checked, the output will start after the first cycle is detected and will then be refreshed on every cycle.

Output reset events

This option controls the definition of reset event insertion into the graph.

If no thresholds are found within the user-specified window width, the automatically detected threshold level will õresetö and tracking will start anew; the output of the rate detector function may also drop to zero. When õOutput reset eventsö is enabled, a reset event will be added to the channel whenever the threshold is reset due to window expiration

  ▪ This helps distinguish zero-valued output due to window resetting and true zero-value output.

In the sample shown, the signal drops to zero during a period of analysis (e.g., due to lead clip falling off). Reset events indicate automatic threshold tracking was in this interval and the points where the search for a new level begins.

lost
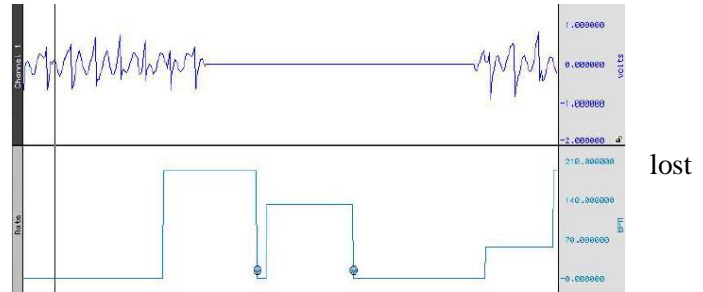
Put Result in New Graph

When this option is checked, the results from the find rate calculation are plotted in a new graph window with data displayed in X/Y format, with time on the horizontal axis. By default, this option is unchecked and the resulting transformation is placed in the lowest available channel of the current graph.

> **NOTE:** When put into a new waveform or used as a calculation channel, the output rate function uses padding to generate a signal at a continuous sampling rate. The extracted value is used for padding until the next cycle is detected. This padding can cause unsuitable weighting for statistical analysis. For accurate statistical analysis with only one value for each cycle, use the offline rate detector "show output in new window" to produce a "value" waveform with one output point for each cycle. This output is suitable for export to Excel or other software for statistical analysis.

Find Rate of Entire Wave

When this option is checked, the rate (or other function from the Find rate command) will be calculated for the entire wave (other than the selected area, if any).

Donø Find

Saves dialog settings on order to close out of the dialog and select an area. When the dialog is reopened, the earlier settings will be retained, after which the OK button can be clicked to perform the Find Rate function. This is useful for setting parameters using an area of a waveform and then repositioning the cursor at another point in the record.

Detect and Classify Heartbeats

This robust QRS detector is tuned for human ECG Lead II signals. It attempts to locate QRS complexes and places an event near the center of each QRS complex to identify the type of heartbeat event:

- Normal The beat was recognizable as a valid heartbeat falling in a human heartbeat rate.

- PVC The beat was shorter than the beats around it and may be a pre-ventricular contraction. These events can be found in the õHemodynamic > Beatsö submenu of the event type listing.

- Unknown The beat wasnøt recognizable as a valid heartbeat. This may occur on the first beat prior to the QRS detector locking onto the signal. It may also occur if tracking is lost due to changes in signal quality.

The Cycle/Peak detector may be used with these events to perform further cardiac analysis.

Locate ECG Complex Boundaries
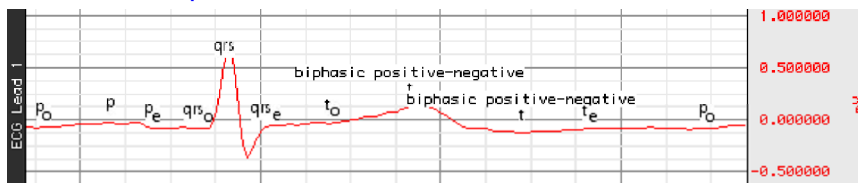
Locate ECG Complex Boundaries performs ECG waveform boundary detection for human ECG Lead II signals; ECG signals must be sampled at 5 kHz or below to be analyzed with this classifier. It will attempt to locate the boundaries of the QRS, T, and P wave and will define events for each individual complex. It will attempt to insert the following events; all of these complex boundaries can be found in the õHemodynamic > ECG Complexesö submenu of the Event Type listing.

Wave	Type	Event Placement & Description
QRS	Onset	Before the beginning of the Q wave
	Peak	At the top of the R wave
	End	After the end of the S wave
T-wave	Onset	At the onset of T
	Peak	At the peak of the T wave
		Note: This may not be a positive peak if the T-wave is inverted. If the T-wave seems to be bi-phasic, two T-wave events will be inserted and the event description will indicate that the T-wave is bi-phasic.
	End	At the end of T
P-wave	Onset	At the onset of P
	Peak	At the top of the P wave
		Note: This may not be the absolute maximum, but rather the likely center of P.
	End	At the end of P

The Cycle/Peak detector may be used with these events to perform further cardiac analysis.

Locate Animal ECG Complex Boundaries

Locate Animal ECG Complex Boundaries optimizes the ECG waveform boundary detection for animal input. Smaller animals such as mice often lack a detectable T wave, so in the setup dialog the T wave boundaries are disabled by default. If appropriate to the experiment, T wave detection can be applied by enabling the õDefine T wave boundariesö checkbox. The average heart rate can also be customized to reflect the normal range of a particular animal subject. (The default rate is 600 BPM.)

For information about the algorithm used in Locate Animal ECG Complex Boundaries, see page 313.

See the Locate Animal ECG Complex Boundaries video tutorial for a detailed explanation of this feature.

Heart Rate Variability

New parameter settings for the HRV algorithm function better on shorter ECG signals and correspond more closely with other implementations.
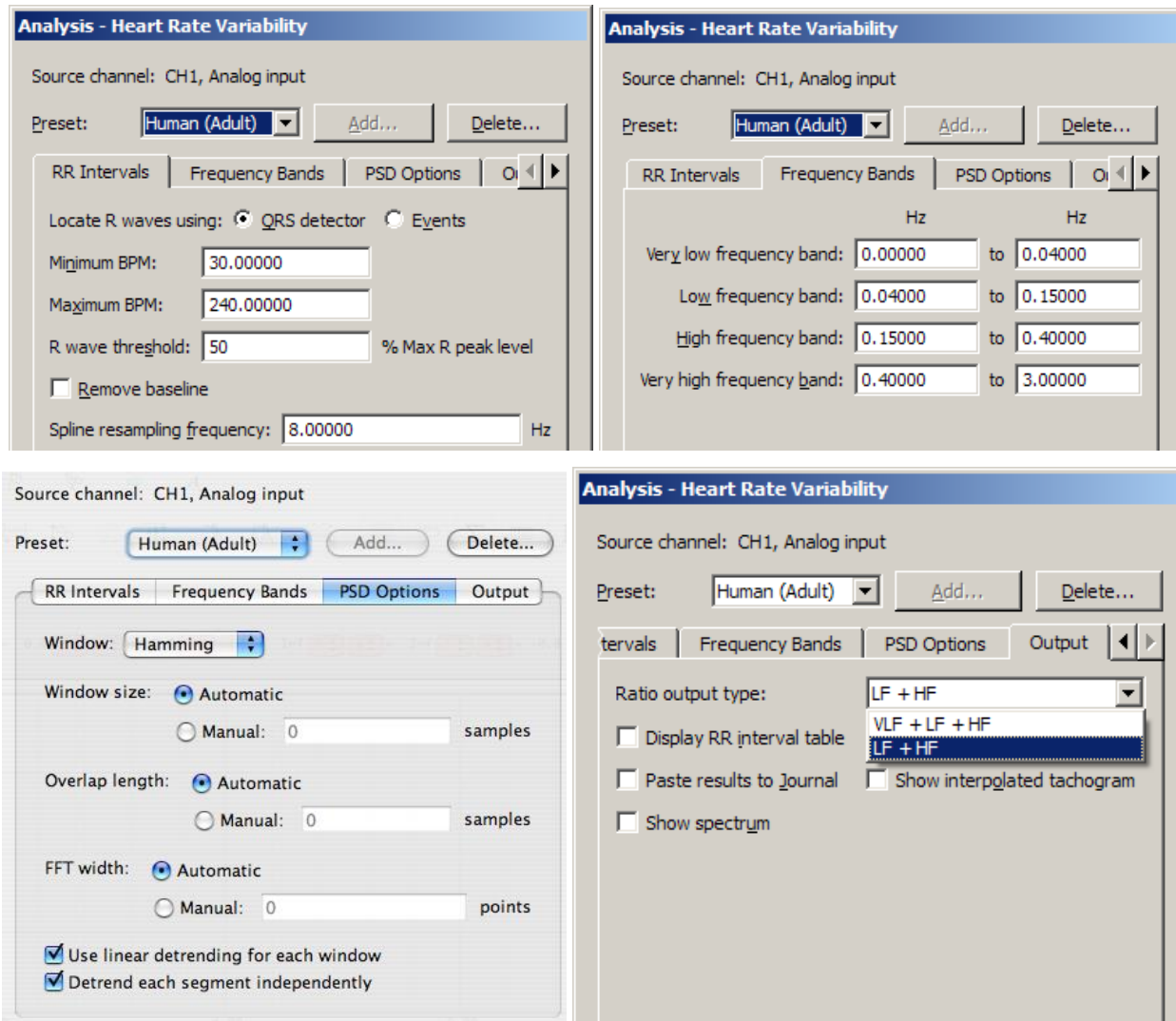
Heart rate variability is the examination of physiological rhythms that exist in the beat-to-beat interval of a cardiac signal. Heart rate variability assists in performing frequency domain analysis of human ECG Lead II data to extract standard HRV measures. The HRV algorithm in BSL *PRO* and above conforms to the frequency domain algorithm guidelines as published by the European Heart Journal. HRV processing in BSL *PRO* consists of three stages:

1. The RR intervals are extracted for the ECG signal.
    - A modified Pan-Tompkins QRS detector is used.
2. The RR intervals are re-sampled to a continuous sampling rate in order to extract frequency information.
    - Cubic-spline interpolation is used to generate this continuous time-domain representation of the RR intervals.
3. The frequency information is extracted from the RR intervals and analyzed to produce standard ratios. Power sums are reported in units of $\sec^2$.
    - A Welch periodogram is used to generate the Power Spectral Density (equivalent to Transform > Power Spectral Density).

The initial implementation of the HRV algorithm was primarily for use with long duration recordings. HRV algorithm improvements allow for further customizations to the algorithm:

- Windowing type for FFTs used to construct the PSD may be changed between Hamming, Hanning, and Blackman
- Overall window length for segmenting source data for individual FFTs to include in PSD average may be modified
- Length of the individual FFTs in the average can be manually specified
- Scaling has been changed for PSDs, which are now scaled relative to the sampling frequency
- Summary of power in individual frequency bands has been changed
- Instead of a straight sum, an average power value is now reported
- Power at endpoints is halved (e.g. divided by 2)
- Sympathetic/Vagal ratios may optionally include the very low frequency band in the total power estimate
- The modifications to the HRV algorithms that affect its power spectrum estimation have also been applied to the PSD transformation.

After selecting Analysis > Heart Rate Variability, choose the appropriate tab(s) and establish settings.

Preset controls, Transform entire wave checkbox, and OK/Cancel buttons apply across all of the tabs.

> **Preset**ô The preset menu can be used to save a variety of HRV settings, including: beat detection parameters, spline resampling frequency, and frequency band ranges. Choose a preset from the popup menu to apply its settings. To construct a new preset with the currently displayed settings, choose Add New Preset. A default preset for adult human subjects is supplied.

IMPORTANTô Recording good data is essential for performing HRV analysis. The protocol for data acquisition, filtering, artifact detection and correction in Application Note 233 results in great improvements in HRV analysis.

> õResults reveal that even a single heart period artifact, occurring within a 2-min recording epoch, can lead to errors of estimate heart period variability that are considerably larger than typical effect sizes in psychophysiological studies.ö ô Berntson & Stowell, 199

- See **Application Note 233 Heart Rate Variability—Preparing Data for Analysis Using BSL *PRO* (online at www.biopac.com)**

The note explains how to optimize ECG R-R interval data for Heart Rate Variability studies by using a template matching approach. It also explains how to identify erroneous R-R interval values caused by signal artifact and shows methods for correcting the errors by using the tools in the BSL *PRO* software. The note explains how to:

A. Record good ECG data
B. Prepare data for the tachogram
   1. Filter the ECG data
   2. Transform the data using Template Correlation function
C. Create a tachogram
D. Identify problems with the tachogram data
E. Correct tachogram data

RR intervals

Select a method to locate R waves: QRS Detector or Events.

QRS detector

The heart rate variability implementation has a built-in QRS detector. The detector does not run on raw source data; it uses a modified Pan-Tompkins algorithm to normalize the ECG data to 1, whereby the peak amplitude of the highest R-wave represents 1. Use the tachogram output to examine the output of the QRS detector.

▪ *R wave threshold*ô Starting with BSL *PRO*, the detection threshold must be specified in terms of percentage of maximum R peak level; this helps to clarify the units in which this threshold is expressed. The default threshold level of .5 should place the threshold in the middle of the R-wave, which should function on a wide range of data sets. If the R-wave amplitude varies a lot, it might be necessary to adjust the threshold level.

  o R wave threshold is expressed in normalized units, which are in the range (-1, 1): positive for positive R wave peaks. The maximum voltage in the signal maps to 1.0 and the minimum voltage in the signal maps to -1.0.

  Pan J and Tompkins WJ. A Real-Time QRS Detection Algorithm. *IEEE Transactions on Biomedical Engineering* **32**(3):230-236, 1985.

Events

R-wave peaks will be located using events already in the graph of the channel of data to be analyzed. This assumes a single event is placed at each R-wave peak and that all of the R-peak events are of the same event type. When using events, the buit-in QRS detector is not used; the exact positioning between the events on the channel is used to extract the RR intervals.

By using events, it is possible to use other QRS detectors within BSL *PRO* for performing HRV analysis. It is also possible to apply spectral HRV-style analysis to data in other domains as long as intervals can be reduced to events.

Spline resampling frequency

For highest accuracy, set to no less than twice the topmost frequency of the very high frequency band.

Frequency Bands

Enter the start and end of each specified frequency band to adjust the boundaries of the frequency analysis. They are preset to the frequency ranges recommended by the *European Heart Journal*. Output of derived parameters is presented in a dialog and may also be pasted as text to the Journal.

▪ Very high frequency band, usually used in rat studies, is disabled if the spline resampling frequency is less than the upper bound of the very high frequency range.

PSD Options

PSD Options establish parameters for the power spectral density transformation used to compute the spectrum from the interpolated tachogram; the options contained in this tab mirror the controls of the Analysis > Power Spectral Density transformation.

The use of linear detrending in each individual segment of source data prior to the windowed periodogram analysis can be enabled or disabled. When disabled, the algorithm may be tuned to correspond to implementations that do not apply linear trending, such as MATLAB, which uses windowing only. The same PSD options are available via Analysis > Power Spectral Density so users can regenerate the spectrum from either the raw or interpolated tachogram output as necessary.

After the user modifies the parameters for the PSD transformation, those parameters will become the new default values each time the dialog is displayed. When the application is relaunched, the default settings will be used (user changes are not persistent).

Window   Used to change the window that is applied to each segment of the source data prior to computing the PSD to be included in the average. Includes the following options:

<div align="center">

Hamming   Hanning   Blackman

</div>

Window size   The specified number of samples must be a power of two. Note that the window function is applied to the entire window width of the data; using a subset of the windowed data will not include the final portion of the windowed data.

- If the FFT size is less than the window size, only a subset of the windowed sample data will be used.

Automatic   If selected, the window size is selected automatically depending on the size of the source data. For a data length of *n* samples, choosing this radio button will use the window size:

$$L = \frac{n}{4.5}$$

Manual   If selected, the window size will be input manually by the user in the associated edit field. The window size must be greater than three and must be less than the length of the data selection. Users will be warned on invalid window sizes when attempting to click OK.

Overlap length   After each individual FFT, the window of source samples is shifted over by a certain amount to compute the next FFT, so there is an overlap of source samples in successive windows of source for the next FFT in the average.

Automatic   If selected, the number of samples to overlap successive windows will be computed automatically. Given a window length *L* computed according to the window width choices, choosing this radio button will use an overlap number of samples:

$$\frac{L}{2}$$

Manual   If selected, the number of samples to overlap successive windows of source data. Overlapping reduces windowing artifacts The overlap length must be positive and must be less than the window size. Users will be warned on invalid overlap lengths when attempting to click OK

FFT width   Automatic   If selected, the number of points to use for each individual FFT will be computed automatically. Given a window length *L* computing according to the window width choices, the number of points in the FFT will be set to:

$$N_{fft} = \left\{ \begin{array}{l} 256, L < 256 \\ 2^{\lceil \frac{\log(L)}{\log(2)} \rceil}, L \geq 256 \end{array} \right\}$$

- The number of points in the FFT is set to 256 if the window width is less than 256. Otherwise the length is set to the next power of two higher than the window width.

Manual   If selected, the number of points in the FFT will be specified manually in the edit box to the right of the radio. The number of points in the FFT will be required to be a positive power of two. It is recommended that the FFT length be set larger than the window size. If longer than the window size, zero point padding is used. Users will be warned on invalid FFT number of points when attempting to click OK. If the user inputs a number of points for the FFT that is shorter than the window width, a confirmation dialog will be displayed to the user warning that the windowing is shorter than the requested FFT width and asked if they want to continue.

Use linear detrending for each window	When enabled, linear regression detrending is applied for each individual segment prior to the FFT computation. When disabled, windowing only is applied.
Detrend each segment independently	*This option is only available when "Use linear detrending" is enabled.* When this option is enabled, detrending is applied independently for each segment; when disabled, detrending from the previous segment will be incorporated into the next segment.
Transform entire wave	When enabled, the entire waveform is delayed. When unchecked, only the selected area is delayed.

- If there is no selection in the graph, the checkbox is enabled and dimmed.

- As the selection changes in the graph with the selection palette, the state of this checkbox is updated.

Output

Create standard result presentation graphs or assess performance of the HRV algorithm. Output options allow access to intermediate computation data for algorithm validation and/or measurements.

RR Interval table

- If the combined output formula is selected, the analysis output will contain an additional line of text: õVLF Ratioö with the corresponding percentage.

Spectrum

Displays the power spectrum density (PSD) estimation from which the PSD summations and sympathetic/vagal ratios are computed.

Raw tachogram

Plots the raw R-R intervals found by the QRS detector. Perform statistical HRV measures on the R-R intervals without exporting the textual R-R table to excel.

Interpolated tachogram

Plots the resampled R-R intervals after cubic spline interpolation is applied and extracts the PSD from this data.

Correlation Coefficient
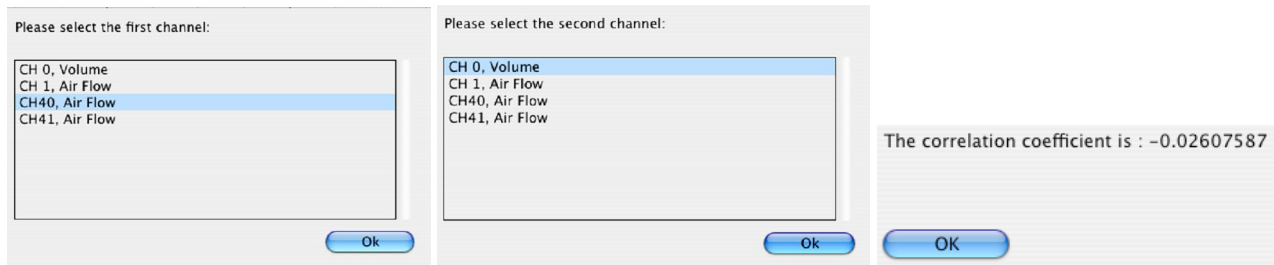
The *correlation coefficient* is a statistical measure related to the degree of variance or covariance between two data series. Given two data series x and y of length n, the correlation coefficient r is given by the formula:

$$r = \frac{n \sum x\,y - \sum x \sum y}{\sqrt{\left[n \sum x^2 - (\sum x)^2\right]\left[n \sum y^2 - (\sum y)^2\right]}}$$

(see http://mathworld.wolfram.com/CorrelationCoefficient.html)

The square of the correlation coefficient can be used to determine the proportion of variance in common between the two signals. As the square gets closer to 1, the signals are a better statistical match for each other.

To derive the correlation coefficient, two channels of data are compared against each other.

- the channels must have the same length
- the channels must have the same waveform sampling rate
- all of the data of the entire graph for the two channels will be used to compute the correlation coefficient.

Digital Input to Stim Events

Digital Input to stim events identifies and labels stimulus events corresponding to any combination of digital inputs. A light bulb icon is placed in the global events bar, the event is labeled with the stimulus event type, and the mouse-over tag includes the event time. All event information is accessible and exportable from the Event Palette.
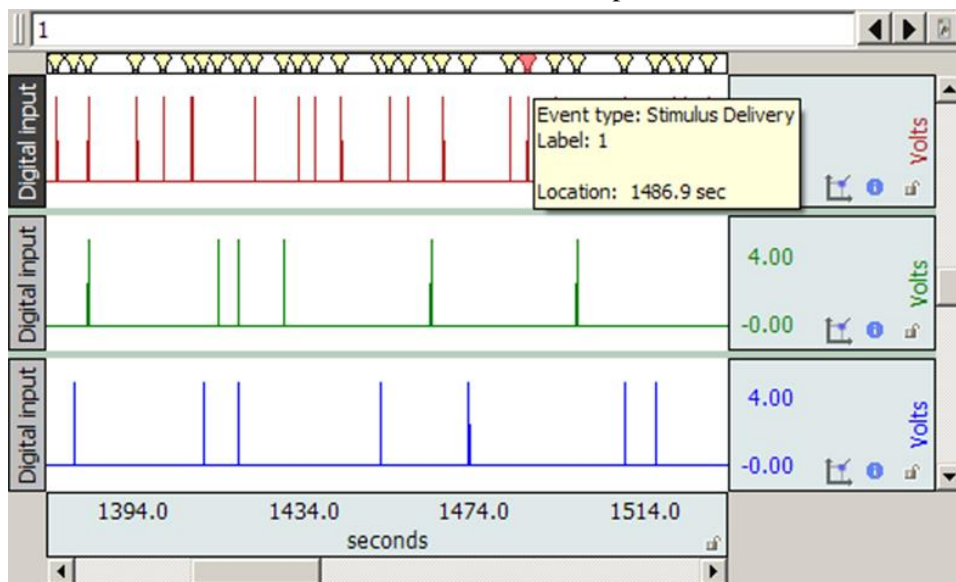
The Digital input to stim events function works with TTL trigger information coming from applications such as E-Prime®, SuperLab®, DirectRT®, MediaLab®, Inquisit®, and Presentation. It converts TTL data acquired on the digital channels of a hardware device into stimulus events. The system also works with analog and calculation channel signals coming from switch transducers. Unlike TTL signals, a voltage threshold level is used to determine the transition from low to high.

This analysis option converts TTL or switch data acquired on hardware into stimulus events. Stimulus delivery events are defined in the graph for each low to high transition of the digital data, the indications of stimulus delivery. The digital channels are interpreted as a binary number. Each stimulus event placed into the graph has the corresponding number included with its label. This allows further analysis to distinguish between different types of stimulus events by using the Cycle Detector's label matching capability.

"Specific channels only" dialog
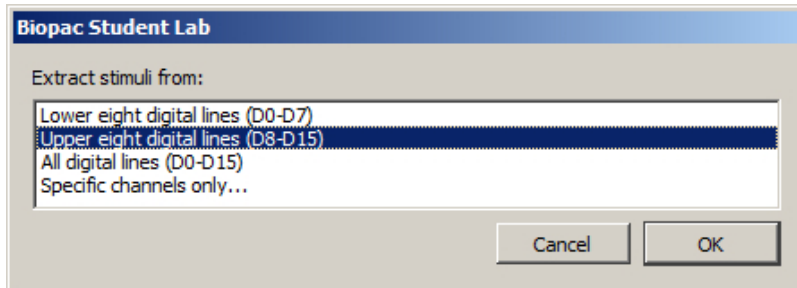
Digital line decoding can be two byte (using all 16 digital lines) or single byte (on either the low eight or high eight digital lines). Big endian bit and byte ordering are used, with digital line 0 representing the least significant bit.

When the stimulus labels are constructed, all numbers are zero-prefixed. All stimulus events will have the same number of base-10 digits with leading zeros, regardless of magnitude. This provides each stimulus event type with a unique label that can be used with the Cycle Detector (which uses substring matching).

Some systems that trigger digital lines such as parallel ports may not be able to do so instantaneously; they may require a time window before the transition from one state to another is fully complete. A "transition latency" time window can be given to the analysis, specified in microseconds, milliseconds, seconds, minutes, hours, or samples.

If non zero, any transitions that are separated by less than this latency are treated as a single transition and only one stimulus event is inserted. The decoded value used for the transition is the maximum value observed during the transition latency window. In the following example graph, the three digital TTL inputs correspond to one event, as marked by the red icon in the global events bar. A transition latency of .5 seconds will consider all three as part of the same event since the transitions occur within .5 seconds of each other.
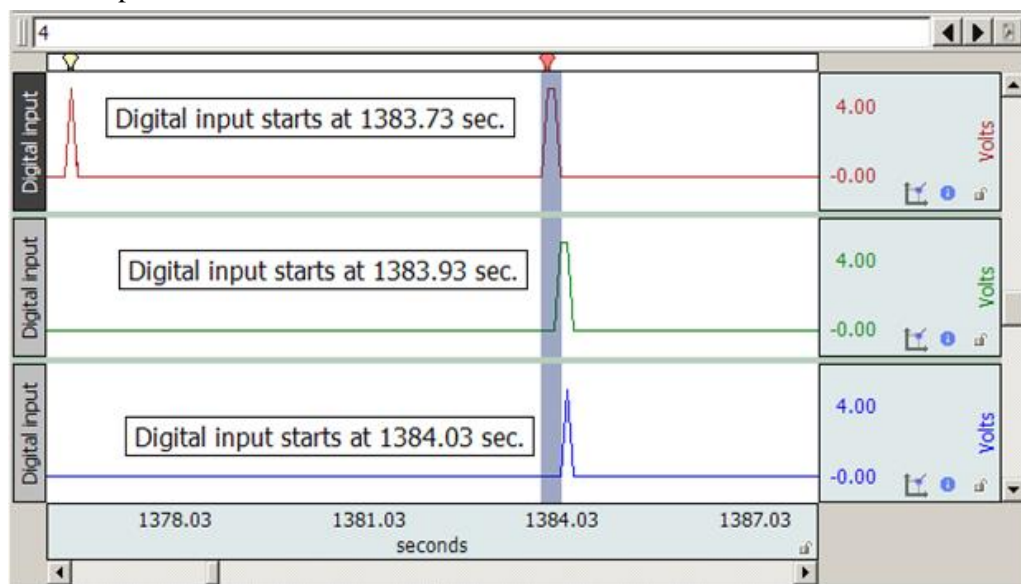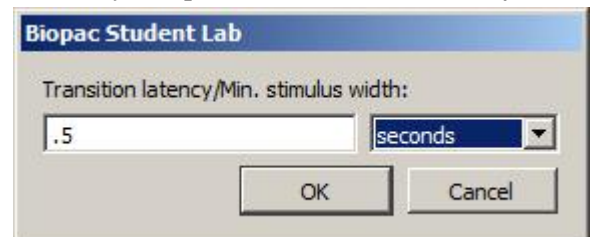
Watch the Digital Input to Stim Events video tutorial for a detailed demonstration of this feature.

Ensemble Average
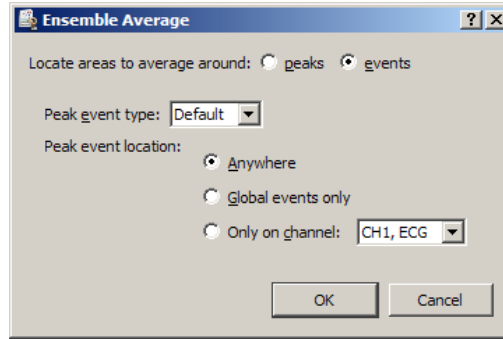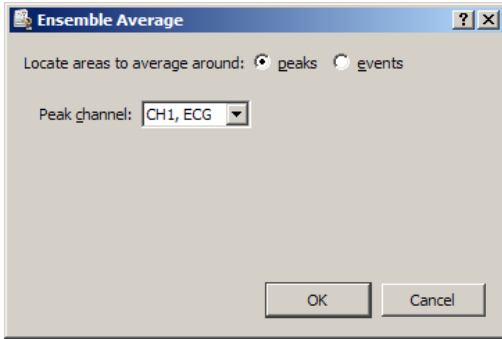
Ensemble Average assists in performing offline averaging. Offline averaging produces an average waveform from a number of cycles, also known as an *ensemble average*. Averages of multiple channels can be extracted simultaneously and be consolidated into a single graph window showing the results.

This option provides two methods for locating individual members of the ensemble.

⮕ **Peaks**: Data-driven peak detection with positive or negative peaks in the data. This method automatically derives appropriate threshold levels from a user-selected peak and is useful for constructing averages keyed to periodic signals with strong spikes, such as ECG.

⮕ **Events:** Place members of the ensemble surrounding events in the waveform. Events must be previously defined by the user, either manually or through another automated process. This method is useful for constructing averages keyed to any types of events in a graph.
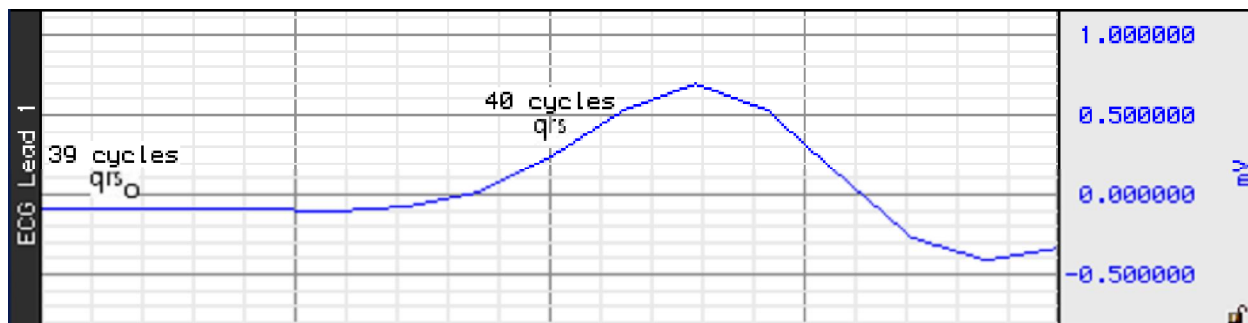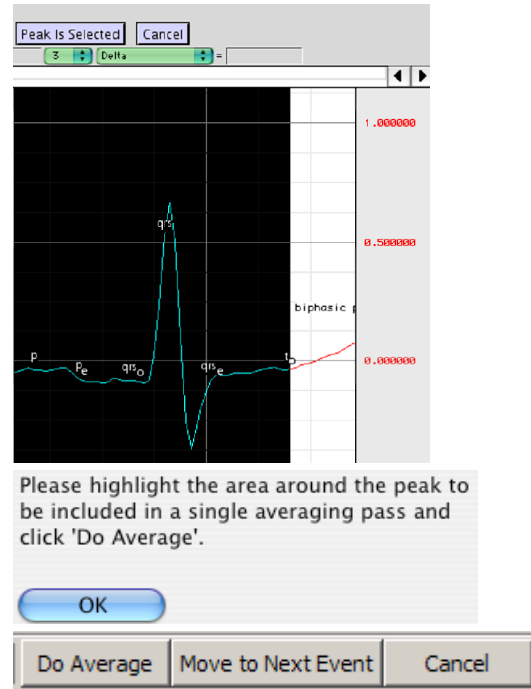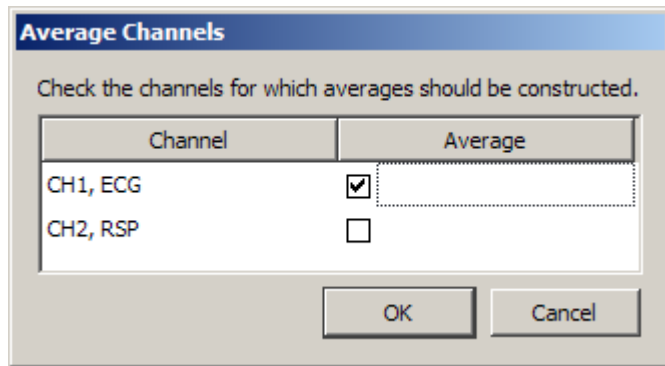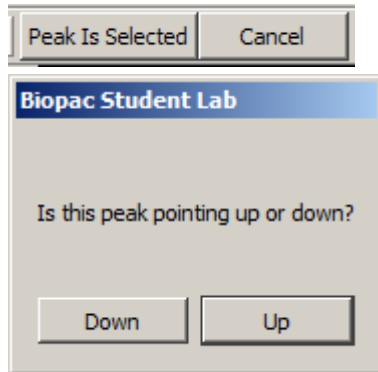
Epoch Analysis
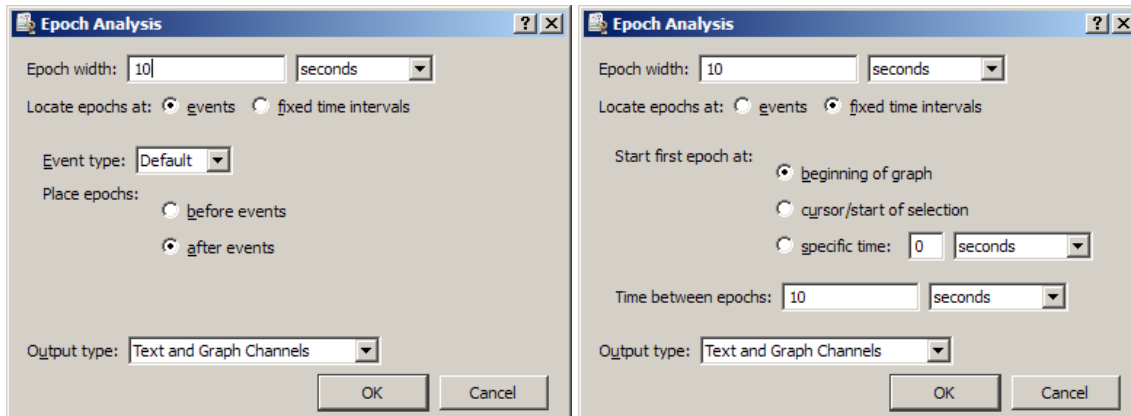
Extracts basic measures from fixed-width time segments of data. A fixed-width time segment of data is known as an *epoch*. The location of these fixed-width intervals can either be keyed off of locations of events in the graph or tied to regular time intervals (e.g. occurring at a constant frequency). All of the standard BSL *PRO* measurements can be extracted on an epoch-by-epoch basis with the exception of calculation measurements.

Epoch-by-epoch measurement results can be viewed either as channels of data in the graph, a textual summary, or on an Excel spreadsheet; textual summaries include a final row with an overall average of each extracted measurement.

Times output by Epoch Analysis are always expressed in seconds; all other units correspond to the current preferred measurement unit settings accessible under Display > Preferences.
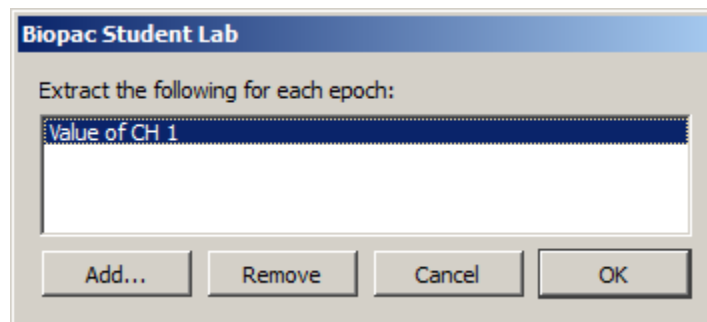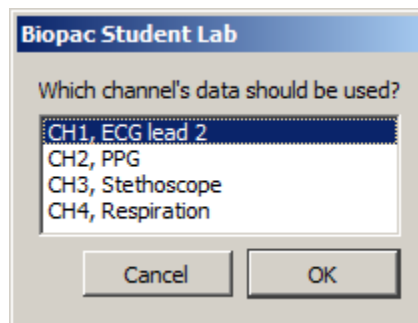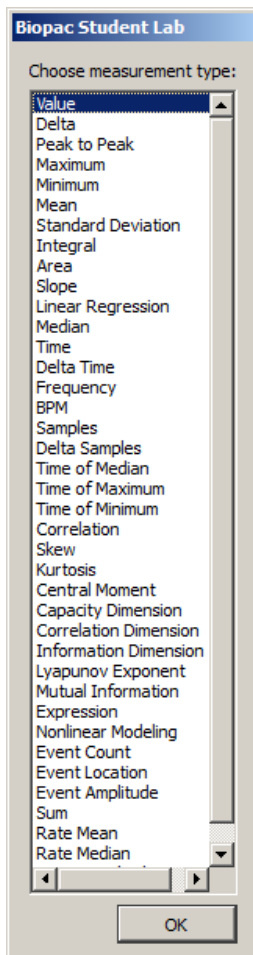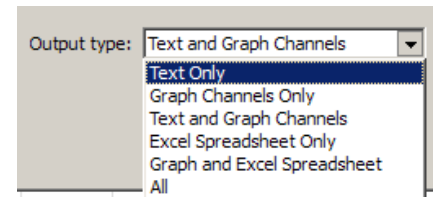
Focus Areas between Events and Segments

In addition to the standard focus area functionalities discussed on page 44, focus areas can also be used as an analysis tool to define areas of interest between certain event types or between appended segments.

Define Between Events

The parameters for defining focus areas using this method are highly customizable, and can be based upon specific event types or titles as well as various event locations in the graph. The following table explains the various focus area start and end event options.

<table>
<tr>
<td>

</td>
<td>

Focus area label basename:

Use to assign a title for the focus areas. Successive focus areas will use the same title with the addition of incrementing numbers.

Event type:

Use to select the type of event for defining the focus area.

Location:

- **Anywhere**ô all channel and global events are included in the event matching criteria.

- **Global**ô when selected; only global events are included.

- **Channel**ô when selected; only events in an individual channel are included. Select the desired channel from the combo box menu.

Event labels must match:

When checked, only events with labels matching the edit field text will be defined. When unchecked, all events of the selected type are matched, regardless of label.

</td>
</tr>
</table>

Define for Appended Segments

This method simply defines the time range between appended segments as focus areas. No configurable options exist for this feature within the Analysis menu.

Waterfall Plot

Assists in configuring the Peak Detector for 3D surface generation. These surfaces showing cycle-by-cycle data of the graph are commonly known as *waterfall plots*. Cycles are located in the graph using the same sequence of steps as the Ensemble Average transformation script. Instead of generating the averaged graph, however, a number of 3D surfaces are generated. One surface is generated for each channel that is selected by the user.

ECG Analysis Algorithm References

BSL *PRO* software implements the open source ecgpuwave ECG boundary location software and the open source OSEA QRS detector and beat classification library for ECG analysis.

Automated ECG Waveform Boundary Location

➲   ecgpuwave ECG boundary location software

BSL *PRO* software incorporates the ecgpuwave ECG boundary location software. Ecgpuwave is an implementation of a waveform boundary detection algorithm primarily developed by Pablo Laguna at the University of Zaragoza in Spain. This algorithm incorporates a variant of the Tompkins QRS detector, but contains additional rules that allow it to automatically extract the following characteristics of an ECG signal on a cycle by cycle basis: onset of P, P peak, end of P, onset of QRS, peak of QRS, end of QRS, onset of T, peak of T, and end of T.

The algorithm is tuned to human ECGs through comparison with manual classification. Particularly, it seems to be within the standard deviation of human examiners for the onset and end of T waves, a particularly difficult feature to extract from an ECG complex. It also has the ability to take multiple ECG leads into account to reduce errors and misclassifications and appears to function for one to twelve lead ECGs. The algorithm is well documented in a number of papers. This algorithm development was sponsored by several government agencies including CICYT in Spain and the NIH.

The ecgpuwave tool is distributed from the PhysioNet NIH servers (http://www.physionet.org). This is a tool written in Fortran that will read WFDB formatted files. It will then output a series of annotations in WFDB format indicating the locations of the various ECG complexes within each cycle. It also depends on another tool, sortann (available from PhysioNet), to perform post-processing. This software reads and writes PhysioBank formatted files.

BSL *PRO* can automate the process of running ecgpuwave on source data and import its output back into BSL *PRO*. To run ecgpuwave on an ECG signal from within Acq*Knowledge*, select the ECG channel as the active channel and then choose õAnalysis > Locate Human ECG Complex Boundariesö*. BSL *PRO* will execute ecgpuwave on that signal and read in its waveform boundary location output, placing events on the channel. This output will only be visible if events are shown.

Alternatively, save the file to PhysioBank format, run ecgpuwave manually from a Terminal, save the annotations to õatruthö and then reopen that PhysioBank file to see the ecgpuwave results. This is the same process that BSL *PRO* performs.

*To apply the proper algorithm for animal subjects, choose õAnalysis > Locate Animal ECG Complex Boundaries.ö

Chapter 15   Display Menu Commands

Overview

The Display menu includes a number of features that control how the waveforms appear on the screen and how much data is displayed at a time.
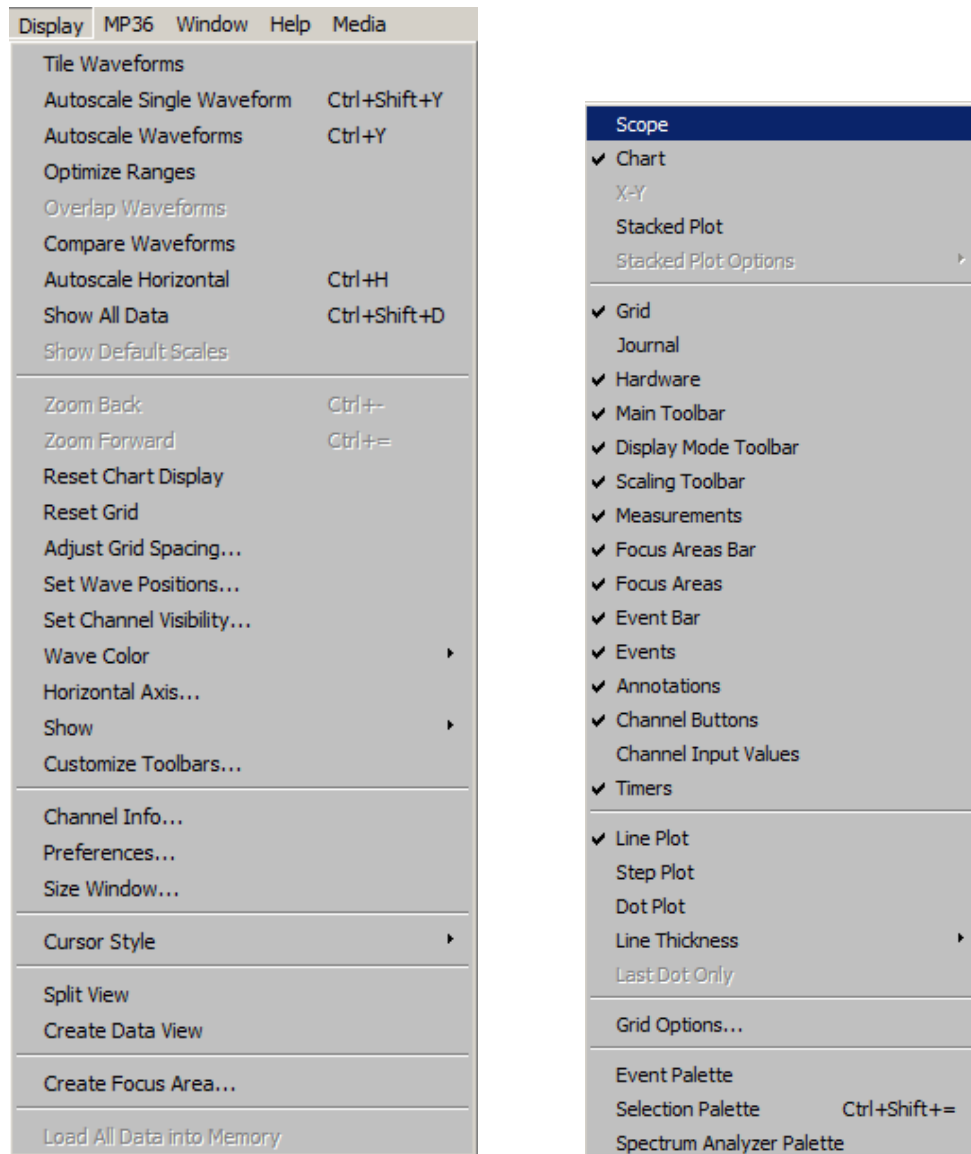
Display menu and Show sub-menu

Although these options change the appearance of the data, they do not change the data itself. In other words, changing the color of a waveform or showing only a portion of the data on the screen will not alter the data stored in the file.

See the following shortcut options for Display menu commands:

- Toolbar shortcuts, page 51
- Context-sensitive shortcutsô page 63

Tile Waveforms

Tiling is an operation performed on all waveforms to visually separate them on the screen. Tile Waveforms adjusts the vertical offset to center waveforms in the display; if there are multiple waveforms displayed in chart mode, the waveforms will be centered in their õtracks.ö Tiling does not adjust the scale of the waveforms; it only affects the midpoints of the visible portion of the waveform. Tiling does not affect the vertical scale factor previously set for each channel (whereas Autoscale may affect the vertical scale factor as well as the offset).

In Scope mode, tiling staggers the midpoint of the channels to visually separate them on the screen while maintaining their scales. In Scope mode, waveforms are spaced evenly along the vertical axis of the screen, and each waveform is centered vertically in its division.

To apply tiling only to the selected waveform, hold down the CTRL key on Windows or the Option key on Mac OS before selecting Tile Waveforms. In scope mode, waveforms are spaced evenly along the vertical axis of the screen, and each waveform is centered vertically in its division. Tiling does not affect the vertical scale factor previously set for each channel (whereas Autoscale may affect the vertical scale factor).

When grids are locked, tiling will retain the appropriate heights and percentages.

When grids are unlocked, the scale may be slightly larger in order to optimize the tick marks displayed on the vertical axis.
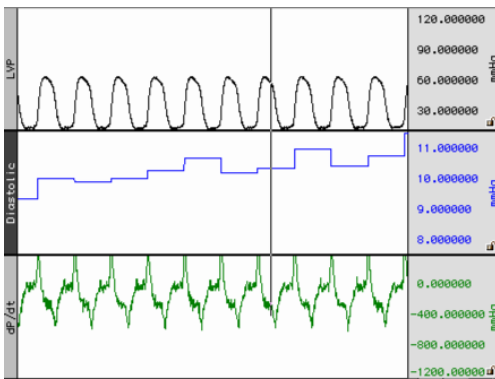
Before Chart mode tiling
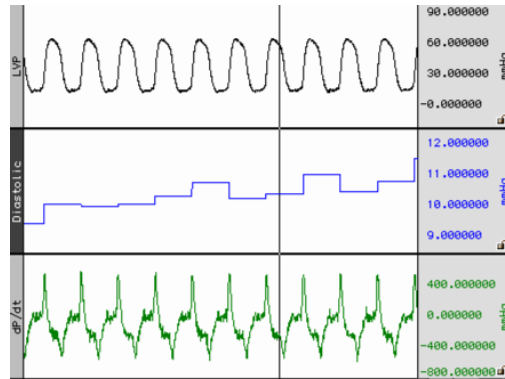
After Chart mode Tiling
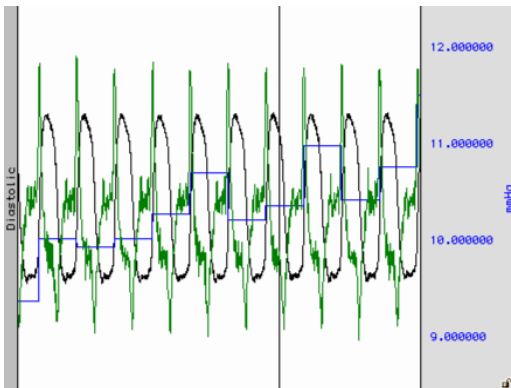
Before Scope mode tiling
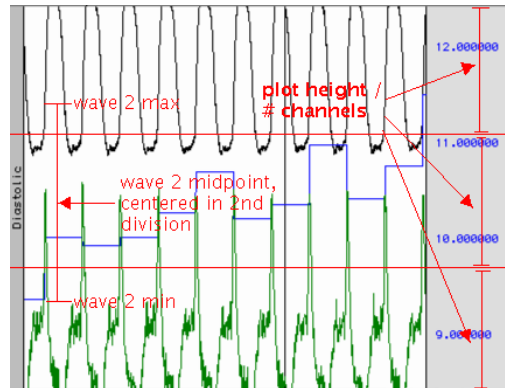
After scope mode Tiling (red lines for illustration only)

Note that the waveforms are centered relative to the horizontal divisions of the plotting area; the range and midpoint of the second waveform (blue square wave) are indicated in the figure above.

Autoscale Waveforms

The primary use of Autoscale is to make all of the data of the channel within the current time range visible on the screen.

When Autoscale Waveforms is selected, BSL *PRO* determines what the õbest fitö is for each displayed waveform. The percentages and midpoints are identical whether grids are locked or unlocked.
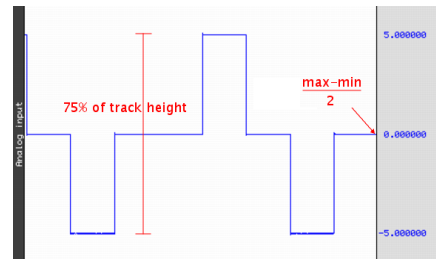
The software adjusts the vertical offset so that each channel is centered in the window (or within the channel track in chart mode) and adjusts the units per division on the vertical axis so that the waveform fills approximately two-thirds of the available area. In chart mode, the waveforms are autoscaled to fit their sections. In scope mode, the screen is evenly divided into horizontal õbandsö and each waveform is scaled to fit the division without overlapping.

➲ The autoscaling algorithm for Chart mode and X/Y mode is:

1. Find maximum value of the channel in the time area, *max*.
2. Find minimum value of the channel in the time area, *min*.
3. If grids are locked, adjust scale such that *max-min* occupies 75% of the channel's track in Chart mode, or 75% of the entire plotting area X/Y mode.
4. Adjust the midpoint so (*max-min*)/2 is at the vertical center of the channel's track in Chart mode, or vertical center of the entire plotting area in Scope and X/Y modes.
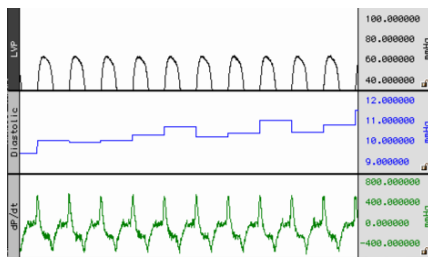
Before autoscaling LVP channel   After autoscaling LVP (red lines for illustration only)
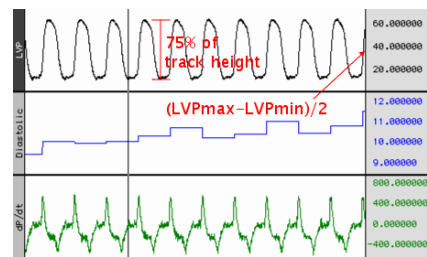
➲ The autoscaling algorithm for Scope mode is:

1. Divide the plot height into *m* equal sections of height *h* each.
2. Assign each visible channel to one of these plot sections.
3. If grids are locked, Scale the waveform such that the range between the max and min values will occupy 75% of *h*.
4. Place the midpoint between the max and min at the center of the waveform's section.

In scope mode, the screen is evenly divided into horizontal õbandsö and each waveform is scaled to fit the division without overlapping.

Note: Autoscaling a single channel in Scope mode results in that channel occupying 1 / (num_visible_channels) of the overall waveform plotting area. It will be placed in the region of the graph that corresponds to its position in Chart mode.

See following page for examples of autoscaling in Chart and Scope modes.

Active Channel 2, Chart   Active Channel 3, Chart   Active Channel 1, Chart

Scope Mode without Autoscale

Same As, except Label is ECG

Same As, except Label is ECG

Active Channel 2   Scople Mode > Autoscale Single Waveform   Active Channel 1
                       Active Channel 3
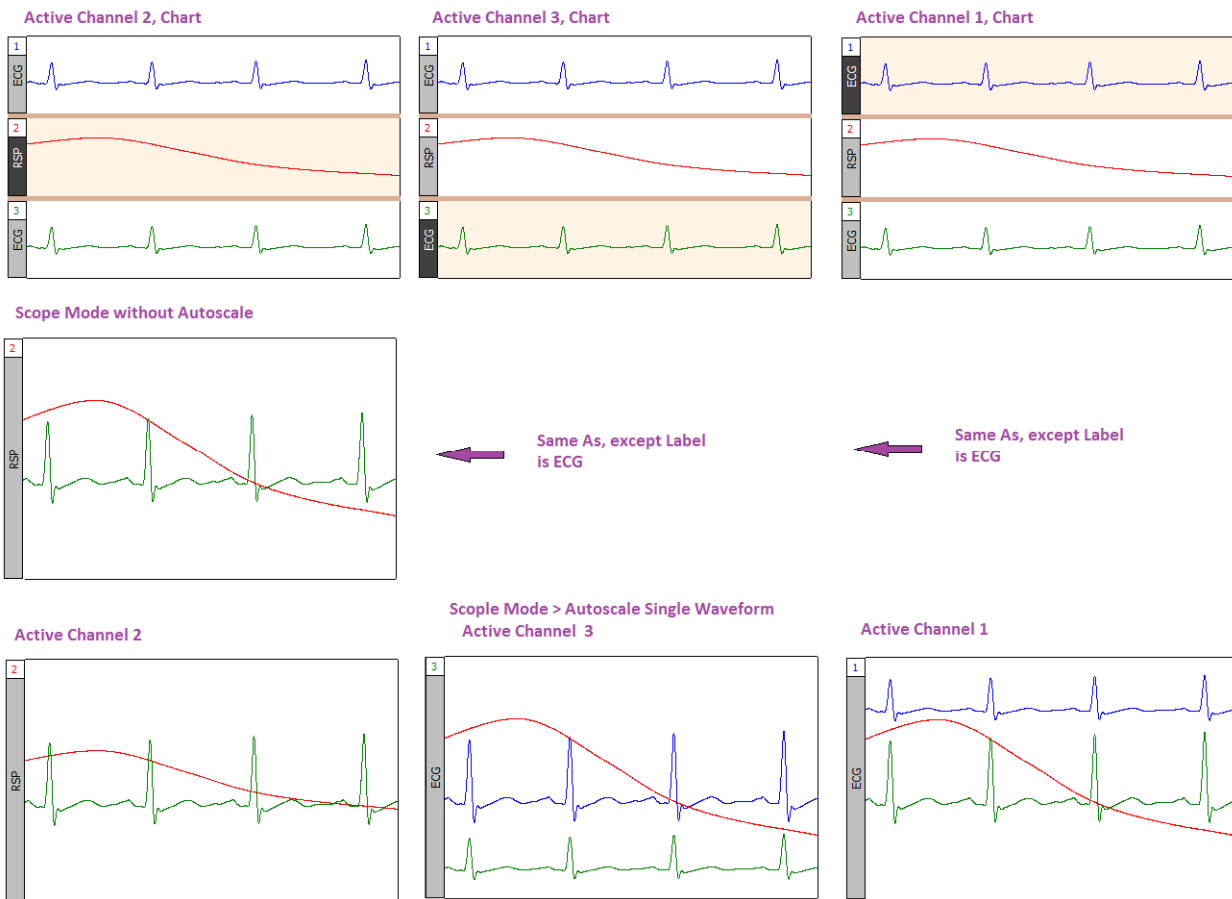
Autoscale Single Waveform

Use this option to perform the above autoscaling operations on a single selected channel rather than on the entire graph.

Optimize Ranges

When Optimize Ranges is selected, the Vertical Scales will be automatically adjusted for all channels that have a Range Guide (green band) showing, such that the range limits are set to the upper and lower viewable limits of the Vertical Scales. This allows the total Range of each input channel to be displayed. This menu item is active when data is present AND at least one data channel has an active Range Guide.

This item is also selectable using the toolbar icon or the right-click mouse shortcut. When selected with the icon or the right-click, this item only optimizes the Range Guide of the active channel. To optimize the ranges for all channels using this toolbar button, hold down the Ctrl or Alt key while clicking it.

Note: The Range Guide is the green vertical band that appears in the Vertical Scale region for analog input channels only (not for duplicated, copied/pasted, or Calculation channels); see page 70.

Overlap Waveforms

Overlapping waveforms places all of the waveforms at the same scale and midpoint so that the plotting location of a specific voltage on screen is at the same spot for every channel. Overlapping is useful for examining closely associated waveforms, such as the calculated diastolic, systolic and mean calculation channels õoverlappedö with the raw blood pressure waveform from a continuous blood pressure signal.

In scope mode, when Overlap Waveforms is selected, the waveforms are õoverlappedö into one screen. All of the currently displayed waveforms are arranged in the graph window with the same vertical scale and offset so all the displayed waveforms will fit on the graph; their magnitude reflects their size relative to the other waveforms. The overall chosen scale for all the displayed waveforms will be a function of the pk-pk value of the combined waves

Compare Waveforms

Compare Waveforms displays all of the channels with the same amplitude scale. Compare Waveforms automatically sets the vertical scale to be the same for all channels and adjusts each channel offset so that all displayed waves are centered in the display. The scale for all the displayed channels is determined by the channel with the largest pk-pk range in the display interval. Compare Waveforms is useful for gauging the relative amplitudes of a number of channels by placing them all on the same amplitude scale and discounting the effect of waveform offset (or baseline).

➲ In Chart mode, Compare Waveforms functions on each channel in its track.
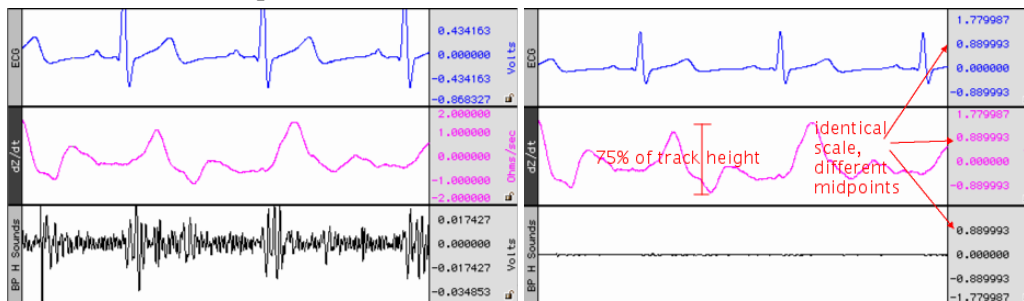
➲ In Scope mode, the channel scaling is similar but disperses the channels through the plot area similar to tiling. For a graph with *m* channels being plotted:
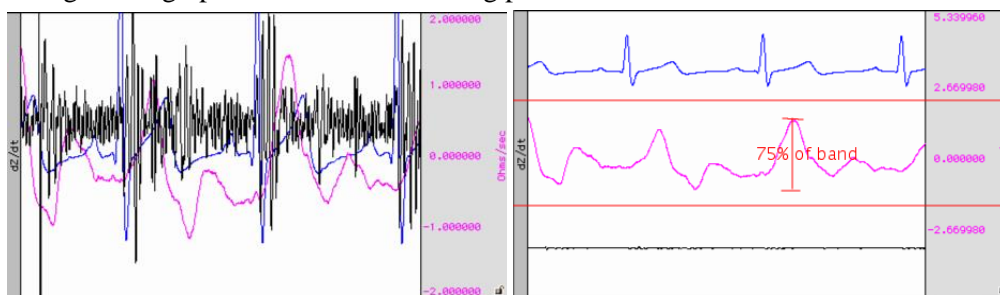
Autoscale Horizontal

The Autoscale Horizontal command is a convenient way to display the entire data file (in terms of duration) on the screen. When this is selected, the display will be adjusted so that the duration of the entire waveform fits in the graph window. For long waveforms, this can take some time to redraw.

An Autoscale Horizontal function cannot be reversed with Edit > Undo. To revert to the previous display settings, use the Display > Zoom back command.

Show All Data

The Show All Data command enhances the view by autoscaling first horizontally, then applies an õautoscale all waveformsö operation. This enables all vertical and horizontal data in the entire graph to be displayed for easy viewing.

Show Default Scales

This option will resets a graphøs vertical and horizontal scaling parameters to the default settings used when the graph was first opened.

Zoom Back / Forward

Zoom functions can affect the horizontal scale, the vertical scale, or both. Zoom restoration is functional for the Zoom tool, Autoscaling, and the Tile, Overlap, and Compare Waveform options. Zoom scales are stored until another zoom function is performed. Zoom scales are stored until another zoom function is performed. Multiple levels of Zoom are supported.

▪ Zoom Back will restore settings one level at a time.Tthis selection can be repeated to restore the original zoom scales. Essentially, Zoom back acts as an õundoö command for the zoom forward command and any other function that changes the amount of data displayed (either in terms of time or amplitude)

▪ Zoom Forward will redo a zoom function after it has been undone. This selection can be repeated to restore the latest zoom scales.

Zoom functions will work without limitation, until another Zoom is performed.

Reset Chart Display

The Reset Chart Display option will redistribute the chart displays evenly after changing the boundaries, so that each channeløs vertical size is the same. This function, which only works in *Chart Mode*, can be useful for expanding a display region for analysis and then returning to the original display.
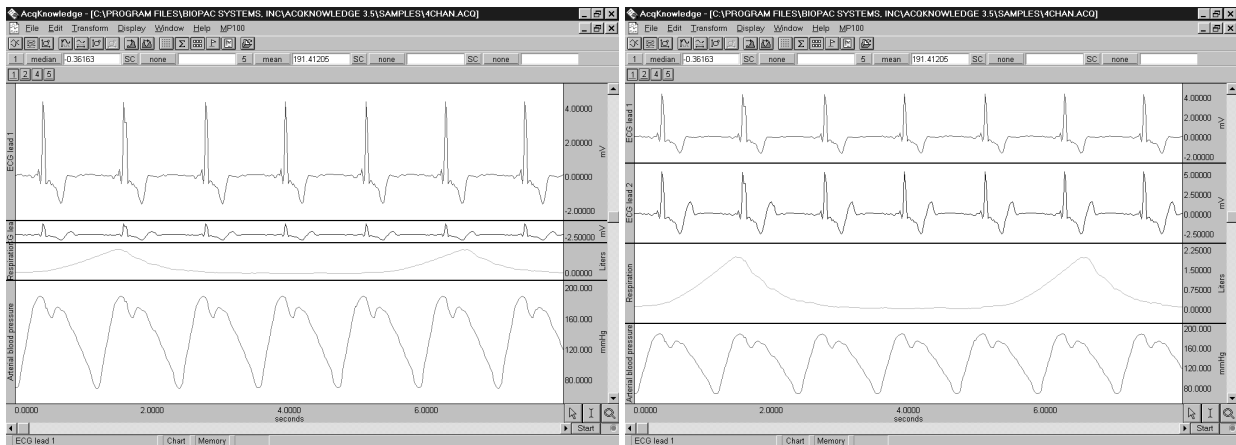
Before Reset Chart Display   õ and after

Reset Grid

To return to the original grid, choose õDisplay > Reset Grid.ö This will reconstruct the default, unlocked grid of four divisions per screen with solid light gray grid lines.

Adjust Grid Spacing

To modify the horizontal and/or vertical grid spacing, choose õDisplay > Adjust Grid Spacing.ö This will generate a dialog for modifying the locked axes of the selected waveform. *See page 74 for details.*

Set Wave Positions...

By default, channels are arranged on the screen based on their channel numbers, with the lower number channels being displayed at the top of the screen. The Set Wave Positions option allows waveforms to be placed in a user defined order.

> ➢   In chart mode this will result in vertical ordering of the individual waveforms.

> ➢   In scope mode this will result in vertical ordering of the individual waveforms after a tiling or autoscaling operation.

Itøs also possible to set any waveform to ignore the autoscaling and tiling functions. This is useful for selectively applying autoscaling to certain graph channels of interest while omitting others.

The waveform positioning function is selected through the Set Wave Position in the Display menu. The following dialog will then appear, with a scrolling list of all stored channels:
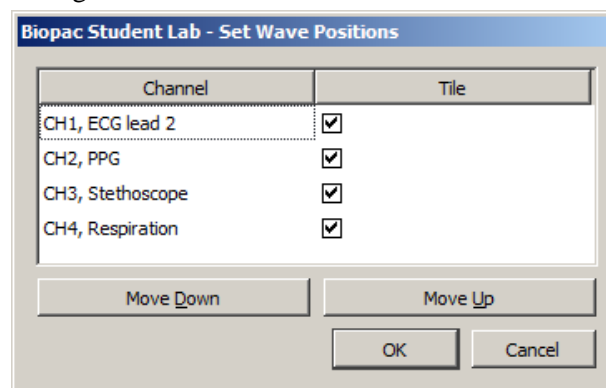
If more channels are present than those displayed, scroll through the list by clicking on the vertical scroll bar at the right.The list will scroll if when moving past the top or bottom and clicking and dragging the waveform positions.

The õTileö checkbox to the left of each channel enables tiling and autoscaling for each channel when checked. Click the checkbox to toggle the enable.

The on-screen position of the waveforms is the same as the ordering shown in the above dialog (from top to bottom). The waveforms can be repositioned by reordering the channel labels as they appear in this dialog. To change the order of any waveform, select the channel label (e.g., CH1, ECG) and then click the Move Down or Move Up button. Repeat this operation until the waveforms are in the desired order.

> ➢ Click OK to apply the selected order to the display screen.
> ➢ Click Cancel to revert all waveform positions to those set before the dialog was opened.

Set Channel Visibility

Set Channel Visiblity offers an alternate means of showing and hiding channels. Simply check or uncheck the channel õShowö checkboxes to show or hide them. All channels can be shown or hidden simultaneously by holding down the Alt key while clicking the left mouse button. See also: Show/Hide Channels on page 84.
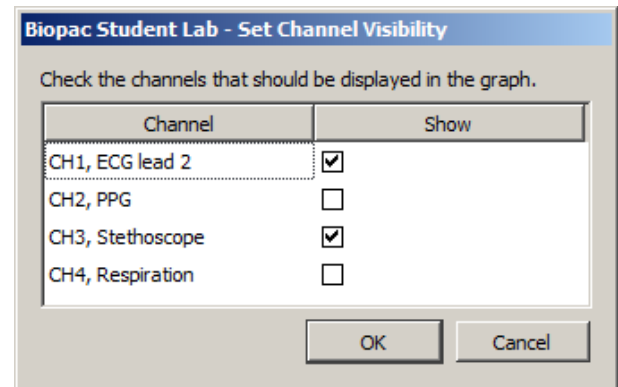
Wave Color

Select Display > Wave Color and then set the desired color to discriminate between waveforms. In scope mode, the vertical scale, channel text, channel units and measurement popup menus take on the same color as the selected waveform. When adding new waveforms, BSL *PRO* assigns waveform colors in the following order: black, red, green, blue, magenta, burgundy, and custom.
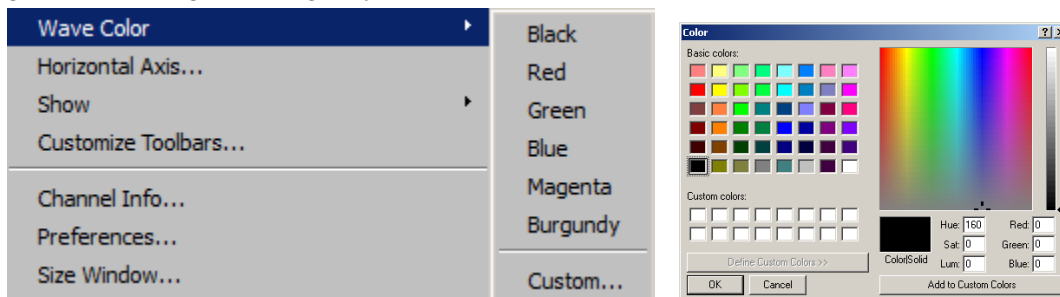
Or, click the right mouse button to bring up a menu, select Color, and then select the desired waveform color from the color palette menu.

Active Slice Color
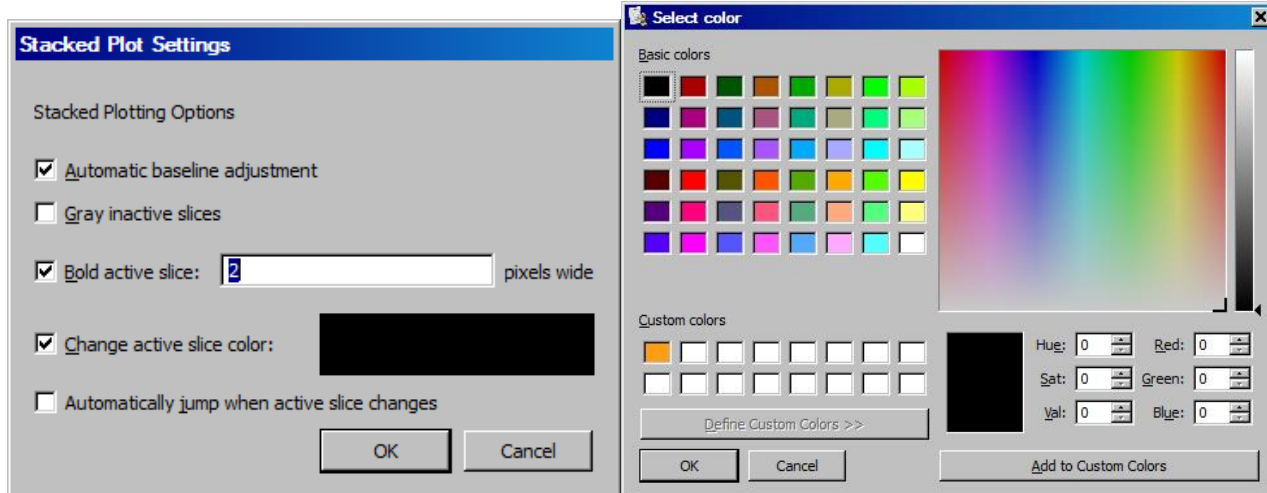
To change the Active Slice Color in Stacked Plot mode (see page 35), use Display > Show > Active Slice and then select Drawing options.

Horizontal Axis

Horizontal Axis generates the Horizontal Scaling dialog. Set the axis in terms of time, frequency, or arbitrary units, and set the horizontal sample interval (the amount of time between two sample points) and the first sample (sample offset).

Time domain scaling has two options to store and display data:
- **(ss.sss)** ô absolute seconds; the time scale for an event occurring 30 seconds into the record would be 30.00 seconds

- **(HH:MM:SS)** ô hours:minutes:seconds; the time scale for the same event would be 00:00:30.

Set the Time Unit precision via Display > Show > Selection palette, then press Enter (return) to accept changes.
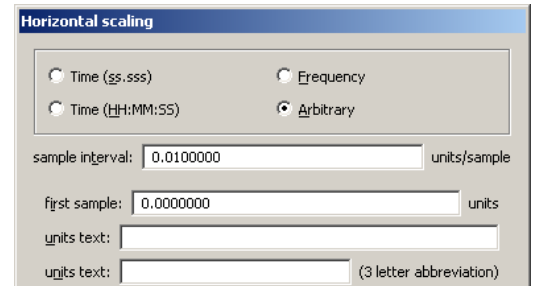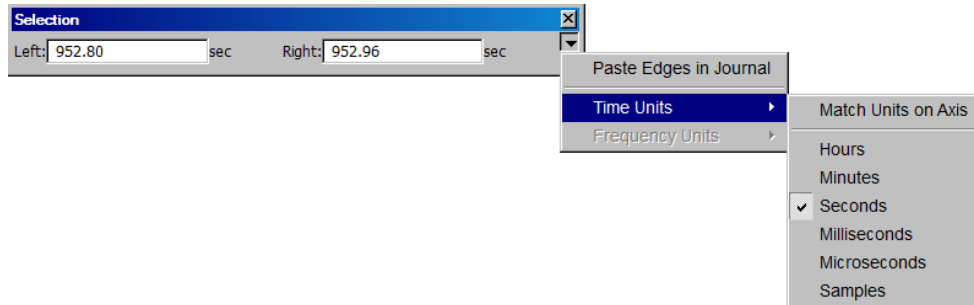
The **Frequency Units** option plots data from a Fourier analysis or other data with a frequency base (rather than a time base). This option is only available when frequency units are present in the graph. As with the time options, this feature is typically used for importing text files from other applications. For instance, when importing a text file with 1,000 sample points that covered a frequency range from 0 Hz to 100 Hz, set the interval to 1000 Hz/100 samples, or 0.1 Hz per sample in the box to the left of the interval text box. Similarly, if the frequency range was 20 Hz to 100 Hz, set the offset to 20 Hz. Arbitrary base units can also be attached to the data (rather than a time or frequency base When the horizontal axis corresponds to wavelength, and the data consists of 100 samples covering a range from 1 to 10 Angstroms, the interval should be 0.1 units per sample.

Arbitrary units are generally useful for changing the time base (or other horizontal scale) of data that has been imported into BSL *PRO* as a text file. For instance, to analyze data imported from a text file that contains 30 seconds of data that was collected at 100 samples per second (100 Hz), the first step would be to open the file (following the directions on page 223).

When arbitrary units are selected, two additional text boxes appear at the bottom of the dialog. The upper Units text box is used to provide a name for the horizontal scale units and the lower Units text box is used to provide an abbreviated label for the horizontal units.
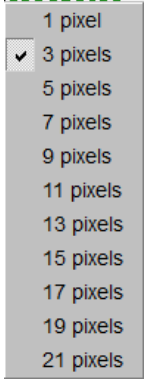
By default, BSL *PRO* assumes that the data was collected at 50 Hz, and would therefore plot the data so that a 60 second record was displayed that appeared to be collected at 50 samples per second. To change this to reflect the rate at which data was actually collected, change the sample interval box in the horizontal scaling dialog. When data are displayed on a 50 Hz time base, the sample interval will read 0.02 seconds per sample. This means that there is a 0.02-second õgapö between sample points in the record. To display data at 100 samples per second, change the interval to 0.01 seconds per sample.
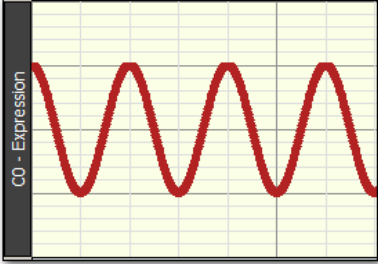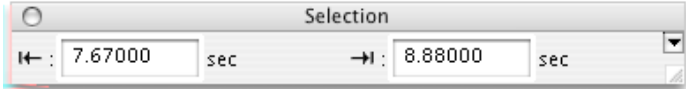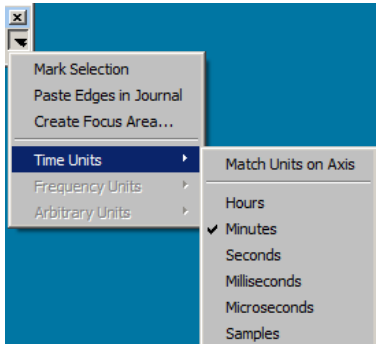
To determine the sample interval for other sampling intervals, divide 1 by the rate at which data was sampled (in terms of samples per second). Thus, a sampling rate of 0.5 Hz would translate into a sample interval of 2.00 seconds between samples, and data collected at 100,000 Hz (100 kHz) would have an interval between sample points of 0.00001000 seconds.

> TIP: To confirm that BSL *PRO* is storing data in the same X-axis it was collected in, choose Channel Info from the Display menu. This will generate a dialog that describes (among other things) the sampling rate BSL *PRO* uses in analyzing the data. Once data has been saved as an BSL *PRO* file, time base information is automatically saved along with the data. BSL *PRO* also saves X-axis in Frequency (FFT) or Arbitrary (Histogram).

Show

Selecting Show from the Display menu generates a submenu that allows control over a number of data display options and what additional information is displayed in the graph window. To enable an option, select it from the submenu; a bullet (É) or checkmark appears next to the menu item when it is enabled. The three display modes and the two plotting modes are mutually exclusive, but the remaining items can be enabled independently.

Show Option	Shortcut	Explanation
Annotations		Toggle show/hide of text annotations.
Channel Buttons		When the Channel numbers option is selected, the channel boxes appear just above and below the graph area. `1` `2` `3` Channel boxes with Channel 1 selected These boxes are useful for selecting channels and õhidingö channels by positioning the cursor over the channel box, holding the ALT key on the Windows or the Option key on the Mac, and clicking the mouse button.
Channel Input Values		When enabled, adds real-time display of channel amplitude values above the graph. (õShow textual value displayö must be enabled in the Vertical Axis settings.)
Chart		Activates the Chart display mode (see page 32).
Display Mode Toolbar		Activates toolbar shortcuts for Chart, Scope, X/Y, Stacked Plot, Horizontal Split View and Data View.
Dot plot		Dot Plot allows viewing of data in a õdotö format. This is useful for demonstrating the concept of discrete digital sampling by dividing the waveform up into data points or õdots.ö
Dot size		Dot size is enabled after Dot Plot is selected. Dot size specifies how large each dot will be. Each dot is measured by the number of monitor pixels it occupies. (Each õdotö corresponds to a sample point. (For example, data collected at 100 samples per second whould display 100 dots per second.)
Focus Areas		Enables Focus Area display. See page 44 for Focus Areas.
Event bar		Enables Event Bar display.
Events		Enables Event Marker region display. See page 192 for Events.
Focus Areas		Enables Focus Area display. See page 44 for Focus Areas.
Focus Areas Bar		Enables Focus Area Bar display on toolbar.
Grid		Superimposes a Grid on the graph window (see page 47). To change grid precision, use the axis scaling dialog of the horizontal or vertical axis.
Grid Options		Activates the Grid Options dialog (see page 76)
Hardware		Show/Hide Hardware õConnected to:ö dialog in the graph display; includes network access.
Journal		Activates the Journal (see page 48).
Last Dot Only		Plots only the most recently acquired data point. Only available in X/Y mode.

Line Plot	Right-click menu	Connects each sample point with a line to create the waveform. Waveforms that are displayed in line plot mode match a true analog plot (as closely as possible). This is the default display mode for most waveforms, except histogram plots, which are displayed in Step Plot mode (see 276). Change line options by right-clicking the mouse, which generates a menu displaying several commonly used features.
Line Thickness		Line thickness is enabled when Line or Step plot are enabled. Use to specify the plot thickness in pixels. Sine wave set to thickness of 5 pixels
Measurements		Displays the measurement popup menus and windows above the graph window (see pages 46 and 85).
Scope		Activates the scope display mode (see page 32).
Selection Palette		Many of the tools within the BSL *PRO* environment are based around the selection. The selected range of data in the graph is used as the source for measurements, waveform editing, transformations, and other operations. The Selection Palette is a floating dialog that can be used to precisely enter the selection. • The Selection Palette can be used to adjust the selection at times when it is not possible to use the selection tool in the graph window, such as when transformation dialogs are being displayed for the graph. • The selection palette offers a way to change the selected area without having to cancel the transformation setup and lose any parameters typed in the dialog. To display the Selection Palette, choose Display > Show > Selection Palette. This small floating dialog contains two edit fields displaying the location of the left and right edges of the selection, using the measurement units displayed in the horizontal axis. As the selection is changed, the new selection boundaries are shown. The Selection Palette also can be used to manually type in the edges of the selection. Double-clicked of the edges and type in the new horizontal position of the edge of the selection. Press õReturnö to adjust the selection to that time location and update measurements and the visible display on the screen. When a graph is displayed in X/Y mode, the Selection Palette can be used to adjust the X-axis range of data plotted on the screen. Limiting the time range can be useful for generating X/Y plots for different intervals of the graph that can then be compared with each
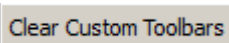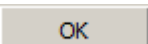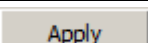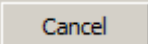
other, such as examining data from different time periods of a recorded signal.

Click the small arrow in the top right of the selection palette for the following additional options:

- **Mark Selection**ô Use this option to bracket a selected area with event markers.
- **Paste edges in Journal**ô This option pastes a line of text into the Journal that includes the left and right edge measurements of the selection.
- **Create Focus Area**ô This option turns data highlighted by the selection palette into a labeled Focus Area.
- **Time units**ô Use this submenu to change the time units used in the selection palette. The following time units are available: Match units on axis; Hours; Minutes; Seconds, Milliseconds, Microseconds and Samples. The Time units submenu will be dimmed unless the graph displays time/arbitrary measures).
- **Frequency units**ô   Use this submenu to change the frequency units used in the selection palette. The following frequency units are available: Match horizontal axis, Kilohertz, Hertz, Millihertz and Samples.

  The frequency submenu will be dimmed unless the graph displays frequency-based measures.

Note   Changing time/frequency units in the selection palette can be helpful during zoom operations when the units displayed in the horizontal axis may not be the most convenient for inputting new selection boundaries.

- **Arbitrary Units**—Use this submenu to change the arbitrary units used in the Selection Palette display (Units or Samples).

Spectrum Analyzer Palette		Provides a dynamic display of the frequency decomposition of data, in real time or post-acquisition. See page 326 for details.
Stacked Plot Options		Displays options that can help visually distinguish the active slice from other slices being drawn in Stacked Plot mode. See page 36 for details. Jump to Start of Active Slice Activate Previous Slice Activate Next Slice Activate Specific Slice... Vertical Separation... Slicing Event... Drawing Settings...
Step plot		Displays waveforms in a õstepö plot, meaning that the lines connecting sample points are drawn either vertically or horizontally. Step plot is most useful for displaying histograms and similar plots, but since it displays data much as it appears to a digital processor (like the MP), it can also be useful for examining the effects of various sampling rates. NOTE: Step plot is mutually exclusive of line plot.
Textual Values	CH=x	When enabled, adds real-time display of channel amplitude values above the graph. (õShow textual value displayö must be enabled in the Vertical Axis settings.)
Toolbar		Displays the toolbar (shortcut) icons across the top of the display (see page 51).
X/Y		Activates the X/Y display mode (see page 32).

Customize Toolbars

Use this feature to create custom toolbars for easy access to post-processing Analysis and Transform actions. Toolbars are dockable and custom toolbar placeholders can be named independently of toolbar actions.

- **Actions** ó Menu list of available Analysis and Transform functions

- **Toolbars** ó List view of custom toolbar placeholders

- **Current Toolbar Actions** ó List view of available actions from Analysis and Transform menu

Button	Function	Explanation
	Add toolbar button	Adds placeholder for new toolbar. (More than one toolbar action can be grouped under one placeholder).
	Remove toolbar button	Removes placeholder for toolbar.
Rename	Rename toolbar button	Allows existing custom toolbar name to be edited.
	Up arrow	Moves a toolbar action up the list.
	Left arrow	Removes a toolbar action from the list.
	Right arrow	Adds a toolbar action to the list.
	Down arrow	Moves a toolbar action down the list.
Clear Custom Toolbars	Clear button	Removes all toolbars from Toolbars and Current Toolbar actions list.
OK	OK button	Enforces addition or removal of toolbars from list or application toolbar region.
Apply	Apply button	Applies changes without closing Customize Toolbar window.
Cancel	Cancel button	Dismisses any toolbar changes without applying.

Spectrum Analyzer Palette Details
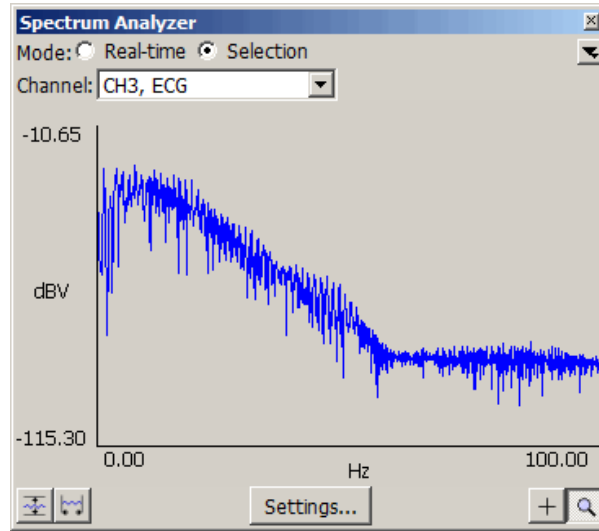
Spectrum Analyzer breaks time domain signals into their respective frequency components to provide a dynamic display of the frequency decomposition of data, in real time or post-acquisition. Spectra can be generated in real time based on the most recently acquired data or post-acquisition based on the selected area of a saved data file.

- Spectrum analyzers can be useful for locating and correcting noise sources in a system as well as other frequency domain analysis.
- The spectrum analyzer displays the FFT of a portion of data of a single channel.

The spectrum analyzer applies to all graph windows displaying data in the time domain. Viewing the underlying time domain data at the same time as the spectral information also provides useful visual feedback with regards to signal quality. The palette allows for continuous availability of the spectrum analyzer across multiple graphs and for positioning alongside original data. The channel is always indicated by the popup menu within the spectrum analyzer itself. The graph whose data is analyzed will always be the topmost graph; this is the graph whose window is highest in the Z ordering.

Mode:

Real-time   Analyzes the most recently acquired data in a graph. The analyzer generates full FFT output so, in linear units, it is the regular FFT multiplied by two. The analyzer extracts the spectrum based on a sliding window of samples at the tail end of the signal and periodically refreshes the spectrum plot during acquisition. The analyzer uses a fixed width window size. The first spectrum will be generated after the number of samples needed to fill the initial window has been acquired. If no data is being acquired, the analyzer will not display any frequency information and will appear to be off.

Selection   Analyzes the highlighted section of the active channel of a saved graph (post-acquisition). Select the channel to be analyzed from the channel popup menu.

Palette popup   (upper right) Displays the spectrum analyzer palette popup menu for performing other operations on the spectrum including extracting the spectrum to a new graph window and copying spectrum data to the clipboard or journal. Options are dimmed if there is no spectrum available.
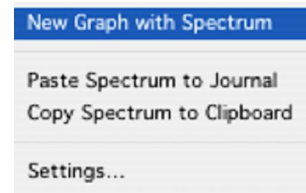
New í   New Graph with Spectrum constructs a new graph window with the contents of the spectrum. This allows for more detailed examination of the spectrum than is possible with the tools in the spectrum analyzer palette.

Pasteí   Paste Spectrum to Journal makes a textual representation using the current Journal preferences and copies the text into the graph journal of the graph whose data is being analyzed. This will prompt to create a journal if none exists.

Copyí   Copy Spectrum to Clipboard makes a textual representation using the current Journal preferences and copies the text to the Clipboard.

Settingsí   Displays the spectrum analyzer settings dialog. Equivalent to using the Settings button at the bottom of the palette; see Settings below for details.

Channel   Indicates which channel of the hardware setup or graph is being analyzed. The õChannelö popup menu contents vary with the analyzer mode:

Real-time   Channel popup menu lists active channels whose õAcquireö checkboxes are checked in MP > Set Up Channels.

Selected   The channel popup menu matches the channel menu of measurements in the topmost graph window. The menu starts with õSC, Selected Channelö which, when chosen, uses the data of the active channel of the graph. The remainder of the menu lists the channel numbers and labels of the channels within the topmost graph.

Plot display   Plot of the spectrum of the corresponding data.

- Vertical axis units match the source channel (displays either õdbVö or linear)
- Horizontal axis displays frequency and is always displayed in õHz.ö

If there is a valid data selection that can be used to compute a spectrum, the spectrum will be displayed in this area. If there is no valid data selection, no axes will be displayed and the plot will be replaced with the text õNot Availableö. The following conditions cause spectra to be unavailable:

- graphs that contain no data (either no channels or only empty channels)
- graph is being displayed in XY mode
- graph uses either frequency or arbitrary units for its horizontal axis

When operating in selected area mode, the following additional conditions also cause spectra to be unavailable:

- selection contains no data on the active waveform
- selection is a single-point selection (not enough data to compute FFT)

When operating in real-time mode, the following additional conditions also cause spectra to be unavailable:

- no data acquisition is in progress

Auto Vert   Click to autoscale the spectrum to fit all amplitudes within the visible spectrum plotting area.

Auto Horiz   Click to autoscale the spectrum to fit all frequencies within the visible spectrum plotting area.

Settings

Plot color   Colorwell that changes the color used to draw the spectrum in the palette. Click to display a standard color picker.

Window   Width specifies the window size used when performing analyses in real-time mode. The spectrum will always reflect the frequency characteristics of the most recently acquired data of the graph, using this window size as the number of sample points to use. This popup will list various powers of two, ranging from 256 to 4096 samples.
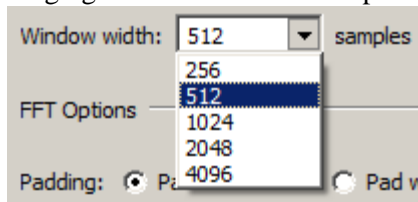
FFT Options

Paddingô used whenever the number of input points is not an exact power of two. Data can be padded either with zero or with the amplitude of the last data point.

Remove meanô Subtracts the mean value of the data is prior to frequency analysis. This helps remove the zero frequency component caused by DC offset.

Remove trendô Connects the endpoints of the data with a line and removes this linear trend from the data prior to frequency analysis. This can help compensate for drifting baselines.

Unitsô control whether the data is displayed using a logarithmic scale or a linear scale.

Windowô enables the standard BSL *PRO* windowing options, to adjust the data to remove effects resulting from the discontinuities of data at the two edges. See page 277 for details about FFT.

Value   Click the crosshair icon ⊞ to display the frequency and amplitude values of the spectrum when moved within the spectrum display. The mouse cursor will change to a crosshair when inside the spectrum plot. The frequency and amplitude values corresponding to the mouse position are displayed above the spectral plot. Hold the mouse button down to display the amplitude of the spectrum at the horizontal mouse position, along with a crosshair cursor highlighting the exact location shown on the spectrum. If the active spectrum is compressed (that is, if multiple samples exist for a particular horizontal position), the value extracted will be the maximum value displayed at that pixel position.

Zoom   Click the magnifying glass 🔍 to perform zoom operations. Click and drag the mouse cursor (which will change to a magnifying glass) in the plot display to select the area to zoom in on. Alternately, click either of the axes of the spectrum palette to display a dialog used to enter display ranges manually. Enter the start and end points of the desired range for each axis. There are no grids in the spectrum analyzer palette, so the axis scaling dialogs of graphs are not applicable. Note: adaptive scaling will be disabled for the spectrum display when either the zoom tool or the axis endpoint entry dialogs are used.

> TIP: To zoom out, hold the Alt key (PC) or Option key (Mac) while clicking mouse over zoomed area.

Channel Information...

The Display > Channel Information command generates an information dialog for the selected channel. Channel Information may also be displayed by right-clicking in the channel and selecting õChannel Infoí ö from the contextual menu.

Channel Information

Line frequency: Unknown

Channel: A3, ECG   Min: -1.0674 Volts

Interval: 200 samples/sec   Max: 2.69094 Volts

Length: 5455 samples, 27.275 sec   Mean: 0.0212502 Volts

	Transformation	Date	Time		Parameter	Value
1	Smoothing	Wed, April 6, 11	14:56:20.760		Smoothing factor	3
					Smoothing value	mean
					starting sample position to transform	1
					ending sample position to transform	5455

Paste Selected Channel to Journal   Paste All Channels to Journal   Close

Line Freq Files created with BSL *PRO* include the line frequency (50 Hz or 60 Hz); files created in earlier versions will list õUnknown.ö

Channel Use this popup menu to select the desired channel for displaying information.

Interval The time between sample points, which is the reciprocal of the sampling rate. The sampling rate can be modified by using the resample function (described on page 270), by changing the interval horizontal scale (see page 321), or by pasting data collected at one sample rate into a graph containing data sampled at a different rate.

Length Indicates the overall length of the channel in samples and in time. The waveform length is generally the same for all channels, but there are exceptions:

- Downsampling a channel during acquisition
- Transform > Resample Waveform/Graph
- Edit operations ó Cut, Copy, Paste, Clear

Min Provides the minimum value for the waveform data.

Max Provides the maximum value for the waveform data.

Mean Provides the mean value for the waveform data.

The fields below the statistical information contain transformation histories, time/date stamps, parameters, and values for selected channels.

Paste Selected Channel to Journal   Pastes transformation modification history for selected channel to Journal.

Paste All Channels to Journal   Pastes transformation modification history for all channels to Journal.

Preferences...

To generate the Preferences dialog, select Display > Preferences on Windows or BSL *PRO* > Preferences on Mac.
Use Preferences to control measurement options, how waveforms are displayed, and other BSL *PRO* features. Select
an option in the list on the left of the Preferences dialog and then set the respective preferences displayed on the right.
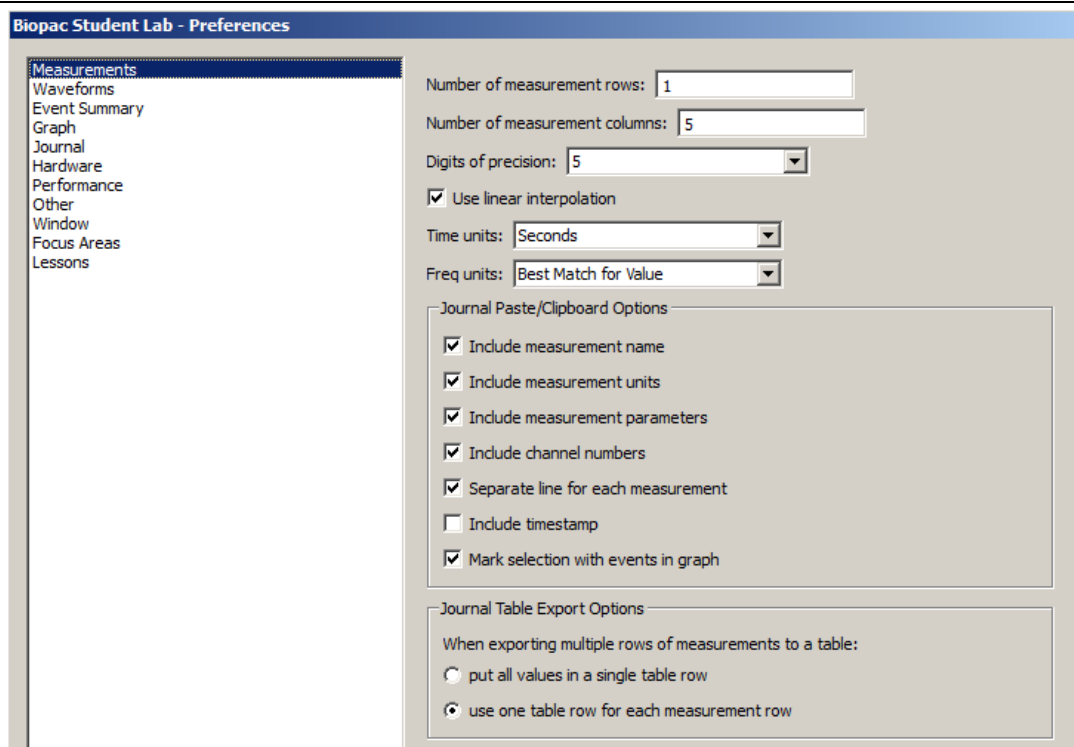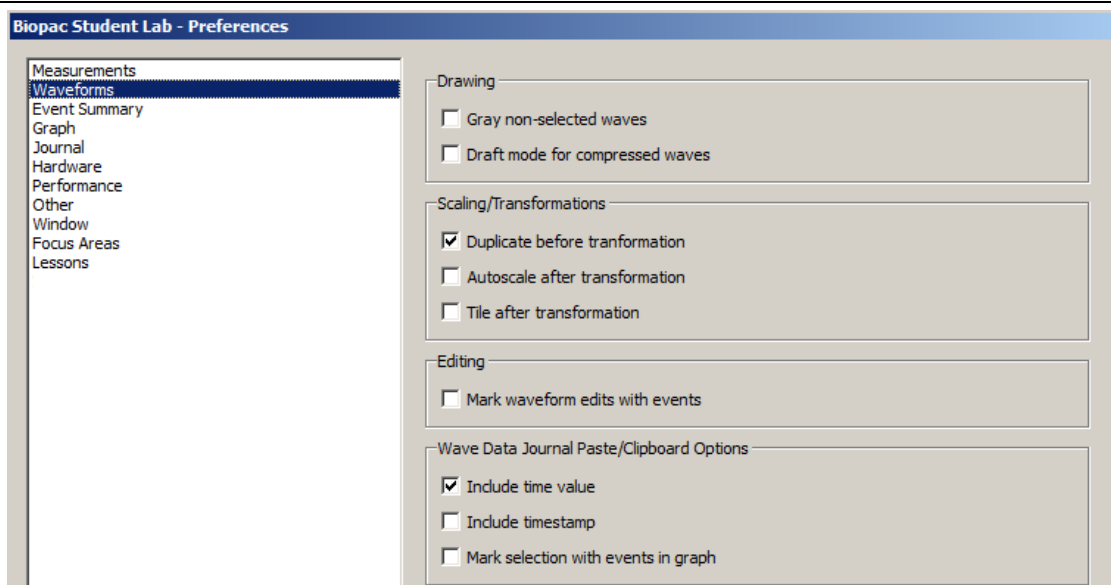
See page í 333	
334	
334	
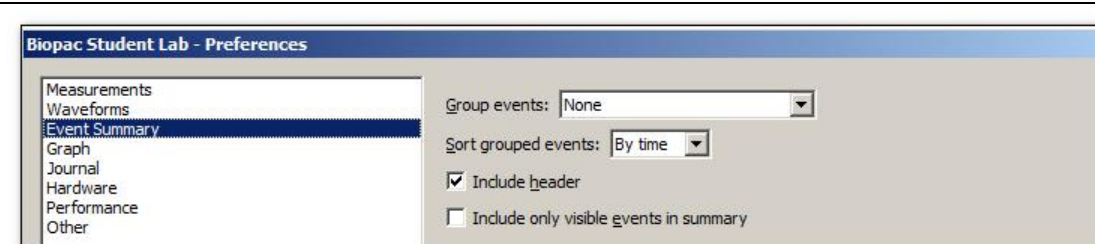
334	**Biopac Student Lab - Preferences**

Measurements
Waveforms
Event Summary
Graph
Journal
Hardware
Performance
Other
Window
Focus Areas
Lessons

Display Style
○ Tabbed (all in single window)   ◉ Windowed (one window per graph/data view)

Editing
☑ Interpolate pasting between graphs   Method: Linear ▼

Maximum levels of undo
○ Unlimited   ◉ Limit to   4   prior operations

☐ Link selections between data views for new graphs
☑ Enable cursor tools during acquisitions
☑ Show append boundary dividers

Axis controls: Transparent ————————————●— Opaque

Chart Track Divider Appearance
◉ Default   ○ Custom: ▮

Plotting Background Colors
Selected channel: [   ]   Reset   Normal: [   ]   Reset

When closing main windows for a graph with Data Views:
Show prompt ▼

Transformation--Recently Used Menu
List 10 most recent transformations

OK   Cancel

335	**Biopac Student Lab - Preferences**

Measurements
Waveforms
Event Summary
Graph
Journal
Hardware
Performance
Other
Window
Focus Areas
Lessons

Default Font for Journals
Font: MS Shell Dlg 2 ▼
Size: 12 ▼

Display
☑ Wrap long lines of text to Journal window width
Tab width: 10 spaces

☑ Auto-paste results in independent journals
Display Style
◉ Docked at bottom of graph window
○ Dockable on any edge of graph window
○ Floating window

336	**Biopac Student Lab - Preferences**

Measurements
Waveforms
Event Summary
Graph
Journal
Hardware
Performance
Other
Window
Focus Areas
Lessons

General
☐ Always work with no data acquisition hardware connected

Line frequency: 60 Hz (United States) ▼
Default analog channel display units: millivolts ▼

Data Acquisition Hardware Priority...
☐ Restore data acquisition hardware configuration on launch

When creating new graph windows use:
◉ Minimal channel setup
○ User-defined default channel setup   Clear Default Setup...
○ Channel setup of last active graph

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336	
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Measurements Preferences

- **Measurement rows**ô sets number of measurement rows displayed in the graph window.

- **Measurement columns**ô sets number of measurement columns displayed in the graph window.
    - o Use Display > Show > Measurements to hide the measurements; see page 322 for details.

- **Precision**ô controls the accuracy of digits displayed right of the decimal (1-8) for all measurement results. For example, with the precision set to 3, a measurement result might be 125.187.

- **Use linear interpolation**ô toggle to enable/disable measurement interpolation.

- **Time/Frequency units**ô sets the measurement unit to use for time and frequency pop-up measurements. This locks the units for the measurement result display (i.e., if seconds is selected, a result of 70 seconds will display as õ70 secondsö rather than õ1.16667 minutesö).
    - o Best matchô Scales units to best match the interval for time and frequency based on the total file. For example, wonøt set a 3 hour file to display in msec.

- **Include for Journal/Clipboard options**
    - measurement name (i.e., BPM, Delta T, Freq, etc.) with the values.
    - measurement units (i.e., volts, mmHg, and so forth) after the numeric values.
    - measurement parameters used to compute the measurement function result, such as the location and operator used for Calculate measurements.
    - channel numbers at the top of each column of data.
    - timestampô Automatically insert the time of day and the date when pasting measurements or wave data. This timestamp can be correlated with selection events to reconstruct the selected area.ô useful for GLP auditing.

- **Use a separate line** for each measurement in the journal/clipboard

- **Mark selection with events in graph**ô Automatically insert a pair of Global Selection Begin and Selection End events at the selection boundaries when pasting measurements or wave data. These events will be timestamped with the time of day and the date when the paste occurred. This timestamp can be matched to the result of õInclude timestampö to recreate selected areas for reconstructing measurement results or re-executing wave data exportingô useful for GLP auditing.

- **Journal Table Export Options** ó Sets the options for how multiple measurement rows are displayed in a Journal table.

BSL *PRO* Manual

o Put all values in a single table row ó Extends multiple measurement rows horizontally into one table row.

o Use one table row for each measurement row ó Divides the measurements into multiple table rows in the same manner shown in the measurement toolbar.

Waveforms Preferences

In the center of the dialog are two options that control how waveforms are displayed on the screen.

- **Gray non-selected waves**ô When enabled, the active wave will be drawn in a solid color and any non-selected waveforms will be drawn using lighter, dotted lines (or with lighter colored dots if dot plot is in use). This can help emphasize the selected waveform when viewing data in Scope mode.

- **Draft mode for compressed waves**ô allows for some (õcompressedö) waveforms to be plotted in õdraftö mode, which results in faster plotting time, although the display is not exact. A waveform is considered compressed when more than three sample points are plotted per pixel on the screen. For example, on a VGA display that is 640 pixels wide, a compressed waveform would be any type of waveform displaying more than 2000 samples (approximately) on the screen at any one time. Using the default horizontal scale (which plots eight seconds of data on the screen), any data sampled at more than 250 samples per second would be considered õcompressed.ö

- **Scaling/Transformations**ô These options handle the way data appears on the screen after it has been transformed (e.g., filtered or mathematically operated on). Neither option affects how data appears on the horizontal axis, although both options change how data is presented along the amplitude (vertical) axis.

    o **Duplicate before transformations** will create a new channel showing the data as it originally appeared before the transformation was applied. This will preserve the original view for comparison to the tranformation.

    o **Autoscale after transformations** will automatically rescale all waveforms after a transformation to provide the õbest fitö along the amplitude axis.

    o **Tile after transformations** tiles all visible waveforms after any transformation, and is mutually exclusive of the autoscale command. When waveforms are õtiledö they appear to be stacked on top of each other.

- **Mark waveform edits with events**ô Insert an event at points where waveform edit commands have been applied.

- **Include time value**ô copies the horizontal scale values along with the waveform data when data is copied to the clipboard. This means that after pasting data from the BSL *PRO* screen into a spreadsheet or similar application, horizontal scale information is retained.

- **Include timestamp**ô Automatically insert the time of day and the date when pasting measurements or wave data. This timestamp can be correlated with selection events to reconstruct the selected area.ô useful for GLP auditing.

- **Mark selection with events in graph**ô Automatically inserts a pair of Global Selection Begin and Selection End events at the selection boundaries when pasting measurements or wave data. These events will be timestamped with the time of day and the date when the paste occurred. This timestamp can be matched to the result of õInclude timestampö to recreate selected areas for reconstructing measurement results or re-executing wave data exportingô useful for GLP auditing.

Event Summary Preferences

For the event summary that can be pasted to the journal, choose a method to group the events (i.e., type or channel), to sort the events (by time or label) and indicate whether to include all events or include only visible events in the summary. Beginning in BSL *PRO*, there is an option to include a header row at the top of the summary.

Graph Preferences

- **Display Style** can be set to **Windowed** or **Tabbed** view. Windowed will display additional graphs in a separate view, whereas the Tabbed option will display all graphs in the main window. Tabbed graphs can be navigated by clicking on the identifying tab at the top of the application window, or by clicking Ctrl+Tab. A tabbed graph may be moved to itøs own window by right-clicking on the desired graph and choosing õMove Tab to New Windowö (below right). The default display setting for BSL *PRO* is windowed view. When set to **Windowed**, multiple graphs apppear as separate windows, which can be positioned as desired.

> o **Interpolate pastings** instructs BSL *PRO* to interpolate/extrapolate time base information when working with data sampled at two different rates. BSL *PRO* will interpolate data to fit the sample rate of the destination window. When doing this, data should be copied to a higher resolution window.

- **Maximum levels of undo**—Set the maximum number of undo operations. Unlimited may be memory-intensive, depending on the detail of each operation.
- **Link selections between data views for new graphs** ó automatically synchronize selected areas of data views between graphs for a new graph.
- **Enable cursor tools during acquisition** – Allows access to cursor tools while recording is in progress.
- **Show append boundary dividers** ó Controls visibility of append event boundary dividers.
- **Axis controls** – Controls visibility of set screen vertical axis controls.

- **Chart Track Divider Appearance** – Users may change the color used to draw the dividers between channels tracks The Preferences > Graph panel contains "Chart Track Divider Appearance" options.
- **Default** uses operating system specific dividers, which is a light color.
- **Custom** activates a colorwell, allowing a solid color to be specified for all dividers. The preference setting and color are shared by all open graphs and data views, as this is an application-level preference.

  - **Plotting Background Colors** ó Customizable background colors for individual graph channels are available.
- **Normal** activates a colorwell for choosing background color of the non-selected channels.
- **Selected channel** activates a colorwell for choosing background color of the selected channel.

  - **When closing**í determines the degree of closing and what prompts, if any, for multiple data views.
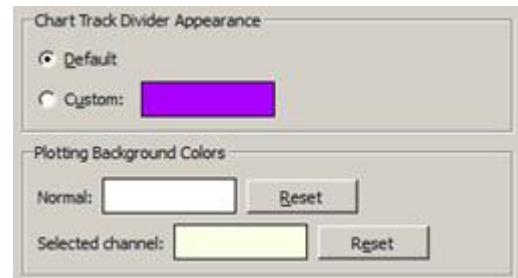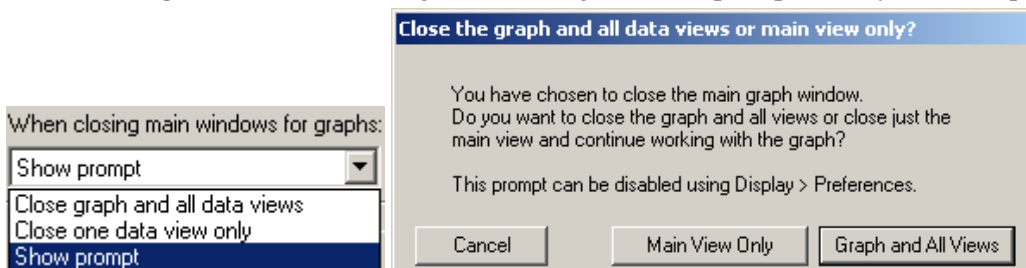
- **Recently Used**—set the number of recently used Transform and Analysis options to list in the Transform > Recently used sub-menu; provides quick access to common options. Recently used items can also be launched using keystroke the combinations appearing in this menu.

Journal Preferences

The Journal Preferences dialog contains options for controlling data format when pasted into the journal or clipboard.

- Change font type and size to any computer- installed font.
- Wrap Journal textô Wraps text to window size.
- Tabs: Specify the tab interval to make columns more readable when using a high precision setting.

Auto-paste resultsô Toggle the checkbox to enable/disable the option to paste results to independent journals.

Display Styleô Choose whether Journal window is fixed, dockable on any edges of graph, or independently floating.

Hardware Preferences

- **Always work with no data acquisition hardware connected** sets the default communication for no connection so the connection error is not displayed each time the software is launched.
- **Line frequency** is specified during software installation and can be changed here. (50 Hz for Europe and 60 Hz for the Americas.)Every time data is recorded, the line frequency setting is saved along with the data. If no line frequency data was saved, the line frequency setting for the installed/active version of BSL *PRO* will be used.

- **Default analog channel display units** ó Use to set default channel units to millivolts or volts.
  - mV ó displays in Millivolt units, visible range +/-50mV (MP36/MP35/MP45 default)
  - V ó displays in Volt units, visible range +/- 10 V
- **Restore data acquisition hardware configuration on launch**
  - If checked: Upon launch, application searches for the previously connected hardware unit. If a different unit is used, a connection warning is displayed.
  - If unchecked (default): Any supported new hardware type/unit is immediately connected upon application launch.
- **Data Acquisition Device Priority** launches a dialog allowing the default hardware device ordering to be set. This ordering is used to establish hardware communication when the application is first launched or if none of the previously-connected MP devices are available.
- **When creating new graph windows use** sets the default channel and hardware options for new graphs.
  - Minimal channel setup ó new graphs will use the applicationøs factory default channel settings for the selected hardware.
  - Use default hardware and channel setup ó new graphs will use the application default hardware/channel settings.
  - Copy hardware and channel setup of last active graph ó new graphs will apply the hardware/channel settings from the previous graph.

Performance Preferences

- **Use all available memory** instructs BSL *PRO* to attempt to use all the available memory for loading data. Otherwise, a variable sized buffer is used to load portions of large data files. This option works best if there is enough free memory to load the entire data file.
- **CPU allocation** sets the priority for CPU (system resource) allocation. For a data focus, move right, for a function focus, move left.
  - If experiencing Buffer Overloads, move toward *Better data transfer for high speed acquisition*.
  - To allow autoscale during acquisitions or jumping between MPs, resizing displays, or working in other programs, move toward. *More responsive*.

Other Preferences

- **Show menu tooltips** enables display of tooltips describing menu item functions. Tooltips appear when menu items are moused over.
- **Lock toolbars to BSL Lessons toolbar positions** ó toolbars cannot be repositioned and are locked to toolbar position used by BSL Lessons.
- **Reset toolbars**—Resets toolbar configuration to default setting.
- **Create configuration file**— Create default menu configuration file to customize menu display. For details on menu customization, see Appendix E on page 390.
- **Maximum number of files in File > Open Recent**—Sets the number of files that will appear in the –File > Open Recentølist.
- **When application is launched:**—Chooses between display of Startup Wizard, new empty graph, or õclassicö lesson choice dialog following application launch.
- **Default audio device**—Use this option to select the default audio device to be used by the application.

Window Preferences

- **Always keep the following windows on top:** — Sets options for keeping any of the following windows active above the main application window: Input Values, Media Capture Preview, Media Capture Viewer, Media Playback Viewer, Gauge View.

Focus Area Preferences
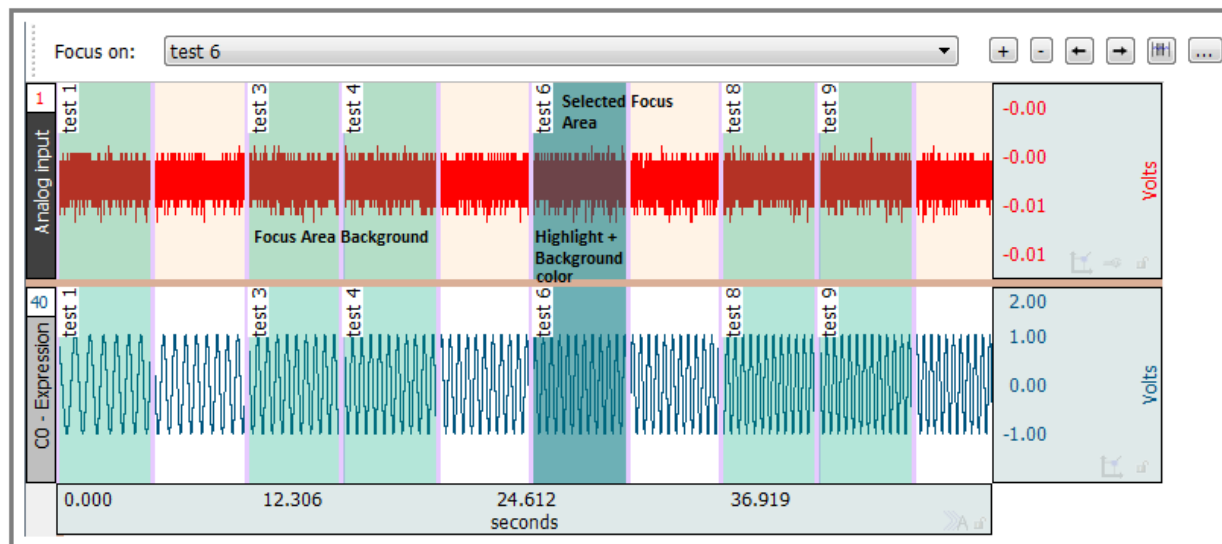
- **Show background**—Sets option for main graph visibility in the background of the selected focus area.
- **Color (background)**—Sets background color of selected focus area. Click color square to change color of focus area background. (This option not active if õShow backgroundö is unchecked.)
- **Opacity**ô Sets transparency level of background. (0 is transparent, 100 fully opaque.)
- **Show borders**ô When checked, borders will appear on both sides of the focus area.
- **Color (borders)**—Click to change the color of focus area borders.
- **Width**ô Controls width of focus area borders.
- **Show labels**ô controls whether focus area labels appear at the top or the bottom of the waveform.
- **Label Position**ô Controls where the Focus Area labels will appear in the graph. Options are at the top part of the waveform or the bottom part of the waveform.

Lessons Preferences
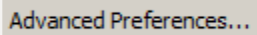
- **Show the following lessons**ô controls lessons appearing in the Startup Wizard and BSL Lessons menus.
- **Show the following *PRO* Lessons**ô controls which *PRO* lessons will appear in the Startup Wizard menu. Unchecked lessons will be hidden from view. Re-check to restore them.

In BSL 4.1 and higher, 11 animal PRO Lessons are included but hidden by default. They may be enabled or hidden as desired in the õShow the following PRO Lessonsö list. (These are lessons that begin with õA,ö as opposed to õHö for the human *PRO* Lessons.)
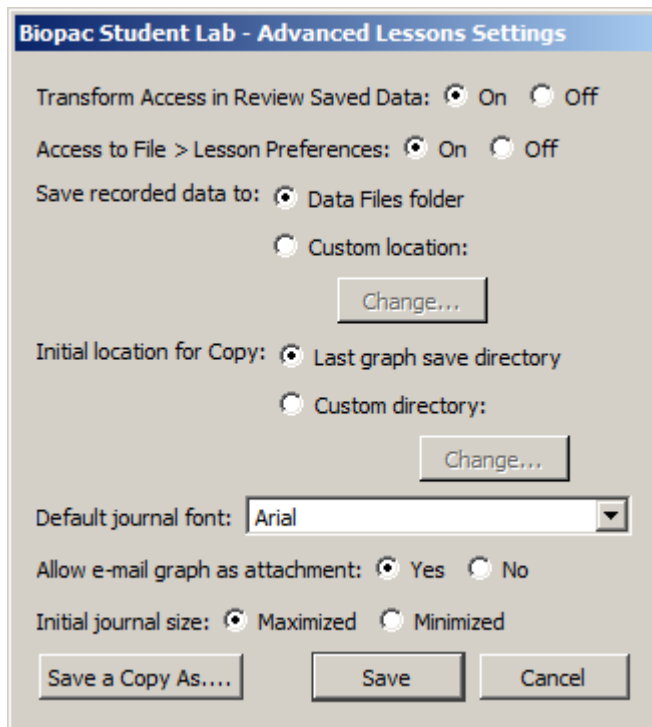
Disabling lessons in Lessons Preferences does not remove them from the application; it merely hides them from view. Disabling all lessons removes the ─Record or Analyze a BIOPAC lessonø option from the Startup Wizard screen. Enabling at least one lesson will restore this option.

- **Advanced Preferences**ô opens a dialog for modifying or adding advanced features to the BSL Lessons analysis mode. Additional features include the BSL *PRO* Transform menu, FFT analysis, Events palette, additional Display, Scaling, and Cursor toolbars, and other customizable functions. For more information about Advanced Preferences, see page 338.
- **BSL Curriculum Management System**ô this is a specially-licensed feature enabling an enhanced level of lesson customization options. For more information, see **Chapter 18** on page 348.

Lessons > Advanced Preferences

| Advanced Preferences... |

Choosing the õLessons > Advanced Preferencesö option launches the Advanced Lessons Settings setup dialog:

Biopac Student Lab - Advanced Lessons Settings

Transform Access in Review Saved Data: ⦿ On ○ Off

Access to File > Lesson Preferences: ⦿ On ○ Off

Save recorded data to: ⦿ Data Files folder
                        ○ Custom location:
                        [Change...]

Initial location for Copy: ⦿ Last graph save directory
                            ○ Custom directory:
                            [Change...]

Default journal font: [Arial ▼]

Allow e-mail graph as attachment: ⦿ Yes ○ No

Initial journal size: ⦿ Maximized ○ Minimized

[Save a Copy As....]   [Save]   [Cancel]

Use the Advanced Lessons Settings options to enhance the BSL Lessons Review Saved Data mode by adding *PRO* style menus and other custom modifications to the Lesson file being analyzed.

FUNCTION	DESCRIPTION
Transform Access in Review Saved Data:	Adds the BSL *PRO* Transform menu and FFT functionality to BSL Lesson files opened in Review Saved Data mode.
Access to File > Lesson Preferences:	Controls whether students have access to the BSL Lessons File > Preferences menu item while running a lesson.
Save recorded data to:	Controls whether lesson files are saved to the default Data Files folder or a user-defined location. Choosing %Custom location+enables the %Change+button for choosing the new Save location.
Initial location for Copy:	Controls where the BSL Lessons %Copy to another location+option saves the copied file. %Last graph save directory+saves the copy to the most recent location the data file was saved to. Choosing %Custom location+enables the %Change+button for choosing a new %copy to+location.
Default journal font:	Selects the font used for all lesson journals.
Allow e-mail as graph attachment:	Controls whether students have access to the BSL Lessons %File > Email graph as attachment+ menu item.
Initial journal size:	Sets the default Journal size to maximized or minimized for the Lesson file under analysis.
Save a copy as…	Creates a file containing a copy of all selected Lessons preferences. This file can be opened in Notepad or another text editor.
Save	Saves all selected settings and applies them to all BSL Lesson files opened in Review Saved Data mode. <u>Note that modified settings are not applied until the BSL application is closed and relanched.</u>
Cancel	Dismisses any modified settings without applying them.

Repairing corrupted preferences

On rare occasions, the system registry used for storing persistent preferences and other information across application launches may become corrupted. This may result in the application not launching properly or crashing when creating graph windows. Should this issue occur, the BSL preferences can be reset to the factory default by holding the Shift key down while launching the application.
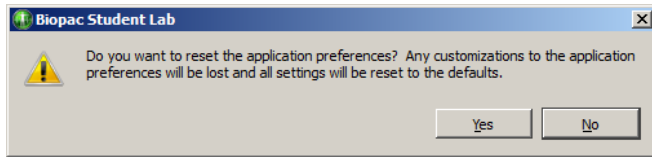
A confirmation dialog will appear prior to the settings being cleared. Once the default preference settings are restored, the application should run normally. After resetting, the preferences may once again be modified as needed.

Scroll options

The Scroll options help navigate through large data files. Right-click on the horizontal scroll bar to generate the contextual menu with scroll options.
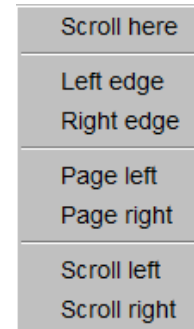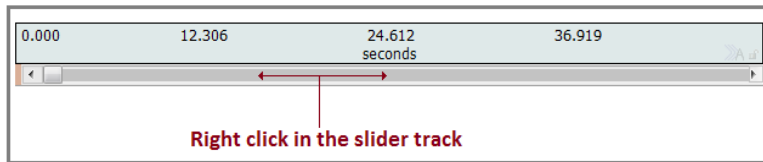
Contextual menu

Size Window...
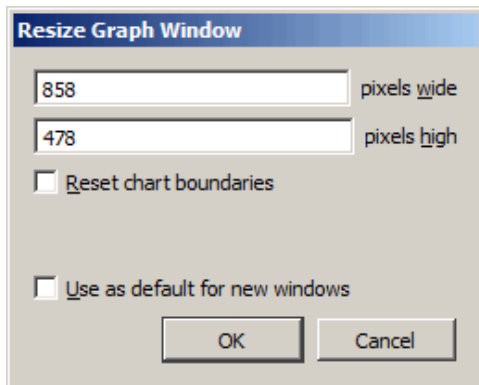
The Size Window function is useful for setting exact dimensions for the size of the graph window. Use this to create consistently sized windows for pasting into documents. The two text box fields are used to enter interior screen width and height, both of which are scaled in terms of pixels.

Each operating system may add additional dimensions as necessary to put in window adornments depending on the appearance configuration preference of the user (e.g. extra space for title bar of the window, any additional space put around the edges of the window frame, etc.).

When õReset chart boundariesö box is checked, the boundaries between the waveforms will be reset so that each channel õtrackö is the same size.

When õUse as default for new windowsö is checked, the user-modified dimensions are applied as the default graph window size.

When õRetain current dialog settingsö is checked, the dimensions used when the dialog was previously dismissed are applied to all subsequent graphs.

Cursor Style

Arrow	Ctrl+B
✔ Selection	Ctrl+I
Zoom	Ctrl+G
Grid	
Event	
Event Remove	
Jump	
Text Annotation	
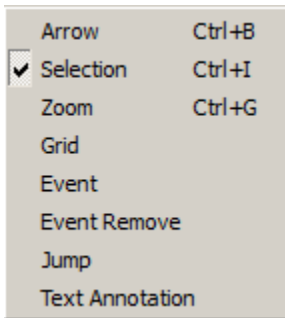
This option allows the active cursor tool to be adjusted via the Display menu. (BSL *PRO* and higher)

Split View

This option allows the horizontal graph display to be split into two independent sections. For horizontal Split View details, see page 47.

Create Data View

🌐 Biopac Student Lab - Data view of 'Untitled1.acq' *

Creates a new Data View for the active (frontmost) graph and names the new window õData View of ÷Filenameøö For Data View details, see page 38.

Create Focus Area

This option becomes available only when an area of data is selected, and brings up a Focus Area naming dialog. For full details on using the Focus Area feature, see page 44.

Load All Data Into Memory

Use with large files to improve plotting performance, measurement response, etc. Memory can hold up to two gigabytes of data.

Chapter 16   Program & OS Menus

BSL *PRO* menu

*Mac OS only*ô System generated menu. Use for About, Quit, and Preferences.

Window menu

The Window menu is a standard OS function. See the Windows or Macintosh OS Guide for details.

Bring All to Front

If other programs are running, this command will bring all BSL *PRO* windows to the front (on top of all other application windows); this command does not change the windows size or position.

Additional options become available when the Tabbed graph display preference is selected. (Right figure)
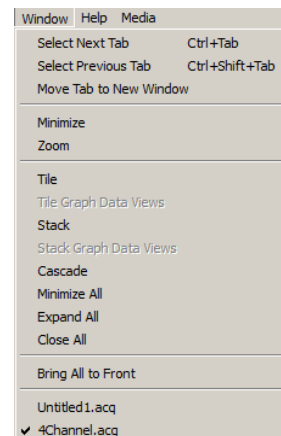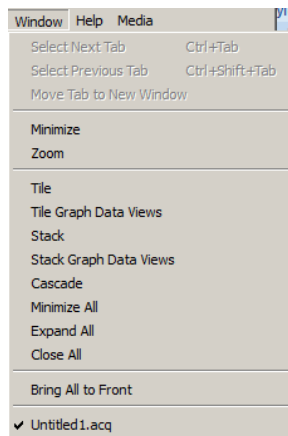
Help menu
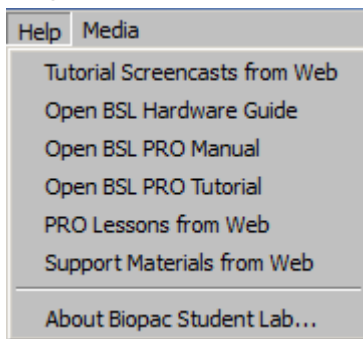
Use the User Support System pdf files for online help with the software.

When About BSL is selected from the Help menu, a screen is generated that provides information about the BSL software being used and the system parameters, which can be useful if technical support is required.

Note: For information about the MP data acquisition unit and firmware, click Help > About Biopac Student Lab.
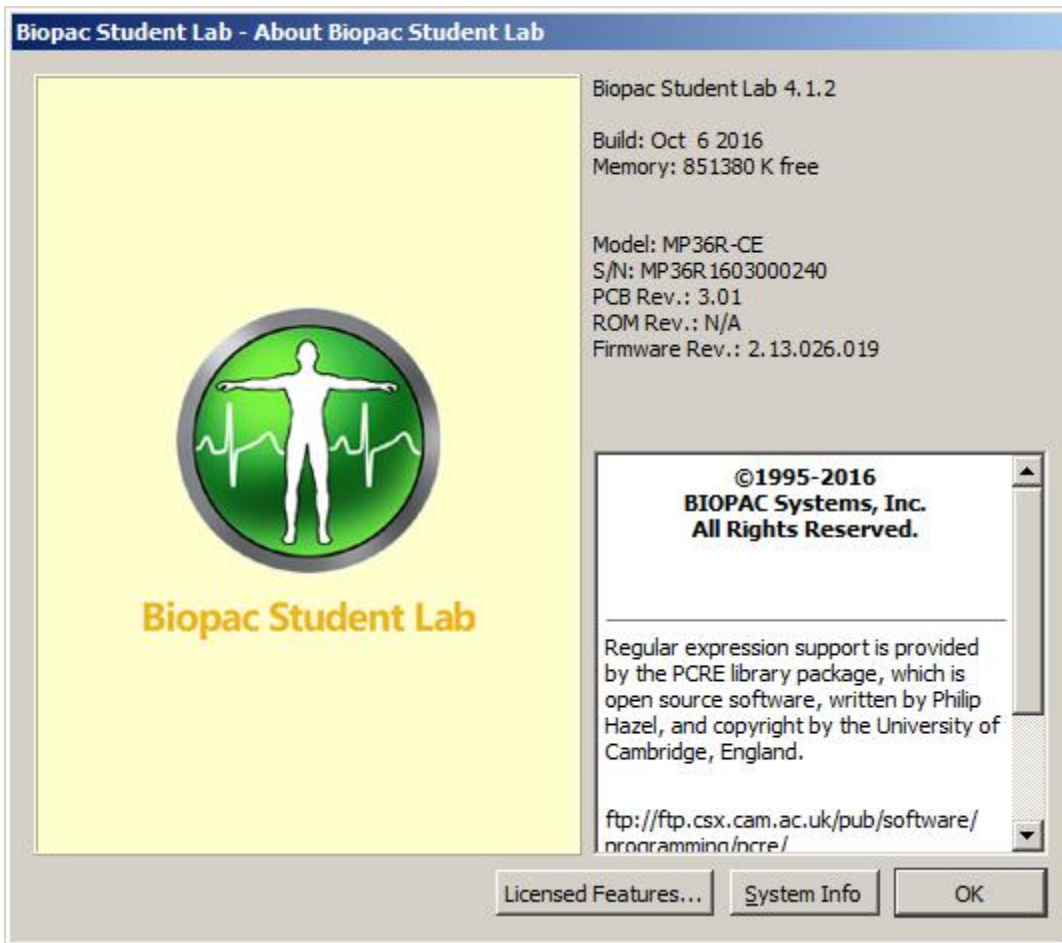
Click the System Info button for more detailed information.
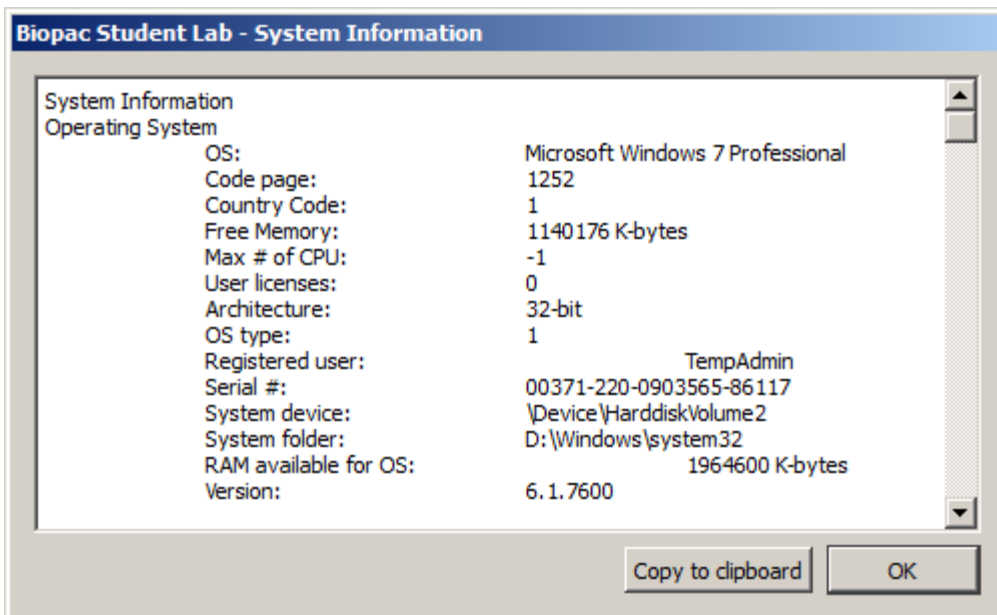
The **Copy to clipboard** button makes it easy to paste system info into an email for Technical Support.

Chapter 17   Media Menu

Media
Set Up...
Show Capture Viewer...
Show Playback Viewer...
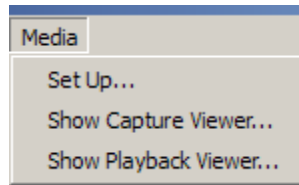
Available in BSL *PRO* for Windows 8 and 7ô Media functionality allows users to capture and playback video and/or audio with a USB web cam or firewire DV device and synchronize it with physiological information from an MP device. The key functionality is a strong link between the video and data cursor when graphs are being used in post-acquisition mode; changing the selection in the graph window will automatically jump the video to the time corresponding to the cursor position. The reverse tie is also in place where erasing the video will move the data cursor to the corresponding data point in the graph.

For synchronized playback of media player with BSL *PRO* cursor in data view, BIOPAC recommends that the users sample the MP unit at least as fast as the video frame rate 30Hz. In this case, any measurement errors are limited to the basic frame rate error window (1/30 sec). For exact match of Video and Data samples, BIOPAC recommends frame rate 25 fps and acquisition rate 25 samples/second (or its derivatives).

Set Up Establish Sources, Output and Media parameters. Set device type for audio and or/video. Use refresh after connecting a new device to make it a selectable option. Browse using standard file open/save functionality to specify media files. If desired, set a Delay between file segments.

Show Capture Viewer Use for video signal directly from a video camera; this option is disabled (grayed) in the record mode when both the Capture video and Capture audio options in the Media Setup dialog are off.

Show Playback Viewer Use to play back media from the disk (stored media files); this option is disabled (grayed) if there is no media assigned to the file.

Show Capture Preview This Media Toolbar icon toggles the preview window display state (show/hide); this option is disabled (grayed) in the record mode when both the Capture video and Capture audio options in the Media Setup dialog are off.

Video Playback and Capture preview include a right-mouse contextual menu item õGrab bitmapö which, when selected, generates a Save As dialog to save the current displayed frame as a *.bmp image.

Media Notes

:: Media capture performance is improved under Windows 8 or 7 OS. If the selected camera drops frames because of poor performance/low quality, the degree of synchronization will be compromised. Testing indicated the Microsoft Lifecam NX-3000 gave reliable performance with no dropped frames.

:: Media functionality is not fully supported in Windows XP.

:: Several BSL *PRO* files can point (link) to the one media file.

:: BSL *PRO* files can link to media files created by other programs. If the media file is shorter or longer than the BSL *PRO* files, just align the two files at the start.

:: BSL *PRO* files alignment precision with the media file is user-controlled through the use of a delay function that allows a forward or backward time shift.

:: BSL *PRO* files store the location (path) of the media file. This path is editable, so the BSL *PRO* file can link to other media files too.

:: Media functionality does not support the *Autosave file* acquisition mode.

Synchronization Tip

Delay allows for a positive or negative time shift to be introduced between start of graph data and start of the linked media file, thus compensating for any data/media alignment issues that may arise. Playback synchronization is often necessary because there is an unknown delay between the actual start of the acquisition and the start of the first video frame. If precise synchronization is required, the Playback synchronization setting allows one to change the timing of the first video frame with respect to the first data sample.

As an example to determine synchronization, an LED can be connected to the I/O output of the MP36/MP35 device. The Digital Outputs Output Control can then be set up to toggle any digital channel (D1-D8) on/off. With the LED viewable in the video, simply determine when the digital output occurred in the graph and enter the appropriate Playback synchronization value necessary to correct the alignment. Note that one can never achieve better than 1/30 of a second synchronization, which is the video frame rate.

BIOPAC Digital LED connected to MP3x I/O port

1) Note: Because synchronization requires a time scale value, it cannot be applied to graphs displayed in X-Y mode, or for FFT and Histogram windows. Once the LED has illuminated and the square wave is visible in the file, the channel can be hidden.

2) After the recording is complete, use the I-beam selection tool to measure the offset between the LED illumination and the leading edge of the digital impulse. Use a Delta T measurement to determine the delay information; Delay may be positive or negative based on camera performance. Delay should be entered in the Linked Media row for each segmentô see page 345.
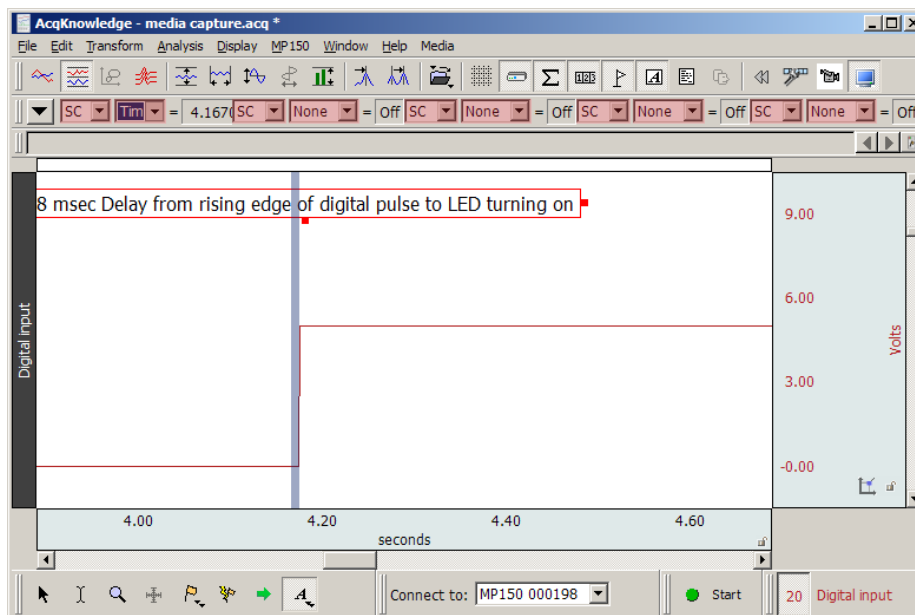
Media > Set Up

Source

Use this dialog to select media source and select audio and video to record. Click Refresh to update the list if a video or audio device is connected after the dialog was opened. When video/audio for capture is selected, an output file must also be selected. Input file name and click OK; this will close the Media Setup dialog and automatically open the media window if the Capture option is ON.

All video camera, audio (microphone) input parameters can be setup by user with the UI provided by camera manufacturer.

All video camera, audio (microphone) input parameters can be setup by user with the UI provided by camera manufacturer, or use the õConfigureö button for direct access to camera properties, such as exposure, saturation, contrast, white balance, etc.
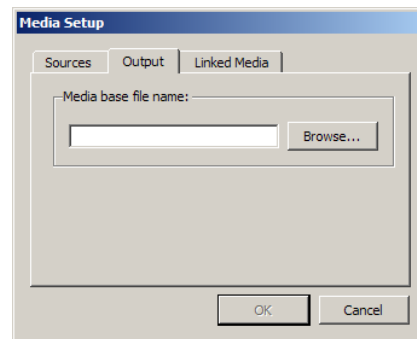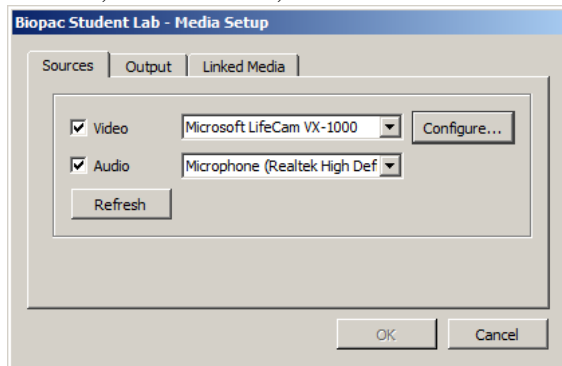
Output

Video/audio capture requires a media file specified with full name with disk location. *.avi or *.wmv file formats are supported. Users can save BSL *PRO* data and media streams onto separate hard drives.

Linked Media

IMPORTANT   A BSL *PRO* data file must be opened before linking to a media clip.
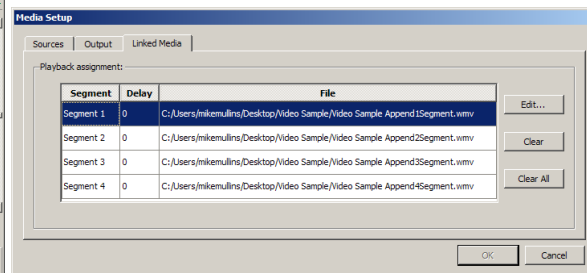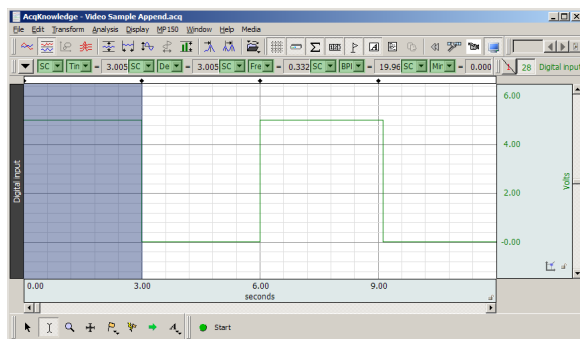
If media was captured with the data file, the Linked Media dialog will display a row for each appended segment in the BSL *PRO* data file and will list the file location of the corresponding media for each segment. The samples above show four BSL *PRO* data segments and four linked media Files.

Click anywhere in the row (or choose the Edit button) to set a delay to synchronize the media file with the physiological data. Delay range: Min= 1 millisecond, Max = segment duration.

   ▪   See Synchronization Tip on page 344.

If media was not captured with the data file, click the appropriate row and click õLinkö to browse to the desired media file from that segment.

Delayô Each segment can have a distinct delay. Click in the Delay cell or click Edit to generate the dialog for Delay entry.

   õ+ö Delay places start of video file after graph start

   õ-ö Delay places start of video file before graph start
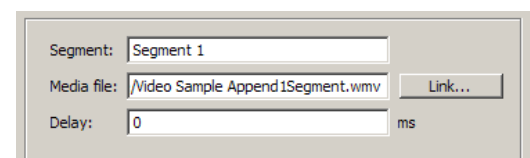
The best possible synchronization canøt be better than the video frame rate (usually1/30 of a second).

Media > Capture

Use Set Up to assign a Source and Output to enable the Capture menu option. There are no Preview window controls and the size reflects default video camera resolution.

Playback Preview

As the media file is manually scrolled or automatically played, the BSL *PRO* cursor keeps moving to reflect the corresponding location in the BSL *PRO* graph. If the BSL *PRO* cursor is moved, the media file is automatically scrolled to keep time sync with the data file.

Media files linked to appended data segments are loaded in sequential order. After playback of the first media segment, the cursor will automatically advance to a still-frame view marking the beginning of the next segment. The Play button must be pressed in order to play back subsequent segments.

Audio   Mute button and level slider

Video   Digital indicator (time in milliseconds or frame number for the segment clip) and Horizontal slider (progress bar) to navigate the media file. The start point can be set from either the media clip or the data file. For precise selection, hold the shift key and use the forward or backward arrow keys on the media player or the keyboard to move single video frame (mostly 1/30 seconds) or data point.

Use the scroll bar to navigate to different frames. Synchronization should be maintained with data in the graph window. This should result in a single sample selection cursor shown at the time closest to the displayed video frame.

The media window displays the text õNo media assignedö in Playback Preview when the media window is visible but there is no video/audio file assignment for given data segment.

During the capture or playback of audio only, the media window will be displayed with a static musical note image as shown at right.

The Playback viewer uses standard media player controls.

	Go to previous segment / go to beginning of segment
	Step backward a frame/sample
	Fast backward / reverse rewind
	Play/ pause
	Fast forward
	Step forward a frame/sample
	Go to following segment
	Mute sound

Media Playback Example

1. Launch BSL *PRO*
2. Open a saved acquisition file.

3. Select Media > Show Playback Viewer.
4. Experiment with the following options:
   - Select I-beam cursor on graph and push õPlayö button on the player.
   - Change selection with I-beam on graph and see the video.

IF media is not assigned, locate the video clip for the appropriate segment:
   a.) Select Media > Set Up
   b.) Select the õLinked Mediaö tab
   c.) Select Segment 1 and click õEdit.
   d.) Click õLinkö and select a saved media file.
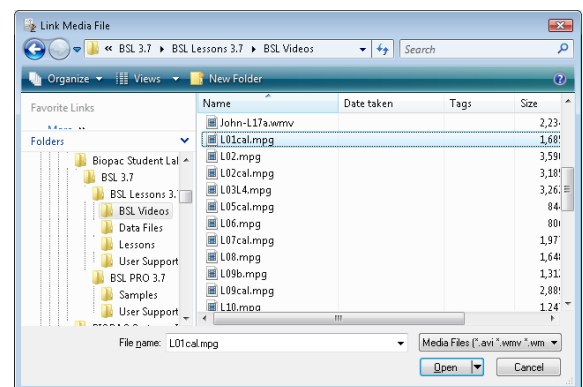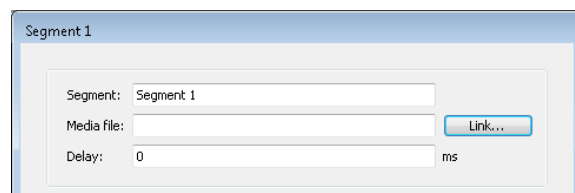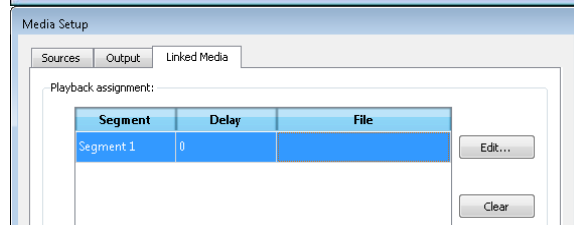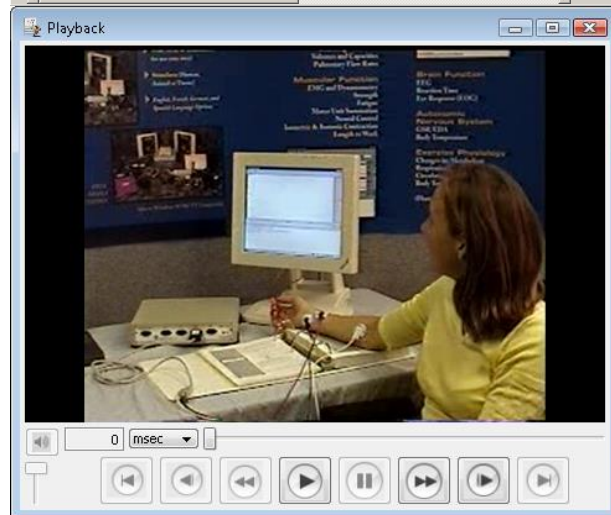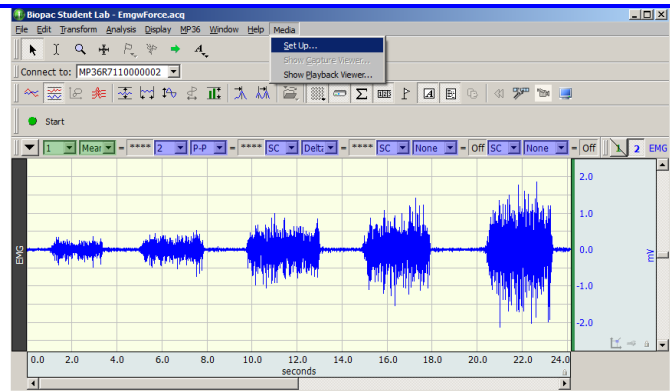
Chapter 18   Licensed Functionality:
BSL Curriculum Management System

<mark>The **BSL Curriculum Management System** is available through optional licensing in BSL 4.1 and above only. The license must be authorized to use this lesson customization tool. To add a license to an existing Biopac Student Lab installation, please contact BIOPAC.</mark>

Overview

The BSL Curriculum Management System is a licensed feature that allows instructors to add customized lesson content and create user-defined onscreen lesson instructions for any existing BSL Lesson. It also has a built-in networking feature allowing instructors to easily broadcast customized content to student workstations over a local network. The level of control over lesson customization in the BSL Curriculum Management System goes well beyond the scope of standard BSL Lessons & *PRO* and is ideal for instructors wishing to create, edit, and modify content in a seamless, flexible fashion.

This chapter is a guide to the powerful features available in the Curriculum Management System and covers:

- How to associate custom recording procedures, analysis procedures, introductions and data reports with any existing BSL Lesson. (Any user-defined PDF can be substituted for the default BSL Lesson PDFs.)

- How to edit onscreen HTML Journal content to create custom onscreen instructions.

- How to configure Instructor (Host) and Student (Client) network settings for sharing lesson content.

- How to share PRO Lessons and Shared Lessons over a network.

    o BSL *PRO* Lessons - H01-H36 and A02-A17
    o Shared Lessons are custom lessons created by the instructor.

Activating the BSL Curriculum Management License

Activating the BSL Curriculum Management System license is accomplished via a BIOPAC License Key (a physical USB License Key containing the Curriculum Management System activation code).

The BIOPAC License Key (USB) allows access to the BSL Curriculum Management System from any machine that has BSL 4.1 installed. It's recommended to use this key on personal laptops or office computers. The key is only required to run the Curriculum Management portion of the BSL software.

To Use the BIOPAC License Key (USB):

1. Connect the Key to an available USB port. (Biopac Student Lab 4.1 must already be installed on the computer.)

Register the key online at www.biopac.com/my-account/product-registration/. Registration is recommended in order to receive hardware support, product updates and BIOPAC License protection/replacement options.

(If no BIOPAC account exists, a prompt will appear for creating one.)

2. The USB key must remain connected in order to use the Curriculum Management System.

Enabling the BSL Curriculum Management System on the Instructor (Host) machine

The first step after license activation is to enable the BSL Curriculum Management System preference on the Instructor or "Host" machine.

1. Launch BSL 4.1 and choose "Create/Record a new experiment" in the Startup Wizard. Click OK to create a new graph window.
2. Go to Display > Preferences > Lessons and enable the **BSL Curriculum Management System Host** option.
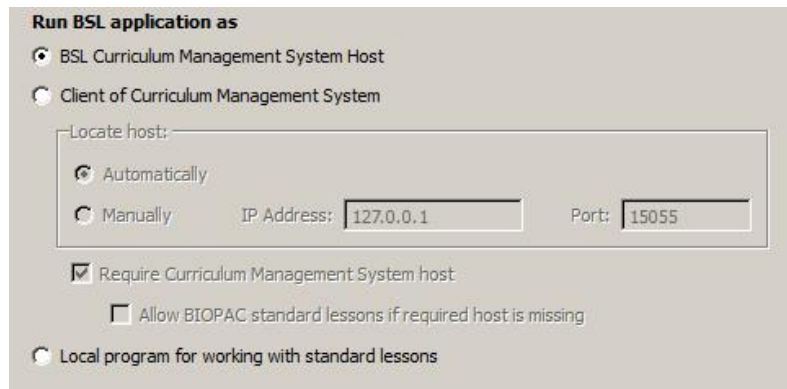
3. Click OK and dismiss the resulting Curriculum Management System prompt.
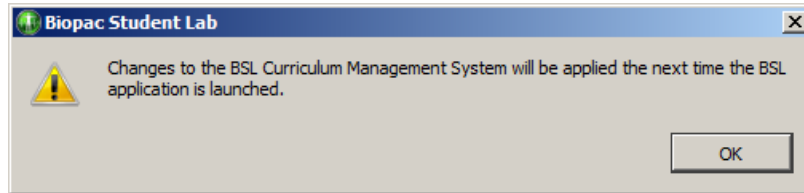
4. Close the BSL 4.1 application and relaunch it. The Curriculum Management System will now be present in the BSL Startup Wizard as the õCustomize my labö option.

5. Choose õCustomize my labö for access to the Curriculum Management System customization options.
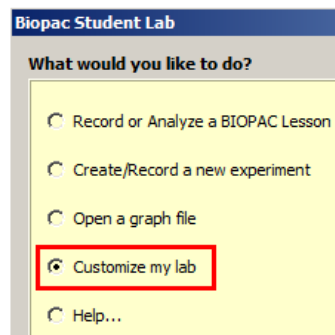
For information on setting up the Student (Client) machines to share the Instructor machine lesson content, see page 363.

What does the "Customize my lab" option do? The
õCustomize my labö Startup option is a portal into
the BSL Curriculum Management System. This
versatile feature enables the user to substitute
modified lesson exercise content in place of the
default BSL Lessons materials by selecting custom
elements from within the BSL 4.1 Startup Wizard
options. Your customized content must be in PDF
format for Analysis Procedures, Introductions, and
Recording Procedures, and BIOPACøs Journal
(*.jcq) format for the Data Reports.

The Curriculum Management System also includes
the powerful **BSL Visual Editor** (accessed via
õOnscreen instructionsö), a flexible HTML editing
and design tool that enables detailed modification of
the default onscreen Journal instructions
accompanying each lesson recording. With the BSL
Visual Editor, you can edit, add/format text,
create/delete/modify tabs and details, as well as
embed graphics and videos into every lesson segment
ranging from setup, calibration and analysis. With
the Curriculum Management System, implementing
custom lesson plans becomes a simpler and more
interactive experience. All edited content is presented
for preview in the lower pane of the Editor and
appears identically as in the actual lesson.

For example, letøs say you want to modify BSL
Lesson 1 (EMG-1) to include variations on the default exercises. Simply edit the Lesson 1 Word document source
(Word doc sources for all lesson procedures are included on the BSL 4.1 installation DVD). Save your changes, and
then create a PDF file of the modified lesson. (Later versions of Word or other text editors, such as OpenOffice,
support the conversion of doc format to PDF, as will the full version of Adobe Acrobat Pro.) This modified lesson can
then be substituted for the default lesson. The Curriculum Management Systemøs selectable options place the
modified files in the Help Menu of the selected BSL Lesson where they are easily accessed by the student.

Modified lessons can be shared from the Instructor machine (host) with any Student machines (clients) over a local
network. Sharing lessons does not require special networking expertise. All shared content is configured in the BSL
Curriculum Management Systemøs General settings via the checkbox options.

Need to revert to the default BSL Lesson or onscreen instructions? The original Lesson procedures and instructions
are not overwritten by creating custom lesson content. Simply uncheck the custom content boxes in the Curriculum
Management õLessonsö settings, or click the õChangeö button and navigate to a different custom lesson file.

Custom onscreen instructions can also be reverted to the default Biopac instructions from the file menu of the BSL
PRO application; File > Set up Curriculum Management System. On the Lessons pane of the displayed dialog, click
the õRevertö button.

For more details on the Curriculum Management System settings, see page 351.

Access the BSL Curriculum Management System lesson customization options by choosing "Customize my lab" in the
Startup Wizard.
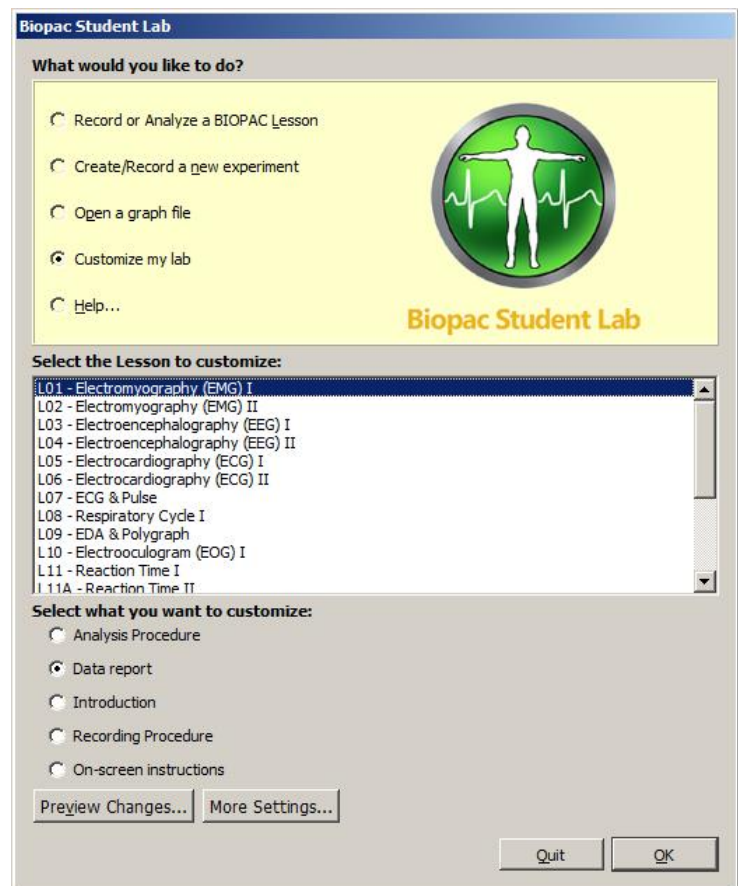
Customize my Lab Radio Buttons and Controls

Select the Lesson to customize: The first step is to select the lesson to apply your custom content to. Choose a lesson from the list before continuing.
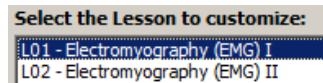
Select what you want to customize: Use the radio buttons to enable specific elements of your customized lesson content (Analysis Procedure, Data Report, Introduction, or Recording Procedure). Choose the desired option, click OK, and a File > Open dialog will be presented. Simply navigate to the location of your custom content and click õOpen.ö This will place your custom PDF content in the Help Menu of the lesson selected for customization and place your custom Data Report and Analysis Procedure into the lesson Journal.
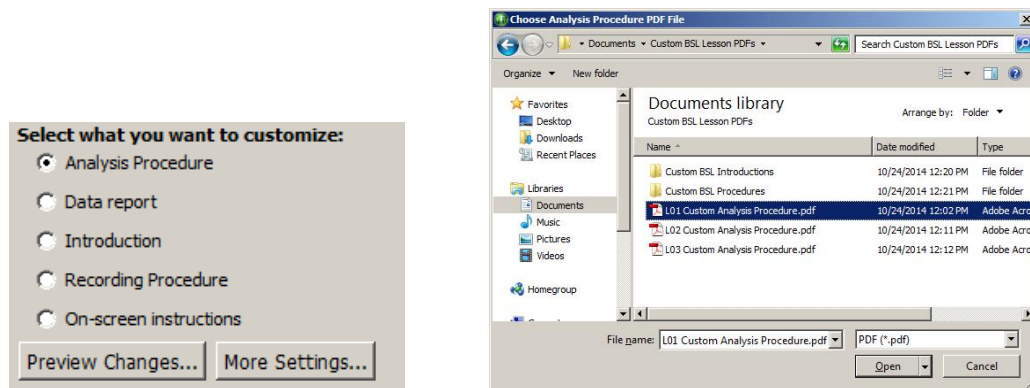
In the above example, a custom Analysis Procedure for L01 is being selected.

Lesson customization radio button details:

Radio Button	Function
Analysis Procedure	Use the Analysis Procedure option for navigating to the directory containing the custom Analysis Procedure (PDF) to be used. Highlight the new file and click %Open.+This will associate the custom Analysis Procedure with the selected lesson and embed it as a tabbed PDF file in the lesson Journal.
Data Report	Use the Data Report option for navigating to the directory containing the custom Journal Data Report (*.jcq) file to be used. Highlight the new file and click %Open.+This will place the new Data Report in the Analysis Journal of the selected lesson.
Introduction	Use the Introduction option for navigating to the directory containing the custom Lesson Introduction (PDF) file to be used. Highlight the new file and click %Open.+This will place the new Lesson Introduction in the Help Menu of the selected lesson.
Recording Procedure	Use this option for navigating to the directory containing the custom Recording Procedure (PDF) file to be used. Highlight the new file and click %Open.+This will place the new Recording Procedure in the Help Menu of the selected lesson.
On-screen instructions	Opens the BSL Visual Editor, which is used to modify the default onscreen HTML Journal instruction content. Use this editor to edit and format text, add tabs, import pictures and videos, and more. See page 353 for details on using the BSL Visual Editor.

Preview Changes

Use the õPreview Changesö option to conduct a trial run of the modified lesson. You also have the option of changing other default Lesson Preferences at this time.

More Settings

The õMore Settingsö dialog presents advanced options for setting up custom lesson content. It essentially performs the same function as the õCustomize my labö radio buttons, but with a greater degree of control and all custom content options presented on a master screen. This is also where custom lesson material for broadcast from the Instructor (host) computer to client (student) computers is selected. (See page 363.)
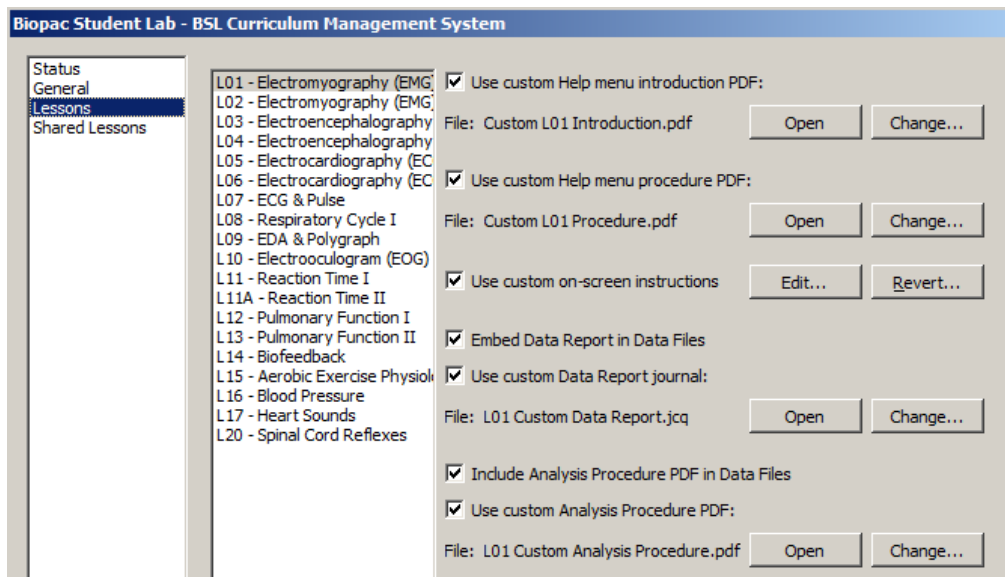
The above Lessons settings dialog may also be accessed from the BSL *PRO* application via the õFile > Setup BSL Curriculum Management Systemö menu option. Options and controls are as follows:

Use custom Help menu introduction PDF: **-** enables option to use custom Introduction in Help menu and broadcasts intro to client (student) computers.

Open – opens the selected custom introduction file for preview.

*Change*í   – opens a File > Open dialog for selecting a different Introduction file.

Use custom Help menu procedure PDF: - enables options for using custom Lesson Procedure in Help menu and broadcasts this content to the client (student) computers.

Open ó opens the selected custom Lesson Procedure for preview.

*Change…*ó opens a File > Open dialog for selecting a different Lesson Procedure file.

Use custom onscreen instructions ó enables the option to show customized Journal instructional content for the selected lesson. If unselected, the standard default onscreen instructions are shown.

Edit ó opens BSL Visual Editor for editing the selected lesson Journal content

Revert... ó discards custom Journal instructional content in favor of the original default content. (The following prompt will appear when choosing this option.)
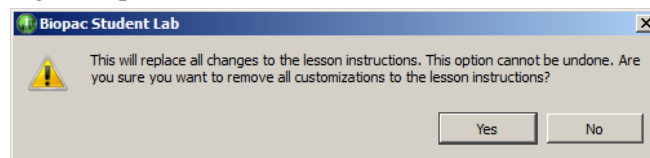
Embed Data Report in data files ó enables option to embed the standard or custom Data Report into the analysis Journal. If unselected, only the lesson segment summary will be displayed in the analysis Journal.

Use custom Data Report Journal ó the custom Data Report will be embedded in place of the standard default data report. If unselected, the standard default Data Report will be used.

Open ó opens the custom Data Report file for preview.

Change… ó opens a File > Open dialog for selecting a different Data Report (*.jcq) file.

Include Analysis Procedure PDF in Data Files ó when selected, the standard or custom Analysis Procedure PDF is embedded as a separate tab in the analysis Journal following the lesson.

Use custom Analysis Procedure PDF: ó the custom Analysis Procedure will be embedded as a Journal tab in place of the default Analysis Procedure. If unselected, the default Analysis Procedure will be used.

Open ó opens the selected custom Analysis Procedure for preview.

*Change…*ó opens a File > Open dialog for selecting a different Analysis Procedure file.

BSL Visual Editor

The BSL Visual Editor is a designing and editing tool used to modify the default onscreen Journal instructions for any selected lesson. If a custom lesson procedure is being used, the corresponding onscreen Journal instructional content can be edited to match the custom procedure.

The BSL Visual Editor is an important component in the Curriculum Management System and allows for flexible manipulation of onscreen Journal content of a running lesson. The Editor consists of a main toolbar area, two control docks, an editing window and a preview area.

The launch BSL Visual Editor:

- Select the õOnscreen instructionsö radio button in the õCustomize my labö Startup screen. (Click OK)

- Select õMore Settingsö and enable the õUse custom onscreen instructionsö checkbox in the BSL Curriculum Management System settings window. (Click OK)

- In the BSL *PRO* application, File > õSet Up BSL Curriculum Management Settingsö and enable the õUse custom onscreen instructionsö checkbox in the BSL Curriculum Management System settings window. (Click OK)

The Editor can interactively modify the following areas of the lesson Journal:

- Fast Track text, including the addition of actions, notes and other text and graphics.

- Collapsible notes and pictures in the Details area

- Tab name and tab title, including the addition and deletion of tabs

- Standard text formatting tools are provided ó edit font size/style/ text and background color

- Text alignment, bulleting and numbering, increase/decrease indent

- Create and insert tables, hyperlinks or HTML code

- Undo, redo, cut, copy, paste, file open/save

- Zoom forward/back text and image size

BSL Visual Editor Window
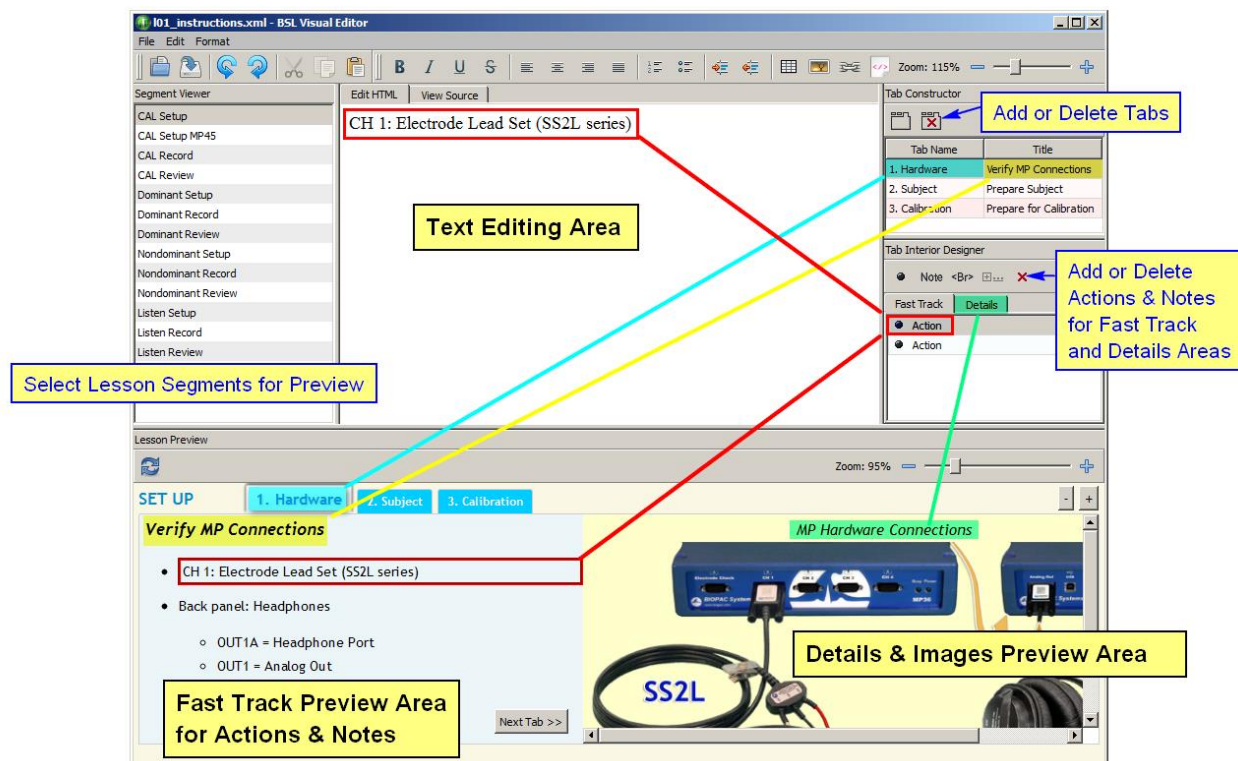
BSL Visual Editor Window

Main Text Editing Area

The Main Editing Area is the workspace for modifying text and other content appearing in the Lesson Preview Area and appears at the center of the BSL Visual Editor screen. Simply enter standard (or HTML) text into this field, or modify existing text using the formatting tools (see formatting toolbar on page 355).

Text Editing Area – View Source Tab

The õView Sourceö tab displays the raw HTML source code for items currently selected in the Editing Area. This field is not editable but the content can be copied into the Editing Area and modified externally.
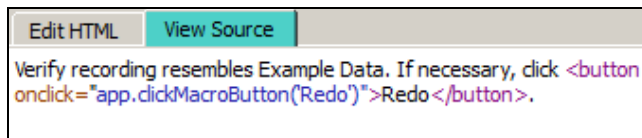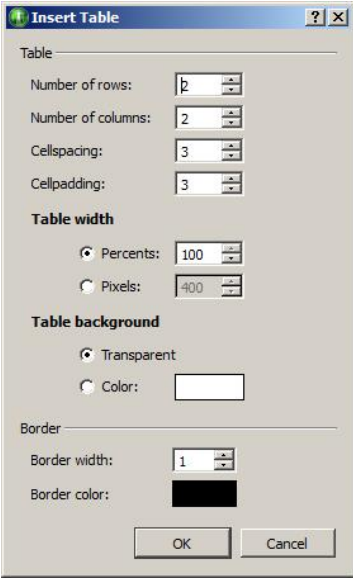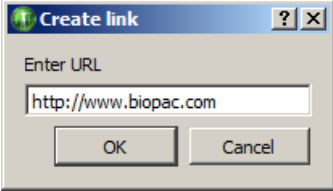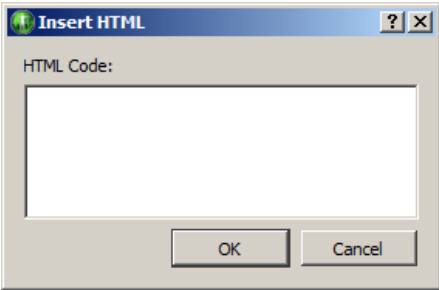
Itøs important to remember that the text in the Editing and Preview Areas mirrors the lesson text for the currently-selected lesson Segment. Other factors affecting Editing Area content are the various elements selected in the Tab Constructor and Tab Interior Designer. (See explanation of these controls below.)

BSL Visual Editor Toolbar

The following formatting tools are available in the Editor:

Tool	Description
	Open button. Launches a File > Open dialog for navigating to a lessons instructions file (*.xml format).
	Save button. Saves the current edits to the lesson instructions.
	Undo button. Removes the most recent editing or formatting operation.
	Redo button. Restores the most recent editing or formatting operation.
	Cut button. Cuts the selected Editor text or content.
	Copy button. Copies the selected Editor text or content.
	Paste button. Pastes the selected Editor text or content.
	Bold button. Toggles bold font style.
	Italics button. Toggles italicized font style.
	Underline button. Toggles underline of selected text.
	Strikethrough button. Toggles strikethrough of selected text.
	Align left paragraph button.
	Align center paragraph button.
	Align right paragraph button.
	Align justified paragraph button.
	Numbered list button.
	Bulleted list button.
	Increase indent button.
	Decrease indent button.

Tool	Description
	Insert table button. This option displays the following table formatting options:
	Insert image button. Displays File > Open dialog for navigating to an image file.
	Hyperlink tool. Displays dialog for entering URL information.
	HTML tool. Displays following dialog for inputting HTML code at the cursor location.

Zoom Tool

There are two independent Zoom tools in the BSL Visual Editor window. The Zoom tool on the top right controls the sizing of the Text editing Area content and the bottom right Zoom tool controls the sizing of the Preview Area content.

BSL Visual Editor Menus

The Editor menus display an alternate method for accessing the formatting toolbar options, plus a few additional controls.
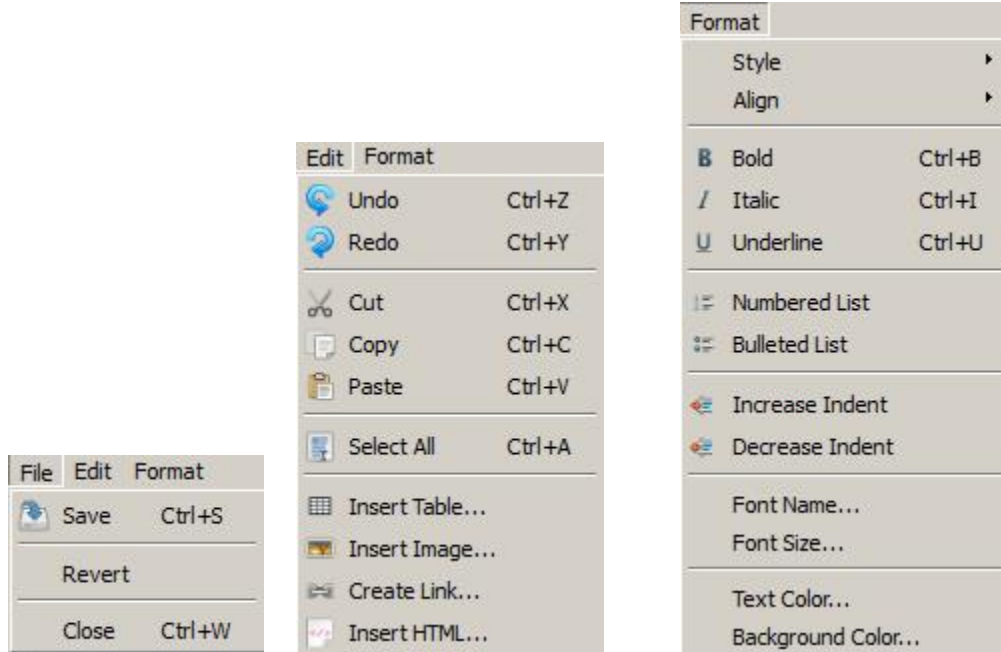
File > Revert

Discards global changes made to the currently open set of instructions.

Format > Font Name, Font Size, Text Color, Background Color

Additional formatting tools for operations not included in the formatting toolbar.

BSL Visual Editor Tools and Controls

BSL Visual Editor controls are described below on a sectional basis. Refer to the above image for their default Editor window locations.

Segment Viewer	The **Segment Viewer** is used to select available lesson recording segments for global editing and preview display. This control is dockable and can be positioned anywhere in the BSL Visual Editor window.
Segment Viewer CAL Setup CAL Setup MP45 CAL Record CAL Review Dominant Setup Dominant Record Dominant Review Nondominant Setup Nondominant Record Nondominant Review Listen Setup Listen Record Listen Review	When a Segment Viewer entry is selected, the **Lesson Preview Area** displays all required actions for that segment in the lower half of the Editor screen. The Lesson Preview closely resembles the instructional Journal presented during the running of an actual lesson. (The Lesson 1 **CAL Setup** segment is shown in this example preview.) **Segment Viewer Limitations:** The Segment Viewer menu is not editable, and only one segment may be selected at a time. New lesson recording segments cannot be added, and default segments cannot be deleted.
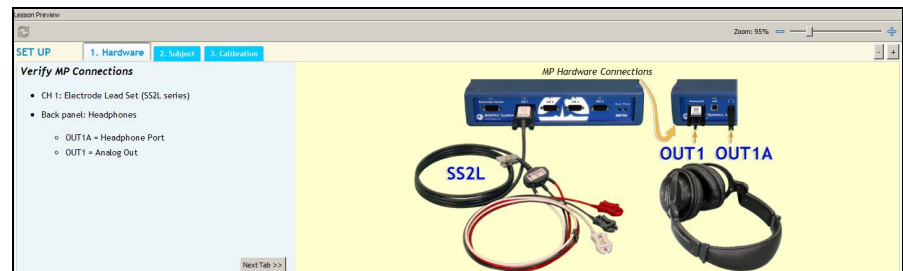
Tab Constructor (for Fast Track content)	The **Tab Constructor** is used for editing, adding and deleting tabs and tab text in the Fast Track Preview Area. This control is dockable and can be positioned anywhere in the BSL Visual Editor window.
Tab Name and **Tab Title** as they appear in the Fast Track Preview Area.	The "**Tab Name**" and "**Title**" fields are directly editable. To change existing Tab text, click into the Tab Name or Title field to select and enter new text. Press **Enter** to accept the new edits. Newly-added Tabs will remain "Untitled" until new text is entered in the active Tab Name and Title fields.
	Use the buttons to add new Tabs or remove existing Tabs.
	New Tabs will appear in the Tab Name list below the currently-selected Tab and to the right of the selected Tab in the Fast Track Preview. To delete a Tab, select it and click the Tab Delete button. (Red "X")
Tab Interior Designer (Fast Track)	Use the **Tab Interior Designer** to select blocks of Lesson Preview text for editing. This control is dockable and can be positioned anywhere in the BSL Visual Editor window.
Lesson Preview of Fast Track text.	**Fast Track** selection:
	The default formatting for BSL Lesson Fast Track text consists of **Actions** or **Notes**.
	Actions are are indented and bulleted by default.
	Notes appear as standard text.
Editing Area for entering/formatting Fast Track text.	Actions or Notes can be reformatted as desired in the main **Text Editing Area**. (See page 354.)
	To enter or edit an Action or Note:
	1. Click on the desired Action or Note item in the list to select it. (The selected text will be outlined in red in the Lesson Preview.)
	2. Type the new text into the Text Editing Area in the center of the Editor screen.
	3. Apply the new text to the Preview by clicking the Refresh Preview button.
	Tab Interior Designer "**Fast Track**" Tools:
	Use the button to add a new Fast Track Action.
	Use the Note button to add a new Fast Track Note.
	Use the button to add an empty space to Fast Track.
	Newly-added Actions or Notes appear below the currently-selected Action/Note in the Fast Track list. (Items in the list cannot be dragged to different locations.)
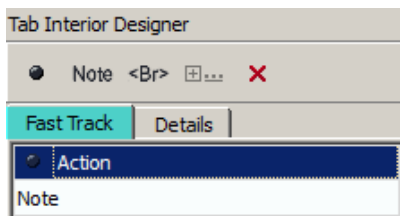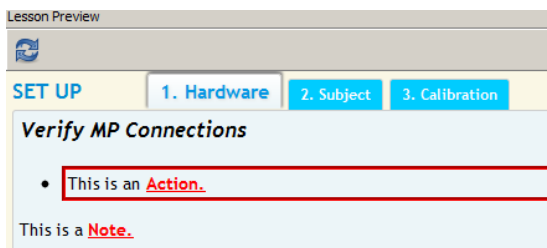
Tab Interior Designer (Details)
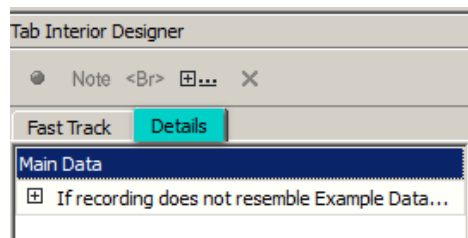
Text Editing Area with **Main Data** selected:
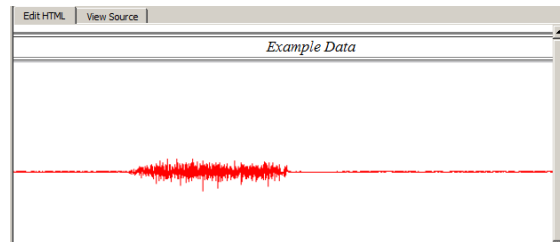
Example of Details with collapsible sub-text:
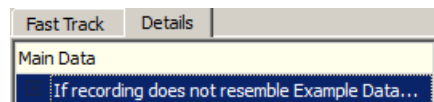
Enter collapsible sub-text in Text Editing Area:
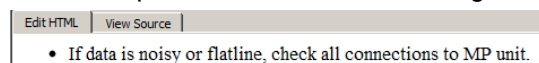
Collapsible sub-text as it appears in preview:
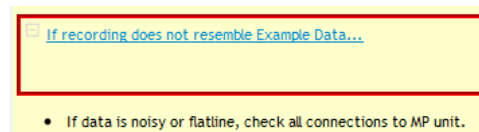
Collapsible means that clicking the underlined Detail text in the Preview Area will show or hide the sub-text.

Use the Tab Interior Designer **Details** option to edit the right pane Preview Area content. This area is where supporting details, illustrations, pictures and videos are typically embedded.

The Details option consists of a **Main Data** entry, which displays the primary content in the Text Editing and Preview areas.

To select **Main Data** content for editing:

1. Click the **Main Data** field.
2. Edit content by typing into the main Text Editing Area in the center of the screen. Import of graphics and videos are also supported. (See page 355 for more Text Editing Area tools.)

To add optional **Details** text to the Main Data:

1. Click the button.
2. Highlight the newly-added %Untitled+entry and enter the desired text.
3. Press the Enter key (or click anywhere in the Editor window) to apply the edit. The new Details text will appear in the lower right Preview area.
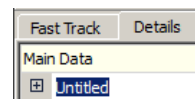
You may also:

- Add collapsible sub-text to the selected Detail by typing it into the Text Editing Area. (See left example.)
- Edit the existing Details of any selected lesson segment.
- Delete Details using the button.

Additional BSL Curriculum Management System Settings

The global settings for BSL Curriculum Management are controlled and displayed in the panels within this screen. Access the BSL Curriculum Management Settings by:

- Clicking the More Settings... button in the BSL Startup Wizard's > **Customize my lab** option.
- Choosing **File > Set Up BSL Curriculum Management System** in the BSL 4.1 *PRO* application.

Status Panel

The Status panel displays current information about the Instructor (Host) and Student (Client) machines during a lesson session.
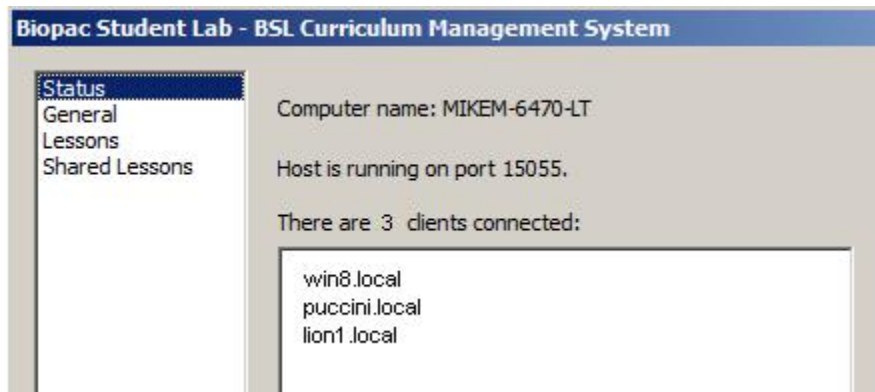
Control	Description
Computer name	Displays the Instructor (Host) machine name.
Host and port status	Displays whether the Host machine is running or stopped. If running, the Host machine's port number is displayed.
Connected Student (Client) machines	Lists all recognized Student (Client) computers on the network using the configuration from the Host machine. They may not be actively transferring data but should still be running BSL in client mode.

General Panel

The General panel contains basic options for configuring the Curriculum Management System that apply at the application level or are shared by all lessons:

Control	Description
Enable BSL Curriculum Management System	Enables the BSL Curriculum Manager, allowing it to broadcast settings and content over the local network.
Host port	Current port number used by the Instructor (Host) machine. Default value is 15055.
Lesson and *PRO* Lesson Startup Wizard visibility	Clients restrict the available choices for the Lessons and *PRO* Lessons tabs on their Startup Wizard to match the lesson preference settings of the Host computer.
Lesson Preferences and Enabled Segments	Enables Student computers (Clients) to use the settings from the Host computer for individual lesson preferences (File > Lesson Preferences when running a lesson) as well as any customizations applied to the Host computer's lesson segment display. Changes to the Host computer's lesson preferences must be applied by running the specific lesson and altering the settings in File > Lesson Preferences.
BSL Application Preferences	Enables Clients to use the Host computer's settings for all application preferences instead of local preferences. This sharing is unidirectional; any changes in application preferences made on a Client machine do not affect the Host. To make a permanent setting change, the Host's Display > Preferences settings must be modified.
Change Password	Use this option to set up or change a password to access any Curriculum Management Settings. When set, the password will be required when choosing "More Settings" option in the BSL Startup Wizard > "Customize my lab" option, or when using File > "Set Up BSL Curriculum Management System" in the BSL *PRO* application.

Lessons Panel

See page 352 for explanation of Lessons Settings panel.

Shared Lessons Panel

Shared Lessons are graph templates with instructor-provided titles made available for use on all Clients. These graph template files may have their own embedded Journals and PDFs to assist in distribution of Instructor materials. This panel configures the specific graph template files being shared.
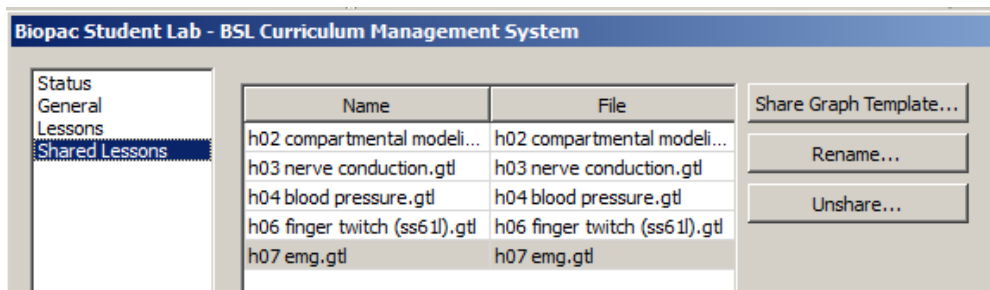
Control	Description
Share Graph Template...	Displays a dialog for navigating to the location of the graph or graph template to be shared.
Rename...	Displays a dialog for renaming the default title of the shared lesson under the "Name" field.
Unshare…	Removes the selected lesson from the shared lessons list.

Setting Up Curriculum Management Instructor (Host) and Student (Client) Sharing

The BSL Curriculum Management System allows for the sharing of default and custom lessons and other instructional materials over a local network, and is split into õHostö software (including configuration controls and editors) and õClientö software. Depending on the Host machine settings, the following information may be shared:

- Application level preferences
- Standard and *PRO* Lesson visibility
- Shared instructor-generated *PRO* Lessons
- Individual lesson preferences
- Replacement help menu introduction and procedure lesson PDFs
- Customized lesson HTML instructions and content
- Replacement Data Report journal
- Replacement analysis instruction PDF for data files

The following Host-Client controls for BSL Curriculum Manager are found in the BSL *PRO* applicationøs Display > Preferences > Lessons:

Control	Description
BSL Curriculum Management System Host	Allows this computer to ‰push+all customized lesson content to the other computers on the local network.
Client of Curriculum Management System	Allows this computer to receive the customized lesson content and onscreen instructions being ‰pushed+from the Curriculum Management System Host computer over the local network.
Locate Host . Automatically	Searches automatically for Curriculum Management System Hosts on the local network.
Locate Host . Manually	Allows the Curriculum Management System Host to be identified by a fixed I.P. address and port number. Use this option is auto-location is not supported on your network.
Require Curriculum Management System host	Check to prompt on application launch if no Curriculum Management System Host is detected.
Allow BIOPAC standard lessons if required host is missing	Allows access to the default uncustomized BSL Lessons if no Curriculum Management Host is detected.
Local program for working with standard lessons	Use the standard BSL Lesson Curriculum.This setting disables the Curriculum Management System.

NOTE: Before sharing the instructional content, enable or disable the desired lessons in the Curriculum Management Settings and the Display > Preferences > Lessons settings.

To share BSL Curriculum Management materials over the network, use the following steps:

1. Launch the BSL *PRO* application on the Instructor (Host) computer.

2. Display Preferences > Lessons. Make sure that õRun BSL application as ó BSL Curriculum Management System Hostö is enabled.

Run BSL application as
◉ BSL Curriculum Management System Host

3. Launch the BSL *PRO* application on the Student (Client) computer.

4. Display > Preferences > Lessons. Make sure that õRun BSL application as ó Client of Curriculum Management Systemö is enabled.

Run BSL application as
○ BSL Curriculum Management System Host
◉ Client of Curriculum Management System

5. Check õLocate host ó Automatically.ö (If your network does not support auto-location, contact your network administrator to obtain the correct I.P. address and port information, and use the õLocate Host ó Manuallyö setting.)

6. Click OK, and click OK to the configuration change confirmation dialog.

Biopac Student Lab
⚠ Changes to the BSL Curriculum Management System will be applied the next time the BSL application is launched.
[OK]
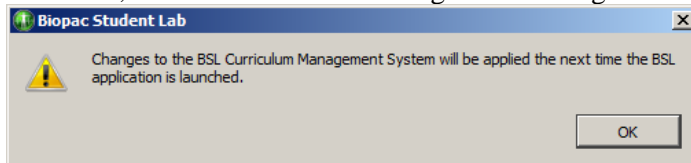
7. Close the BSL application on the Student (Client) computer.

8. Relaunch the BSL application on the Student (Client) computer. The following dialog will appear:

Browsing for BSL hosts...   Time left: 7 seconds
▮▮▮▮▮▮▮▮▮▮▮▮▮▮   30%
[Cancel]
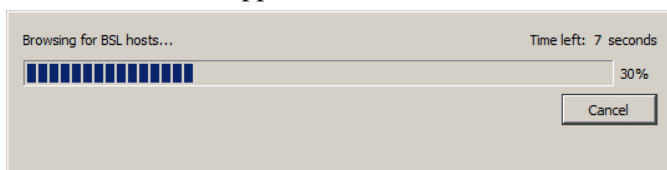
9. The Student (Client) computer will connect automatically to the Instructor (Host) computer over the network, and all configured Host preferences and shared materials will be available to the Clients.

Note: Although detection of multiple Instructor (Host) computers is supported, only one Host computer may be used at a time by a Client. If multiple BSL Curriculum Management Host computers are found on the network, the following message will be displayed.

Multiple BSL Customization Servers have been located on your network. Please select the server to use for your Lesson content:

puccini.local
WilliamXP.local

[Cancel] [OK]
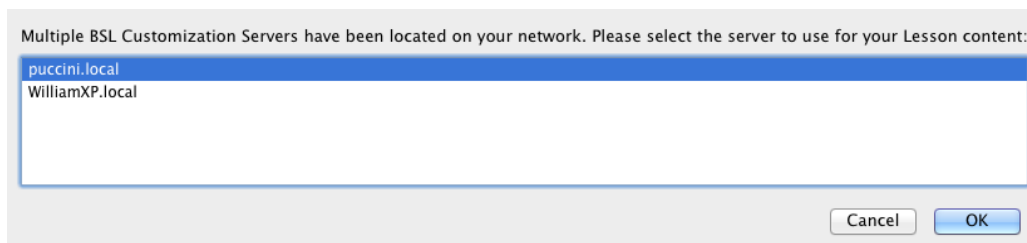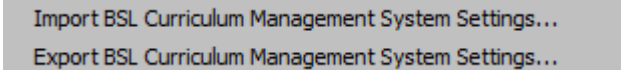
Importing and Exporting Curriculum Management Settings

Customized content and saved Curriculum Management System preference settings can be exported into a proprietary custom settings archive file called *.csp format. The Import/Export functionality allows for customized content and preferences to be exported to a single file that can then be transferred between computers.

This feature is useful not only for backing up custom settings, but also offers the ability to edit content on an office/home computer and then easily move (import) those files to a host in the lab.

To access this feature, launch BSL and select the õCreate and record a new experiment,ö then choose the File menu and note the two Import and Export Curriculum Management Settings options:

Import BSL Curriculum Management System Settings…
Export BSL Curriculum Management System Settings…

In order to use the **Import** option, a saved Curriculum Management Settings archive (*.csp) file must be available. A saved settings file must first be created by using the õ**Export**í ö option, or a saved settings file must be available from another machine with BSL installed.

To Export Curriculum Management Settings

1. Choose the õExport BSL Curriculum Management Settingsö option. This launches a File > Save As dialog.

File name: Backup CMS Archive File
Save as type: settings archives (*.csp)

e Folders   Save   Cancel
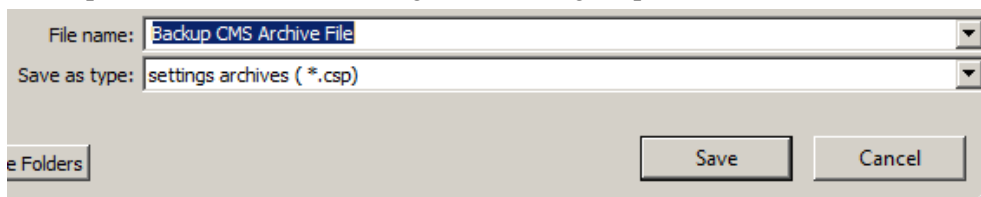
2. Name the settings archive (*.csp) file and Save it to a location of your choice.

The following confirmation dialog will appear after the archived Curriculum Management settings are exported.

Biopac Student Lab

BSL Curriculum Management System settings archive was successfully created.

OK
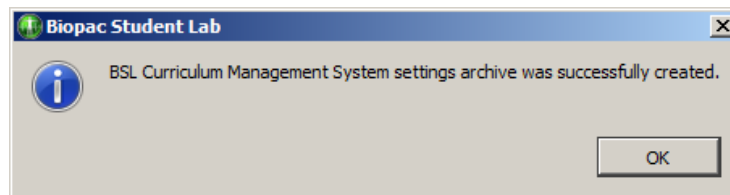
To Import Curriculum Management Settings

1. Choose the õExport BSL Curriculum Management Settingsö option. This launches a File > Open dialog.
2. Navigate to the location of the saved *.csp file, select the file and click Open.
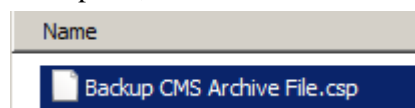
Name

Backup CMS Archive File.csp

The following confirmation dialog will appear after the archived Curriculum Management settings are imported.

Biopac Student Lab

BSL Curriculum Management System settings were successfully imported.

OK
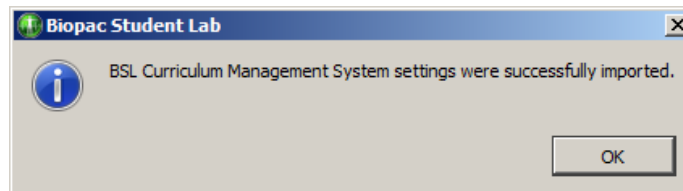
Chapter 19   Licensed Functionality: Network Data Transfer

Network Data Transfer (NDT) functionality is available through an optional license available with BSL 4.1.2. The license must be authorized to access NDT functionality. To add an NDT license to an existing MP System, please contact BIOPAC.

Network Data Transfer (NDT) is a real-time data transfer system that allows access to the data being acquired into a graph by BSL *PRO* for use in an external application; the BSL process and the custom application may run on the same computer.
Make TCP or UDP connections to external applications and stream binary data during acquisitions.

The NDT license

- Allows Network Data Transfer functionality

- Includes Network Data Transfer Preferences

- Click for a [Network Data Transfer video tutorial](#).

Most of the settings for the network data transfer functionality are set by clients through control connections. Several settings for the BSL server may be set directly in the BSL preferences. Versions of BSL that include network data transfer functionality have an additional "Network" group of settings underneath their Preferences. These Preferences are accessed from the Display menu (Windows) or from the Biopac Student Lab menu (Mac OS):
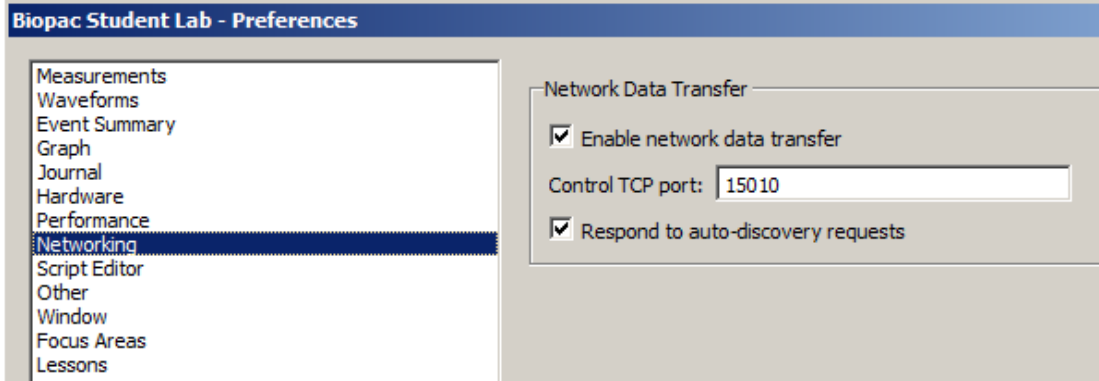
NDT is a basic method for allowing third party applications to tap into the data stream being generated by both the MP unit and BSL during data acquisitions. NDT provides:

- Networking facilities that allow for integration into a distributed application environment

- Basic control facilities to allow external applications to query and control the BSL application state.

The NDT system is split into two separate types of connections: data connections and the control connection.

A. Data connections deliver data from BSL to external applications during acquisitions.

B. Control connections are made from external applications to BSL to query application state and adjust data connections.

The *server* refers to the BSL process and the computer on which it is running. The *client* refers to the custom application that is to receive data from BSL and the computer on which it is running.

All connections should be made using standard network protocols, either TCP or UDP. Single system image architectures should make connections using the loopback interface. It is assumed that network implementations have appropriate IP networks in place with routing between machines that can be identified either by IP address or by hostname. Firewalls must be properly configured to allow network communications between the client and server. Appropriate network configuration is the user's responsibility.

Data Connections

Data connections are used to deliver data from the BSL server to the client application. Data connections stream both data acquired from an MP unit and computed data from BSL calculation channels. Data connections are available in a variety of formats and can be configured to meet the needs of the client application and bandwidth requirements.

Data connections are created only at the start of acquisitions. It is not possible to õattachö to data acquisitions that are already in progress.

XML-RPC calls for retrieving data are also described in this section. These connections are not persistent and not established from server to client, but rather a request made from client to server. The recommended mode of operation is regular TCP or UDP operation.

Variable Sampling Rates

BSL *PRO* uses variable sampling rates that allow different channels of data to be acquired at different sample rates. This allows fast moving signals (such as EMG) to be acquired at high sampling rates while simultaneously recording slow moving signals (such as respiration) at lower sampling rates. The primary use of variable sampling rate is to optimize storage requirements by minimizing space spent retaining slow moving data.

In addition to the storage optimizations, variable sampling rates are also used to optimize data connections. Channels that are sampled at lower rates require less network bandwidth to transfer from client to server. If channels of data cannot be disabled and overall bandwidth is limited, variable sampling rate can be used to lower the bandwidth required to move data between the server and the client.

The use of variable sampling rates requires the client to be aware of downsampled channels and handle data accordingly. Variable sampling rate may also affect the interpretation of the incoming data connection stream, as indicated below.

Transfer Types

Clients may choose between two different transfer types:

- **Single connection** uses one data connection between the server and the client to deliver all data

- **Multiple connection** uses multiple data connections delivering data simultaneously

Single Connection

The single connection transfer type uses a solitary connection between the server and the client to deliver data. When multiple channels of data are being delivered, all data is sent over the single connection in an interleaved format. The interleaved format mingles the data of all channels in order. For example, an interleaved representation of two samples from three channels of data would be: C1 C2 C3 C1 C2 C3. This is equivalent to two sample frames where a *frame* contains the data at a particular sample location for all of the channels, in this case õC1 C2 C3.ö Frames are delivered sequentially over the data connection.

The single connection transfer type allows for all data to be processed from a single location and uses only one network connection resource. Single connection transfer has drawbacks including the need for the client to demux the data stream as well as account for variable sampling rates.

Variable Sample Rate Considerations

When variable sampling rate is being used, the single connection transfer type has the characteristic where not all frames have the same size. If a frame occurs at a sample position where a channel is not being sampled, that channel will not be included in the frame.

All downsampling within the BSL variable sampling rate environment occurs at integer divisions of the base sampling rate. Only frames with indexes (zero-based) that are evenly divisible by the downsampling divider will contain data for that channel.

It is the responsibility of the client to compute and retain the frame index and to properly check channel dividers against the frame index to determine which channels are represented in that frame.

Frame 0 always contains a data point from every channel.

For example, consider a three channel acquisition. Channels 1 and 3 have a downsampling divider of 1, that is, they are being acquired at full speed. Channel 2 has a downsampling divider of 2, that is, channel 2 is being acquired at half speed. The first five frames of data in the single connection transfer type will appear as follows:

C1 C2 C3 | C1 C3 | C1 C2 C3 | C1 C3 | C1 C2 C3

Note how frames 1 and 3 are shorter as they occur at positions where channel two is not defined.

If variable sampling rate is being used, clients are required to perform proper frame indexing in order to demux the interleaved data stream. If clients cannot handle variable sampling rate correctly and are using the single stream transfer type, clients should check all of the downsampling dividers using the control connection to BSL and warn the user if the configuration cannot be supported with that client.

Multiple Connection

The multiple connection transfer type uses a single connection from server to client for each channel of data that is being delivered. Using multiple connections offers the benefit of avoiding the client having the need to demux all of the data from each sample. If the client is operating in a high-load environment, the elimination of the demuxing may be useful in reducing processor overhead. It also allows client code to be simpler if variable sampling rate is being used.

The primary disadvantages of using the multiple connection transfer type are the usage of more network ports and the client assuming responsibility for synchronization of data across multiple channels. The data immediately available on one network connection may not be guaranteed to be the identical sample index of data being received for another channel. The client must keep track of sample index on an individual channel basis to properly synchronize data across multiple channels.

Variable Sampling Rate Considerations

Using variable sampling rate in a multiple connection transfer type is significantly easier. Each individual channel's connection delivers data at that channel's sampling rate. On a given connection, all samples have an identical length.

Clients still must be aware of variable sampling rates. The sampling rate of information on a downsampled channel connection is different than the sampling rate of information on an upsampled channel connection. If the client is performing any time domain measurements or other computations involving the sample interval, the difference in inter-sample-interval must still be taken into account.

XML-RPC

The XML-RPC transfer type allows clients to explicitly request data from the server. Instead of data being automatically pushed to clients, the client must post an XML-RPC function call to the server. This allows the client to query the server for the most recently acquired data sample value for a particular channel. Clients that do not require continual data streams or interact with only slow moving data may wish to use this method communication method. This method returns values only; no information about sample indexes or lengths is returned.

XML-RPC has significant overhead for both client and server, so this transport method cannot handle more than a few requests per second. If faster response time is required, the client should implement either the single connection or multiple connection streaming methods.

XML-RPC is not a true data connection as it does not involve the server constructing a streaming connection to the client.

Transport Protocol

Data connections offer a choice of using either TCP or UDP as the transport protocol for delivering data to the client. Choice of protocol depends on application requirements. When a client is receiving data, it is assumed that all data connections are using the same transport protocol.

TCP/IP

TCP is the preferred transport protocol. As TCP guarantees reliable, ordered delivery, all data is simply transferred from the server to the client without any additional information. Data is streamed continuously as it becomes available. TCP is recommended for all clients that require a guarantee of receiving all information. It is also recommended for any configuration using up to two computers.

The port number used for data connections is specified by the client using the control connection prior to the start of acquisition. Once a client passes along port information, the client should begin listening for connections on that port.

When using TCP data connections, the start of acquisition is signaled to clients by the establishment of a connection on an appropriate port to the client. The end of an acquisition is signaled by the termination of the connection.

UDP

UDP is a connectionless protocol that does not guarantee either delivery or properly ordered reception of packets by clients. Data connection is allowed to be switched to UDP delivery mode. The primary benefit of using UDP datagrams is that a single data stream can be multicast to a number of computers. Multicasting is not offered implicitly by the BSL data connection protocol but can be achieved implicitly by requesting a data connection be bound to a broadcast address.

UDP delivery used fixed size datagrams. The default size is 512 bytes. Clients can modify this size to any fixed number of bytes prior to the start of acquisitions. The UDP packet size is stored in the template and is different for each graph. UDP clients that require a specific packet size should set that packet size prior to the start of each acquisition.

Each datagram will contain the following:

Field	*Data Type*	*Offset*	*Description*
Starting sample index	unsigned long (four bytes, network order)	0 byte	This indicates the starting sample position of the first sample of data contained in the packet. This number is always monotonically increasing and can be used to reassemble datagrams that are received out of order. This field is always stored in network order. Usage of htonl()/ntohl() should convert from network order into host endian.
Length of data section in bytes	unsigned long (four bytes, network order)	4 bytes	Total number of bytes in the data section. Data is sent by BSL as it is available, so not all data packets will contain the same amount of data. This field is always stored in network order. Usage of htonl()/ntohl() should convert from network order into host endian.
Data section	(type and endian specified by client)	8 bytes	Data section containing the binary data that was acquired. The data is converted into the appropriate data as configured by the client.

All of the data delivery is performed as data is available from the MP unit. The actual size of the data section in packets that get delivered to the client is dependent on the speed of data acquisition and other activity on the host computer. If variable sampling rates are being used, frames will not be split up. All of the data for the final frame is contained in the UDP packet. If a frame will not fit in the amount of space in a packet, it is sent in the next packet.

There are no provisions for clients to request retransmissions of packets from the server. Clients should be aware that data may not be delivered when using UDP and should be prepared to examine sample indexes at the beginning of each packet and handle missing data accordingly (padding, warning user, etc.).

The port on which datagrams is delivered is specified by the client prior to the beginning of acquisition on the control connection. Once the client specifies its port, it should begin listening for datagrams delivered to that port. The start of acquisition is signaled by the first datagram that is sent to that port. The sample index of the first datagram corresponds to the first hardware sample of data acquired by BSL. If the graph is initially empty, the index is zero.

Unlike TCP connections which get explicitly disconnected at the end of acquisitions, there is no direct messaging for UDP delivery indicating the end of acquisitions. Datagrams will not be sent to the client after the end of acquisition.

Clients requiring explicit termination notification should either use TCP or implement a timeout mechanism combined with an XML-RPC getAcquisitionInProgress call on the control connection to locate the end of acquisitions.

XML-RPC

The XML-RPC õget most recent data sampleö call will use standard XML-RPC connection semantics involving the client making an HTTP POST request to the server and interpreting the response as appropriate. Handling of XML-RPC can be performed by a library in the client's appropriate implementation language.

Real-time Delivery Guarantees

No delivery time guarantees exist for any data connection. Data is delivered to the client as it becomes available. The overall latency of the system from physical sample time to data delivery is dependent on a number of factors including network load, BSL overhead (which is variable due to calculation channel processing time, user interface activity, thread scheduling, and other operations), system load, and other factors. The actual sampled data itself is guaranteed to be accurate; the sample time of a signal acquired into the hardware unit is always accurate.
It is only the time between the physical time corresponding to a sample and its delivery to the client application that is variable.

Clients that require strict real time guarantees or more predictable latencies should investigate using the hardware API on their local machine.

Data Formats

It is assumed that the data transfer feature is used in a mixed host environment, potentially with clients running in environments that have restricted data types. The sampled information delivered by a data connection is allowed to be controlled to appear in a variety of different formats for the client:

- 64 bit floating point ó This format will always be available for all channels and may be delivered in either big endian byte order or little endian byte order. This is equivalent to a C style double data type.

- 32 bit floating point ó This format will always be available for all channels and may be delivered in either big endian byte order or little endian byte order. This data type is not native to BSL, so the precision of received data may differ from data as recorded by BSL. This is equivalent to a C style float data type.

- Signed 16 bit integer ó This format is available only for analog data channels. It may be delivered in either big endian byte order or little endian byte order. This is equivalent to a C style short data type. Clients receiving data in 16 bit integer format should use the control connection to determine appropriate floating point scaling factors that need to be applied to the data to convert into actual units.

Data formats should be specified by the client prior to the start of acquisition. If left unspecified, the default data format depends on channel type:

Channel Type	Default Data Type
Analog	16 bit signed integer, little endian
Digital	16 bit signed integer, little endian
Calculation	64 bit floating point, little endian

XML-RPC get most recent sample requests will always return the double type of XML-RPC (in ASCII notation).

Default Data Connection Settings

If the client does not modify any data connection settings, the following is used:

- Single connection transfer type

- TCP/IP transport protocol

- Port 15020 for single connection

- For multiple connections, each channel type (4 analog channels, 8 digital channels and 16 calculation channels) is set as follows: analog channels [15020-15023], digital channels [15040-15047], calculation channels [15060-15075].

● Default data formats for each channel type as indicated in the õData Formatsö section

Note that no channels are enabled for delivery by default. Both data connection delivery and get most recent sample tracking are disabled. Clients will still need to enable channels in order to receive data.

Locating BSL Servers

It is possible that clients and servers may be located on networks with dynamic IP addresses or other features that make establishing the connection between machines difficult. In this case, a simple UDP broadcast mechanism can be used to locate known servers.

BSL will listen for incoming UDP packets on port 15012. If the UDP packet contains the sequence of ASCII characters õAcqP Clientö and only that sequence, it will send a broadcast packet containing õAcqP Server Port:ö followed by the port number on which the server is listening for control connections. The port number is expressed in base 10 ASCII notation.

It is possible to configure BSL to not acknowledge discovery requests for security purposes.

Control Connections

Clients connect to a BSL server using control connections. A control connection allows the client process to control how data is going to be delivered to it, query settings, modify settings, and perform other basic operations without requiring graphical interaction with the BSL environment.

On the start of an acquisition, all data connections are established to the client that most recently established a control connection unless the client has modified the destination by using the changeDataConnectionHostname command.

It is possible to configure BSL to not respond to any control connections for security purposes.

The majority of all control connections use XML-RPC. The XML-RPC specification can be located at http://www.xmlrpc.com/spec. XML-RPC consists of an HTTP POST request being assembled by the client along with data content expressed in the XML-RPC notation. The remote procedure call will then return with an appropriate response to the caller. By design, XML-RPC is client and platform agnostic.

XML-RPC implementations exist for a number of languages. If there is no implementation in the client's language, hardcoded requests can be embedded or a small helper application or shared library can assist in providing the control connection interface.

The URI that should be used when connecting to the server is the recommended õ/RPC2ö for XML-RPC. For example, a URL for localhost control connections would be õhttp://localhost/RPC2.ö

TCP Port

Only one control connection may be opened by a client to a server at a time. The server will listen on port 15010 by default. As this port may conflict with other network services or may need to be modified for firewall accessibility, BSL will allow the server port to be modified by the user in the Display > Preferences panel. Clients should be aware that control connection port numbers are not fixed and should either allow users to change the port number from the client or use the dynamic discovery mechanism for locating BSL servers.

Control Procedure Calls

Control procedure calls are remote procedure calls with a set method name and response. All method names and strings are case sensitive. The available control calls are roughly split up into querying acquisition parameters, configuring data delivery, and limited calls for modifying acquisition parameters and affecting application state.

Channel Index Parameter Structures

Some procedure calls take a *channel index structure* as a parameter. This is an XML-RPC structure that consists of the channel type and index. The channel type is a string member named õtypeö that is one of the following strings: analog, digital, calc. The channel index is an integer member named õindexö and contains a zero-based index indicating the channel. For example, the following channel index parameter structure can be used to refer to calc channel 2 (recall, in BSL calc channels are indexed from zero):

```
<struct>
```

```
<member>
        <name>type</name>
        <value><string>calc</string></value>
</member>
<member>
        <name>index</name>
        <value><int>2</int></value>
</member>
</struct>
```

Querying Acquisition Parameters

The calls for querying acquisition parameters are intended to allow clients to request information required for them to fill out appropriate parameters and to verify that previous control requests have been properly applied. The following control calls are recognized:

getMPUnitType

Method name: acq.getMPUnitType
Parameters: None
Return value: int

Retrieves the type of MP unit to which the server is connected. This may be zero (indicating no unit is connected, e.g. õNo Hardwareö mode), or 36 (for MP36).

The client can use this value to decide between appropriate templates to download or other channel settings.

getEnabledChannels

Method name: acq.getEnabledChannels
Parameters: string
Return value: array populated with int

Retrieves the channels that are available for acquisition and data delivery over a data connection to the client. The type of channels that are to be returned are specified in the string parameter. The string parameter may be one of the following: analog, digital, calc. The type must be lowercase. õanalogö returns information about analog channels, õdigitalö digital channels, õcalcö calculation channels.

The enabled channels are returned as an array of channel indexes, zero-based. These are the indexes that can be validly used in calls for configuring data connection parameters.

getChannelScaling

Method name: acq.getChannelScaling
Parameters: channel index parameter structure
Return value: struct containing scaling

For channels that can be delivered in short integer format, the channel scaling provides the scale factor and offset used to convert the short into physical units using the formula: sample*scale+offset. The scaling is returned as a structure containing two double-valued members: õscaleö contains the multiplication factor, õoffsetö contains the offset factor.

Channels that cannot be delivered as short integers cannot be scaled. If this method is called with an invalid type of channel, a fault response is returned.

getSamplingRate

Method name: acq.getSamplingRate
Parameters: None
Return value: double

Returns the current sampling rate expressed in Hz. This is the rate at which data is sampled for a channel whose downsampling divider is 1.

getDownsamplingDivider

Method name: acq.getDownsamplingDivider
Parameters: channel index parameter structure
Return value: int

Retrieves the downsampling divider for a particular channel. A channel is sampled at the base sampling rate divided by this factor. This factor is also used to determine which frames contain samples for this channel.

Data Connection Configuration Commands

While it is possible to configure data connection parameters using BSL, frequently clients may need to alter data connection configurations based upon dynamic information regarding the machine on which they are running (e.g. port collisions with other services, unexpected endian changes, etc.). The following commands may be used to configure how data is delivered to the application.

getDataConnectionMethod

Method name: acq.getDataConnectionMethod
Parameters: none
Return value: string

Returns the method currently being used for data connections between the server and client. The string value is either: single, multiple. õsingleö corresponds to a single data connection being made between the server and the client with all data interleaved over that connection. õmultipleö corresponds to opening an individual connection to the client for each channel.

changeDataConnectionMethod

Method name: acq.changeDataConnectionMethod
Parameters: string
Return value: 0 on success, or fault code

Changes the method used to deliver data to the client. The parameter is a string that is one of the following: single, multiple. õsingleö opens up a single data connection and sends data in an interleaved fashion. õmultipleö opens up an individual data connection for each channel.

getDataConnectionHostname

Method name: acq.getDataConnectionHostname
Parameters: none
Return value: string

Returns the currently set hostname for data connections. When data connections are established on the start of acquisition, the IP address associated with this hostname is sent the data. Hostnames must properly resolve in order for data connections to be made; DNS configuration is outside of the scope of the network data transfer feature.

If this hostname is empty, data connections is made to the most recently connected client application. This is the default setting.

Hostnames are unique on a graph by graph basis and are saved in templates and graph files. Clients redirecting data to another machine should check and set the data connection hostname as appropriate prior to the start of acquisition.

changeDataConnectionHostname

Method name: acq.changeDataConnectionHostname
Parameters: string
Return value: 0 on success, fault on error

Changes the destination machine for data connections, the recipient of the network delivered data. If the parameter is an empty string, data connections will automatically be made to the most recently connected client. The empty setting is the default.

If non-numeric hostnames are specified as parameters, they must be resolvable. If a hostname cannot be resolved, a fault is returned. Proper DNS configuration of the server is beyond the scope of the network data transfer feature.

getTransportType

Method name: acq.getTransportType
Parameters: None
Return value: string

Retrieves the transport type that is being used to deliver data from the server to the client. The transport type is a string that is one of the following: tcp, udp. Note that the XML-RPC data delivery method may be used in addition to this transport type if channels are enabled.

changeTransportType

Method name: acq.changeTransportType
Parameters: string
Return value: 0 if successful, else fault code

Change the transport type that is used to deliver data from the server to the client. The transport type is a string that has one of the following values: tcp, udp. XML-RPC last value data delivery may be used in addition to this type provided channels are enabled properly.

getUDPPacketSize

Method name: acq.getUDPPacketSize
Parameters: None
Return value: int

Returns the current size in bytes of UDP packets that is delivered to clients. Datagrams are always this fixed byte length although each individual datagram may contain varying amounts of data.

setUDPPacketSize

Method name: acq.setUDPPacketSize
Parameters: int
Return value: 0 on success, fault on error

Changes the size in bytes of UDP packets that are delivered to clients. Each individual datagram will always be this fixed length although the amount of data sent in specific packets may vary.

getUDPBroadcastEnabled

Method name: acq.getUDPBroadcastEnabled
Parameters: None
Return value: boolean

Determine if UDP packets are sent only to the client or are broadcast to the broadcast IP of the network. Broadcasting is supported only when the transport type is UDP.

changeUDPBroadcastEnabled

Method name: acq.changeUDPBroadcastEnabled
Parameters: Boolean
Return value: 0 if successful, fault code on error

Modify whether UDP packets are sent only to the client or are broadcast to the broadcast IP of the network. Broadcasting is supported only when the transport type is UDP.

getSingleConnectionModePort

Method name: acq.getSingleConnectionModePort
Parameters: None
Return value: integer

Returns the port number on which the server will connect to the client to deliver data. This port is used only when the connection mode is set to õsingleö which interleaves all data over a single connection.

changeSingleConnectionModePort

Method name: acq.changeSingleConnectionModePort
Parameters: integer
Return value: 0 on success, else fault code

Modifies the port on which the server connects to the client to deliver data. This port is used only when the connection mode is set to õsingleö which interleaves all data over a single connection.

getDataDeliveryEnabled

Method name: acq.getDataDeliveryEnabled
Parameters: channel index parameter structure
Return value: boolean

Query whether a channel is enabled for data delivery. Channels must be enabled for data delivery in order for their data to be delivered to the client. Not all channels that are being acquired are required to be delivered to data delivery.

changeDataDeliveryEnabled

Method name: acq.changeDataDeliveryEnabled
Parameters: channel index parameter structure, Boolean
Return value: 0 for success, else fault code

Change whether or not data delivery is enabled for a particular channel. Data delivery can only be changed prior to the start of an acquisition. Changes to data delivery enabling are only applied on the next start of acquisition.

getMostRecentSampleValueDeliveryEnabled

Method name: acq.getMostRecentSampleDeliveryValueEnabled
Parameters: channel index parameter structure
Return value: Boolean

Query whether a channel is enabled for most recent data sample requests. If a client wishes to use the XML-RPC calls to fetch the most recent value of data acquired of a channel, the channel must be enabled for this functionality prior to the start of acquisition.

changeMostRecentSampleValueDeliveryEnabled

Method name: acq.changeMostRecentSampleDeliveryValueEnabled
Parameters: channel index parameter structure, Boolean
Return value: 0 for success, else falut code

Change whether or not a channel is enabled for most recent data sample requests. When a channel is enabled, XML-RPC calls can be used during an acquisition to return the most recent sample of data acquired (or computed) for the channel. Any changes to the enabled state of a channel is applied on the start of the next acquisition. If a client wishes to use XML-RPC calls to read the value of a channel, that channel must be enabled prior to the start of the acquisition.

getDataConnectionPort

Method name: acq.getDataConnectionPort
Parameters: channel index parameter structure
Return value: int

Retrieves the port on which the server will deliver the data for the channel specified in the parameters to the client. Per-channel data connections are only used if the data connection method is set to õMultiple.ö

changeDataConnectionPort

Method name: acq.changeDataConnectionPort

Parameters: channel index parameter structure, integer
Return value: 0 for success, else fault code

Changes the port on which the individual connection is made by the server to the client to deliver the data for the channel specified in the parameters. This style of connection is used only if the data connection method is set to õMultiple.ö

getDataType

Method name: acq.getDataType
Parameters: channel index parameter structure
Return value: structure

Returns the data type that is being used in the binary data streams for the channel's data. The return value is a structure with a type and endian member. The type member, named õtypeö, is a string and contains one of the following values: short, double, float. These strings correspond to their matching C-style data types. The endian member, named õendianö, is a string and contains one of the following values: little, big. õlittleö corresponds to little endian byte order, big endian bit order. õbigö corresponds to big endian byte order, big endian bit order.

changeDataType

Method name: acq.changeDataType
Parameters: channel index parameter structure, type structure
Return value: 0 on success, or fault code

Changes the data type that is used for binary data streams of the channel's data. The type structure is a struct containing two members. The õtypeö member is one of the following strings: double, float, short. Each string corresponds to the matching C-style data type. The õendianö member is one of the following strings: little, big. Each corresponds to the matching byte endian. Bit order within a byte will always be big-endian.

Not all channels may be able to support all data types. If the channel cannot be transmitted in the requested data type, a fault code is returned.

setDataConnectionTimeoutSec

Method Name: acq.setDataConnectionTimeoutSec
Parameters: integer of new timeout in seconds
Return value: 0 on success, or fault code

Changes the timeout in seconds after which the data connections is closed when acquisitions complete. Clients may need to set this keep-alive timeout in order to receive the trailing data at the end of acquisitions. The default value is õ0ö seconds which terminates all data delivery connections immediately when the final sample of data is acquired.

Reading Data During Acquisition

Normally data is delivered to clients during acquisitions using data connections. Data connections are either TCP or UDP connections established from the server to the client over which the server streams the incoming data. In some languages and environments however, it may not be possible to handle continuous data streams. The following XML-RPC commands are offered to assist these types of clients. Due to the large overhead of processing connections and XML-RPC requests, this data transfer type is not recommended and TCP/UDP should be used wherever possible.

getMostRecentSampleValue

Method name: acq.getMostRecentSampleValue
Parameters: channel index structure
Return value: double, or fault code

This procedure allows clients to read the most recent data value of a specific channel during acquisitions. In order for this call to be successful, a data acquisition must be in progress and the channel must be enabled for most recent sample value data delivery. Issue a changeMostRecentSampleValueDeliveryEnabled call prior to acquisition to allow this procedure to be used.

getMostRecentSampleValueArray

      Method name: acq.getMostRecentSampleValueArray
      Parameters: none
      Return value: array of structures with channel info and values, or fault code

      This procedure allows clients to retrieve the most recent data values of all channels during acquisitions in a single call. If clients are interested in the values of multiple channels, using this method is more efficient than performing consecutive getMostRecentSampleValue calls (which require an individual POST request per call).

      Only channels that are enabled for most recent sample value data delivery is returned. Issue a changeMostRecentSampleValueDeliveryEnabled call for each desired channel prior to acquisition in order for this to return the value for a channel.

      The return value is an array of structures, one per channel. Each structure contains two members. The õchannelö member will contain a channel index structure with members set to appropriate type and index information for the channel. The õvalueö member is a double that contains the most recent sample value of the channel specified in the õchannelö member.

      This procedure cannot be called unless there is an acquisition in progress and there is at least one channel enabled for most recent sample value delivery.

Other Control Connection Commands

Control connections will also allow for the following additional commands to be used by clients:

loadTemplate

      Method name: acq.loadTemplate
      Parameters: base64 encoded binary BSL graph template
      Return value: 0 on success, or fault code

      Attempts to open the passed template within the BSL environment. The parameter is a base 64 encoded BSL õgtlö graph template file. Only templates in Windows or Mac BSL are allowed to be used with this command. The parameter must include the entire contents of the template file.

      The parameter in the XML-RPC call should be a base64 parameter with the raw binary contents of a graph template file. When this parameter is decoded, it should correctly provide the contents of a template file on disk.

      This function will return 0 on success, otherwise a fault code if the template could not be loaded. Once a template is loaded, the hardware settings contained within that template is used for subsequent data acquisitions. Templates for BSL 4.1.2 and higher will retain any data connection settings that have been specified by clients. After loading a template, clients should re-send any configuration information for ports and data connection methods if they do not match the new settings from the template.

      If the template data is corrupted or incompatible, user interaction may be required on the server computer to dismiss any error messages when attempting to load the template. If user interaction is required on errors, this call may not return until the user interaction has completed. Clients who are using XML-RPC bindings that offer timeout services may wish to use them with this function.

getAcquisitionInProgress

      Method name: acq.getAcquisitionInProgress
      Parameters: none
      Return value: Boolean

      Query whether data acquisition is currently in progress or not. A value of true is returned if data acquisition is occurring in any open BSL graph window.

toggleAcquisition

      Method name: acq.toggleAcquisition

Parameters: none
Return value: 0 on success, else fault code

Toggles data acquisition in the frontmost graph. If data acquisition is in progress, it is halted. If none is in progress, data acquisition is started in the graph.

Note that this function invocation may block if physical user interaction is required to start the acquisition in the graph, such as dismissing an overwrite warning, warnings on incompatibilities between different MP unit types, specifying a save location for acquisition to disk, etc. If the implementation of the XML-RPC binding used by the client supports timeout capabilities, it is highly recommended to enable timeouts for this function.

setOutputChannel

Method name: acq.setOutputChannel
Parameters: channel index structure, float output value
Return value: 0 on success, else fault code

Changes the voltage on the specified output channel of the MP device. For analog outputs, the value should be in the range (-10, 10) for the voltage level. For digital outputs, a value of 0 will turn the specified line off, a non-zero value will turn it on. The latency of when the output line is changed is variable and non-guaranteed. Additionally, the output channel may be modified by other areas of the software including control channels, manual user intervention, configured stimulators, etc.

The valid output channels are dependent on the type of MP device that is connected.

- MP36 units allow no analogs and digital 0-8.

Part D—Appendices

Appendix A — MP Unit Specifications

MP Acquisition Unit

The MP data acquisition unit is the heart of the Biopac Student Lab *PRO* System. The MP Unit has an internal microprocessor to control data acquisition and communication with the computer. The MP Unit takes incoming signals and converts them into digital signals that can be processed by the computer. There are four analog input channels, one of which can be used as a trigger input. Itøs necessary to connect the MP Unit to the computer and connect electrodes, transducers, and I/O devices to the MP Unit. Itøs recommended to take a few minutes to become familiar with the MP Unit prior to making any connections.

The MP36/35 Data Acquisition System is a physiological data recorder designed for medical educational purposes. This system is used in medical education and research facilities. This system is not used for the mitigation, cure or diagnosis of disease. This device is NOT used in the home. Subject to IEC60601-1, the MP36/35 Data Acquisition System is CLASS II, type BF equipment.

Symbols — MP36, MP35, and MP45

Symbol	Description	Explanation
	Type BF Equipment	Classification
	Attention	Consult accompanying documents
	On (partial)	Turns MP35 on assuming AC300A power adapter is powered by the mains
	Off (partial)	Turns MP35 off if but AC300A power adapter remains powered by the mains
	Direct current	Direct current input
	USB	USB port
	Functional Earth Ground	Functional Earth Ground Connection
	Class II Equipment	Class II Medical Equipment, as established by IEC60601-1
	Fuse	Equipment Fuse

Compliance

Safety

The MP36/35 satisfies the Medical Safety Test Standards affiliated with IEC60601-1. The MP36/35 is designated as Class I Type BF medical equipment

EMC

The MP36/35 satisfies the Medical Electromagnetic Compatibility (EMC) Test Standards affiliated with IEC60601-1-2.

Types of Input Devices

There are three types of devices that connect to the MP UNIT: electrodes, transducers, and I/O devices.

Electrodes are relatively simple instruments that attach to the surface of the skin and pick up electrical signals in the body.

Transducers, on the other hand, convert a physical signal into a proportional electrical signal.

Input/Output devices (I/O for short) are specialized devices like pushbutton switches and headphones.

Simple Sensor Connectors

Regardless of the type of device connected, every sensor or I/O device connects to the MP UNIT using a õSimple Sensorö connector. Simple Sensor connectors are designed to plugs only one way into the MP UNIT, so no worries about plugging things in upside down or into the wrong socket.

Electrodes, transducers, and the pushbutton switch all connect to the channel input ports on the front panel of the MP UNIT.

Headphones and the stimulator connect to the õAnalog outö port on the back panel of the MP UNIT.

MP36/35 only: A digital device may connect to the õI/O Portö on the back panel

MP36/35 only: A trigger device may be connected to the õTriggerö port on the back panel.

Front Panel
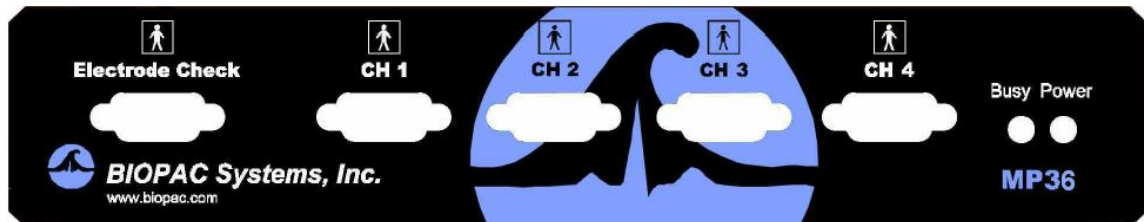
Front Panel, MP36/35 UNIT

The front panel of the MP UNIT has an electrode check port, four analog input ports, and two status indicators.

Electrode Check

The Electrode Check port is a diagnostic tool used with the BSL *PRO* software to determine if the electrodes are properly attached to the subject. See page 158.

Input ports: CH 1, CH 2, CH 3, and CH 4

The inputs on the MP UNIT acquisition unit are referred to as Channels. There are four 9-pin female analog input ports on the front of the MP UNIT. The Biopac Student Lab Lessons software will always check to see that the proper sensors are connected to the appropriate channel.

Status indicators

The Busy status indicator is activated when the MP UNIT is acquiring data and also during the first few seconds after the MP UNIT is powered on to indicate that a self-test is in progress. (When the MP UNIT passes the power-on test, the Busy light will turn off.)

The Power status indicator is illuminated when the MP UNIT is turned on.

Back Panel
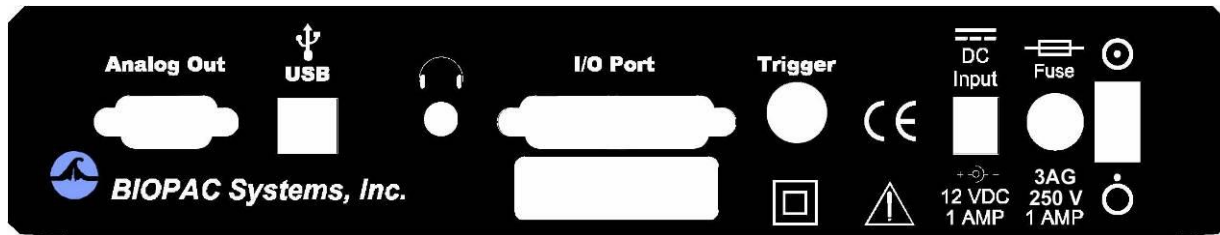
Back Panel, MP36/35

The back panel of the MP36/35 has an analog output port, a USB port, an I/O Port, a Trigger Port, a DC input, a fuse holder, and a power switch, and the unitøs serial number.

Analog Out port

There is one 9-pin male õDö analog output port on the back of the MP UNIT that allows signals to be amplified and sent out to devices such as headphones.

USB port (MP36/35 only)

The MP36/35 connects to the computer via a USB Port, located just below the word USB.

Uses a standard USB connector.

Should only be used to connect the MP36/35 to a PC or Mac.

Headphone Output (MP36/35 only)

Accepts a standard (1/4+or 6.3mm) stereo headphone jack.

I/O Port (MP36/35 only)

Accepts a DB 25 Female connector.

Input/Output port used to connect digital devices to the MP36/35.

Trigger Input (MP36/35 only)

Accepts a male BNC connector.

Input port used to send trigger signals from another device to the MP36/35.

Used to synchronize MP36/35 units when more than one MP36/35 is used.

DC Input

Use the DC Input to connect an AC300A power adapter or BAT100 battery to the MP36/35.

The power supply requirements for the MP UNIT are 12 VDC @ 1 Amp. Only use the AC300A power adapter with the MP36/35. The AC300A is a 12 VDC @ 1.25 Amp power supply adapter that can connect to any mains rated as 100-250 VAC @ 50/60 Hz, 40VA.

The receptacle is configured to accept a õ+ö (positive) input in the center of the connector and a õ-ö (negative) input on the connector housing.

The functional earth ground on the AC300A Power Adapter is tied to Mains earth ground and accessible metal parts on the MP36/35 unit.

☐   The AC300A power adapter is Class II and when it is used to power the MP36/35, the MP36/35-AC300A combination is Class II. The MP36/35 unit also incorporates an additional level of isolation between the AC300A power adapter and the Subject.

Fuse holder
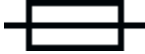
⊏⊐   The fuse holder contains a fast-blow fuse that helps protect the MP UNIT from shorts on its power, analog, and digital I/O lines. The MP36/35 uses a 1.0 A, 250 V, 3AG, fast-blow fuse and the MP30 uses a 2.0 A, 250 V, 3AG, fast-blow fuse.

To remove the fuse, use a screwdriver to remove the fuse cover located below the word Fuse.

Power switch

⊙ON position ô   powers up the MP UNIT

○OFF position ô   cuts the flow of power to the MP UNIT

Mains Power Disconnection

To completely disconnect the MP36/35 unit and the AC300A power adapter from all poles of the supply mains, extract the power cord plug from the mains outlet. Extract the plug by grasping the plastic shell of the plug and pull firmly away from the mains outlet in a direction perpendicular to the face of the mains outlet. Take care not to touch the metal blades associated with the plug. This procedure will fully power down (de-energize) the MP36/35 unit and AC300A power adapter. Please note that the power switch on the back of the MP36/35 unit turns power ON and OFF to the MP36/35 unit only.

Cleaning Procedures

Be sure to unplug the power supply from the MP UNIT before cleaning. To clean the MP UNIT, use a damp, soft cloth. Abrasive cleaners are not recommended as they might damage the housing. Do not immerse the MP UNIT or any of its components in water (or any other fluid) or expose to extreme temperatures as this can damage the unit.

Sterilization and Disinfection

Disposable, sterile, single-use-only, accessories are used with the MP UNIT for educational (teaching) applications. Non-disposable accessories can be disinfected, if required, with Cidex® or equivalent.

Safety Note

BIOPAC Systems, Inc. instrumentation is designed for educational and research oriented life science investigations. BIOPAC Systems, Inc. does not condone the use of its instruments for clinical medical applications.

Instruments, components, and accessories provided by BIOPAC Systems, Inc. are not intended for the cure, mitigation, treatment, or prevention of disease.

The MP UNIT is an electrically isolated data acquisition unit, designed for biophysical measurements.

Exercise extreme caution when applying electrodes and taking bioelectric measurements while using the Biopac Student Lab with other external equipment that also uses electrodes or transducers that may make electrical contact with the Subject.

Always assume that currents can flow between any electrodes or electrical contact points. In case of equipment failure, it is very important that significant currents are not allowed to pass through the heart.

If electrocautery or defibrillation equipment is used, it is recommended that the BIOPAC instrumentation be disconnected from the Subject.

MP36/35 Input > Output Scaling

The MP36/35 hardware can pipe signals from any channel input to the output using the õCHX to Outputö control panel in the BSL *PRO* softwareô due to the difference between the input and output range, there will be a change in signal level (scaling). The output range depends on the MP device and the output pin used as shown in the following table. Note that when using MP35 output pin 2, there is an additional baseline offset (2.048 V) applied.

Output Pin (Analog Out port)	Pin Description	Output Range (Volts)
Pin 1* - MP36/35	Headphones, A.C. Coupled	-2.048 to +2.048
Pin 2 - MP36	Low Voltage Stimulator, D.C. Coupled	-10 to +10
- MP35	CH Data, D.C. coupled	0 to +4.095 V (baseline offset of 2.048 V)

The input range is gain dependant. The table below shows the scaling (multiplying) factors to use for each gain setting.

Gain	Input Range +- millivolts	Output Scale***—*accurate to ±10%* Factor 1 Pin 1 (Headphone out) and Pin 2 (MP35 only)	Factor 2 Pin 2 (Low Voltage Stimulator) ó MP36 only
x5**	± 2 V	1.024	5
x10	± 1 V	2.048	10
x20	± 500 mV	4.095	20
x50	± 200 mV	10.238	50
x100	± 100 mV	20.475	100
x200	± 50 mV	40.950	200
x500	± 20 mV	102.375	500
x1,000	± 10 mV	204.750	1,000
x2,000	± 5 mV	409.500	2,000
x5,000	± 2 mV	1023.750	5,000
x10.000	± 1 mV	2047.500	10,000
x20,000	± 0.5 mV	4095.000	20,000
x50,000	± 0.2 mV	10238.000	50,000

Notes

*   1: To properly measure the output signal at least a 2K Ohm load is required.

**   2: x5 only available on MP36 and MP45.

***   3. Input to Output scaling is accurate to within 10%.

Example:

MP35, input signal level = ±10 mV (20 mV- pk to pk), input gain = x100, Output on pin 2.

Signal output level = 20 mV-pk to pk x 20.475 = 0.4095 V pk to pk.

However there is a baseline offset of 2.048 V, so actual signal output level is:

   Lowest level = 2.048 V ó (0.5 x 0.4095 V) = 1.843 V

   Highest level = 2.048 V + (0.5 x 0.4095 V) = 2.253 V

Calibration

BIOPAC transducers can provide accurate õrelativeö measures without calibration.
For example, the voltage output of the EDA/GSR transducer (SS3LA) will change by 1 mV given a change of 10 micro Mhos across the electrode(s) connected to the transducer.
For accurate õabsoluteö measurement, the voltage output of the transducer must be correlated exactly to a physical parameter (such as air flow) and must adjust for temperature, pressure, humidity, and orientation (gravity effects)ô all of which can vary greatly. Factors beyond the transducerøs accuracy also influence õabsoluteö measurement, such as connections in the system or to the subject. While the MP36/35 is a very sensitive, DC stable acquisition unit, too many factors influence true õabsoluteö measurement to achieve it without calibration.

Calibration Guidelines

Calibration is required if **ALL** of the following are true:

1. Precise, absolute, measurements are required.

   õPreciseö is considered better than 5% accurate; some transducers may provide better than 5% accuracy without calibration.
   õRelativeö measurements are often acceptable. Measurements on humans can vary so greatly from person to person that in most cases a õrelativeö measure of change is sufficient.
   For example, when measuring EDA with the SS3LA, the preset: õElectrodermal Activity (GSR) Changeö is often used and no calibration is required.

2. The transducer will be plugged into an Analog Input channel.

3. Communication between the MP36/35 and transducers that can be plugged into the õI/O Portö on the back of the MP36/35 (such as the noninvasive blood pressure cuff) occurs serially; since A/D conversion is not used, readings will directly match the output of the connected device.

4. The operational bandwidth of the transducer extends down to 0 Hz (DC - see page 108 for details). When an AC Coupled Preset is selected for a transducer, õrelativeö measurements are taken and calibration is not required.

Appendix B - Frequently Asked Questions

Q: I have a large data file and it seems to take a long time to redraw the screen. Is there anything I can do to speed it up?

A: Yes. Several remedies are available for this.

(1) The simplest solution is to check the Draft mode for compressed waves and Use all available memory boxes in the Preferences dialog (shown below). Checking these two boxes will cause BSL *PRO* to plot data faster (at the expense of some precision) and use as much available memory as possible.

Biopac Student Lab - Preferences

Measurements
Waveforms
Event Summary
Graph
Journal
Hardware

Drawing

☐ Gray non-selected waves

☑ Draft mode for compressed waves

Biopac Student Lab - Preferences

Measurements
Waveforms
Event Summary
Graph
Journal
Hardware
Performance

Graphs

☑ Use all available memory to load graph data immediately

(speeds drawing and measurement computations)

(2) Reduce the time interval per division, which causes less data to be displayed on the screen at one time, and should reduce plot time.

(3) Load all data into memory; see page 340 for details.

Q: Can I use other software with the MP System? Can I use BSL *PRO to control other data* Acq*uisition hardware?*

A: No. The MP System was designed to work with the BSL *PRO* software. However, the software can read in previously acquired text files generated by BSL *PRO* or any other software.

Q: I have a device that outputs an RS-232/RS-422 signal. Can I connect this to the digital I/O lines?

A: No. These types of digital output devices have their own communication protocols and are more complex than the digital pulses that the MP System can accept as inputs.

Q: I imported a text file and the time scale is wrong. What happened?

A: When a text file is imported, BSL *PRO* assumes (by default) that the data was sampled at 100 Hz or 100 samples per second. This is arbitrary, and there are two ways to adjust this. Both methods involve calculating the interval between sample points. To calculate the sampling interval, itøs necessary to know the rate at which the data was originally sampled. The sampling interval is calculated by dividing one by the sampling rate. Adjust the sampling interval to the appropriate value via the File > Open dialog before the data is read in, or if the data is already present, change the time scale in the Display > Horizontal scale dialog.

For instance, if 20 minutes of data was originally collected at 2 Hz and is read into BSL *PRO* as a text file, the software will interpret this as data collected at 100 samples per second. To set the time scale to accurately reflect the data, change the sampling interval from 0.01 to 0.5 seconds per sample.

To change this setting before data is read in, click the Options button in the File > Open dialog and change the value in the Sampling Interval dialog. To change the time scale after data has been read in, adjust the units per division in the Display > Horizontal axis dialog. If the data are time-domain data, adjust the seconds/sample interval at the bottom of the dialog. This value defines the interval between sample points, and can be changed to fit the rate at which the data was originally acquired.

To resolve the sampling limitation, use an MP System.

Q: I just filtered a waveform and now my data file is huge. Why is that?

A: When BSL *PRO* performs any type of transformation on a waveform (e.g. digital filtering, waveform math), it converts the entire waveform from integer format (two bytes per sample) to floating-point format (eight bytes per sample). Since each sample point in the waveform now takes up four times as much space, the file should be approximately four times as large. BSL *PRO* still saves the file as compactly as possible, and since some of the information stored describes the time base, the file size will not increase by exactly a factor of four.

Q: My MP data acquisition unit seems to be connected, but I can't acquire data. What should I do?

A: This can be caused by one of several conditions:

(a) Check to make sure that the MP data acquisition unit is ON and, if so, that all the connections to the MP data acquisition unit were made properly. When the MP data acquisition unit is powered up, a light on the front panel of the MP data acquisition unit will illuminate. If the power light will not illuminate, check to make sure the proper power supply is connected. The power supply that comes with the MP data acquisition unit is rated at 12 VDC @ 1 Amp, and using other power supplies may result in damage to the MP data acquisition unit.

(b) If the proper power supply is connected but the power light still does not illuminate, disconnect the power supply and check the fuse in the back of the MP data acquisition unit. The fuse is a standard 2.0 Amp fast blow fuse, and can be changed by unscrewing the fuse cap and replacing the fuse.

(c) If the power light does illuminate, the next step is to see if the busy light (next to the power light on the front panel of the MP data acquisition unit) illuminates when the MP data acquisition unit is powered up. When the MP data acquisition unit is powered up, the busy light should illuminate for three or four seconds and then extinguish.

> NOTE: The busy light is normally off (except at startup), but it will remain on while data is being acquired and will illuminate for the duration of each trial when data is being acquired in averaging mode. If the busy light does not illuminate when the system is powered up or does not turn off after a few seconds, contact BIOPAC at one of the locations listed in Appendix A.

Q: I Set Up the channels but I only seem to be acquiring noise. What's wrong?

A: A number of phenomena can cause this. Check to make sure that the settings in the Set Up Channels dialog correspond to the channel switch settings on the amplifier modules and/or direct analog connections to the UIM100C. When a direct analog input is set to the same channel as an amplifier, the resulting data will appear quite noisy or erratic. Verify that no two amplifiers are set to the same channel.

Another possible cause is that the gain settings on the amplifiers are too low and should be increased. Itøs recommended to select Autoscale waveforms from the Display menu. This will automatically adjust the waveforms to provide the õbest fitö in terms of scaling the data to fit in the available window space.

It is also possible that the electrodes/transducers themselves are the source of the noise. Proper electrode adhesion techniques involve abrading the skin and securing the electrode in place to reduce movement artifact.

Q: What is the storage and operation accuracy of BSL PRO?

BSL *PRO* performs all internal calculations to the accuracy defined by the IEEE format for double precision floating point numbers and stores the results of those calculations in double precision floating point format. This format assigns 8 bytes to all numbers involved in calculations or resulting from calculations. The 8 bytes (64 bits) are assigned as 52 bits to mantissa, 1 bit to sign, and 11 bits to exponent. The effective decimal accuracy for calculation operation or storage will be defined as [2 to the 52] power or approximately 4.5 E15. Accordingly, the effective decimal accuracy will be between 15 and 16 digits.

Appendix C - Filter characteristics

Filter types

BSL *PRO* employs two types of digital filters:

    (a) Finite Impulse Response (FIR) perform post-acquisition filtering

    (b) Infinite Impulse Response (IIR) perform filtering calculations online (during an acquisition) or post-processing (after an acquisition)

Although the similarities between the two types of filters outweigh the differences, some important distinctions remain.

1.   First, IIR filters are typically more efficient than FIR filters, which means that IIR filters can filter data faster than FIR filters, which is why IIR filters are used for online Calculations.

2.   Second, IIR filters tend to be less accurate than FIR filters. Specifically, IIR filters tend to cause phase distortion or õringing.ö When the phase of a waveform is distorted, some data points on a waveform are shifted (either forward or backward in time) more than others. This can result in the intervals between events (such as the Q-R interval or the inter-beat interval in an ECG waveform) being slightly lengthened or shortened compared to the original signal. In practice, however, the effect of this distortion is usually minimal since the frequencies which are most distorted are also attenuated the most. By contrast, FIR filters are phase linear, which means that the interval between any two sample points in the filtered waveform will be exactly equal to the distance between the corresponding sample points in the original waveform.

3.   Third, IIR filters have a variable Q setting that defines the filter response pattern, but FIR filters do not have a Q component. The optimal Q of an IIR filter is 0.707, with lower values resulting in a flatter response and higher values resulting in a more peaked response. The default Q for all IIR filters is 0.707 (except for Band pass filters where Q defaults to 5), which is appropriate for nearly all filter applications.

In the examples on the following page, the filter responses of several different types of filters are compared. All of the filters are 50 HZ low pass filters operating on the same data.

The first graph shows how the number of filter coefficients in FIR filters (Q) affects the filterøs frequency response. Note that as the number of coefficients (Q) increases, the filter becomes more accurate. A good rule of thumb is to set $Q \times 2(f_s/ f_c)$, where f_s = sampling rate and f_c = cutoff frequency.
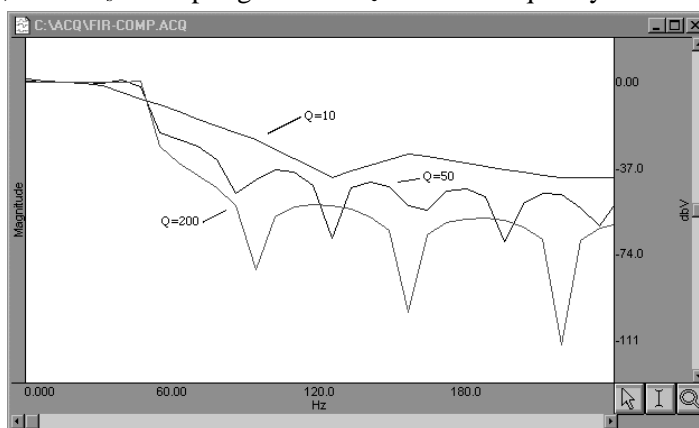
FIR filter performance as a function of number of coefficients (Q)

The next graph shows how the pole or zero locations of the filter, as related to filter õpeakingö (specified by Q), affect the frequency response of the filter. The õQö in this case is <u>not</u> to be confused with the Q from the FIR filter. Note how increasing õQö in the IIR filter case affects filter õpeaking.ö
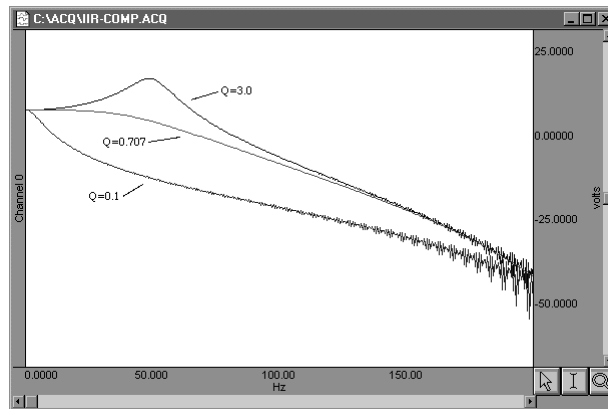
FIR filter performance as a function of changes in pole or zero locations

Coincidentally, the FIR (Q = 10) and IIR (Q = 0.707) filters have very similar responses in this case.

Technically, the coefficient setting for FIR filters determines the number of multiplies performed by the filtering algorithm. In practical terms, it determines how õsteepö the frequency response of the filter is. Filters with a large number of coefficients have a steep roll-off, whereas the frequency response of filters with a smaller number of coefficients is not as steep.

Window Functions

Window functions are used for two purposes in BSL *PRO*. Windows are applied to the impulse response in the (FIR) digital filtering functions, and can optionally be applied as part of the FFT function. In either case, a window refers to a computation that spans a fixed number of adjacent data points.

Typically, window functions are used to eliminate discontinuities that may result at the edges of the fixed span of points of the digital filter function (FIR filters) or the data points of the FFT.

Digital filtering. When a window is used in digital filtering, the impulse response of the filter (rather than the data itself) is modified. When the impulse response smoothly approaches zero at both the beginning and end of the data, this works relatively well. When the impulse response is not so well behaved, edge effect occurs. Edge effects can be minimized by windowing, or forcing the edges of the impulse response to smoothly approach zero. The exact process depends on the window selected (see below).

Another way to minimize edge effect with an FIR filter is to increase the number of coefficients used to transform the data.

FFT. The FFT function also windows data, although the nature of the windowing function is somewhat different in the sense that the window operates on the data. One of the assumptions of the FFT is that the input data is an infinitely repeating signal with the endpoint wrapping around. In practice, the endpoints are almost never exactly equal. Check this by choosing the Delta measurement item from the measurement popup menus, which returns the amplitude difference between the first selected point and the last. To the extent that the endpoints differ, the FFT output will produce high frequency components as an artifact of the transformation.

▪ BSL *PRO* displays only the positive coefficients of an FFT. In this FFT presentation, there is an implicit negative frequency component for each positive frequency component, so when looking at amplitude levels in a linear FFT, multiply by two (negative frequency can only be created with positive frequencies in the real world).

By windowing the data, the effects of this phenomenon are greatly diminished. When data are windowed, a window is moved across the data, much as the smoothing function moves across the data. Whereas the smoothing function simply takes the average of a specified number of points, each type of window weights the data somewhat differently.

The <u>W</u>indow pull down menu offers the following options:
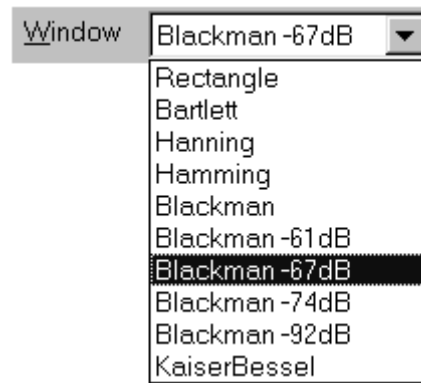
Bartlett implements triangular windowing and Rectangle does not window the data. The õshapeö of the other windows is defined by the following formula, where $n = \sum_{0}^{N-1} n$ and A, B, C and D are constants:

$$A - B\cos\frac{2\pi n}{N} + C\cos\frac{2\pi 2n}{N} + D\cos\frac{2\pi 3n}{N}$$

The table below details the different parameter values for each type of window.

Type of Window	Parameter Values			
	A	B	C	D
Bartlett	n/a	n/a	n/a	n/a
Blackman	0.42000	0.50000	0.08000	0.00000
Blackman -61	0.44959	0.49364	0.05677	0.00000
Blackman -67	0.42323	0.49755	0.07922	0.00000
Blackman -74	0.40217	0.49703	0.09392	0.00183
Blackman -92	0.35875	0.48809	0.14128	0.01168
Hanning	0.50000	0.50000	0.00000	0.00000
Hamming	0.54000	0.46000	0.00000	0.00000
Kaiser-Bessel	0.40243	0.49804	0.09831	0.00183
Rectangle *Windows/PC only*	n/a	n/a	n/a	n/a

Appendix D - Hints for Working with Large Files

It is not uncommon for users to generate large data files (on the order of several megabytes) through some combination of (a) high-speed acquisitions, (b) long acquisitions, and (c) multi-channel acquisitions. Users frequently encounter system limitations (such as storage space limitations) and find the files are difficult and slow in loading to memory.

The software included with the MP System (MP36, MP35 or MP45) stores the data in as compact a format as possible. Each sample takes up roughly two bytes of storage space. When a waveform (or a section of a waveform) is transformed (i.e., filtered or integrated) each data point takes up roughly eight bytes of storage space. As a result, file size can change drastically after transforming one or more waves.

> *Note* BSL *PRO* data files greater than 4 GB can be opened, but edit, transformation and analysis operation cannot be performed. 3 GB of RAM is the maximum that can be allocated by the application and a maximum of 60 channels are supported.

The following tips can help get the most out of the MP System when working with large data files.

➢ Use virtual memory

Since BSL *PRO* runs under Windows® 10/8/7 or Mac® OS X 10.10-10.13, most computers are able to take advantage of the virtual memory feature. While this is slower than conventional memory, it will at least make it possible to load some files that might otherwise be impossible to load.

➢ Remove waveforms

Since each waveform adds to the total size of the file, try removing (or copying to another file) some of the waveforms from a multi-channel file. This is especially true for performing transformations of some sort on at least one of the waves.

➢ Sample slowly

Theoretical and methodological concerns will, to a large extent, dictate sampling rate. However, if it's possible to reduce the sampling rate, choose to do so. Or, use Transform > Resample (page 270) to resample data after collecting it.

➢ Set preferences

Check the õUse all available memoryö and the õDraft mode for compressed wavesö options under the Preferences menu item. This should decrease the time it takes to redraw waveforms and allow the software to access all available memory for storage.

➢ Store to disk

Although slightly slower than storing to memory, acquiring data directly to disk allows recovery of data in the event of a power loss to the MP System. Furthermore, much larger data files can typically be stored directly to disk than to memory.

➢ Use the Append mode

The Append mode allows pausing of the acquisition for arbitrary periods. This can be helpful when recording only a few key events that will occur randomly over a long period of time, since it will reduce unnecessary data.

➢ Compress Files

Use the File > Save As > Compressed option to store or transfer data

> *Note* Copy/Paste and Transformations require BSL *PRO* to allocate additional memory and then load the data into memory; when these operations are executed on large data files, the application may crash.

Appendix E - Customizing Menu Functionality

BSL *PRO* now includes a powerful customization feature allows menu options to be displayed selectively. For a specific procedure, it may be helpful to limit the menu options to list only the functions necessary for the experiment, thereby reducing the chance for confusion or error. For example, it may be helpful to remove the õSetup Triggeringö and õOutput Controlö options from the MP menu, as shown below:
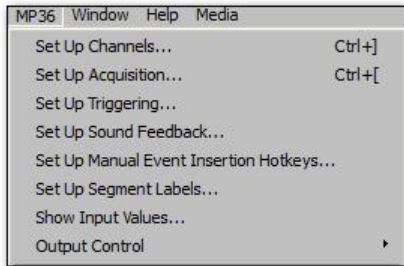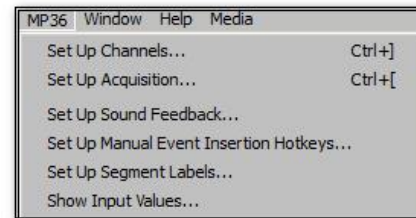
Default MP menu   *Customized MP menu*

Follow the simple procedure below to customize the menu display.

1.   With the BSL *PRO* application closed, navigate to the menu.dsc file: DRIVE:\ProgramData\BIOPAC Systems, Inc\Biopac Student Lab 4.0\menu.dsc

2.   Open the menu.dsc file in Notepad.
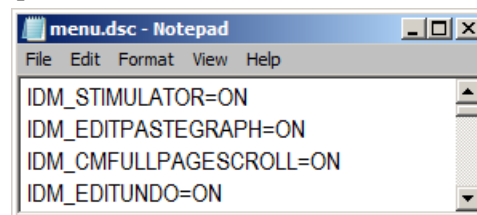
3.   Find the menu and item to be changed (scroll through list as necessary) and type õOFFö to disable the menu display. In the example below, the IDM_STIMULATOR option has been changed to OFF.

   ➢ Note that ON/OFF is case-sensitive must be typed in ALL CAPS.

   ➢ Deleting a file listing instead of typing OFF will not remove the feature; it will default to ON unless OFF is entered.
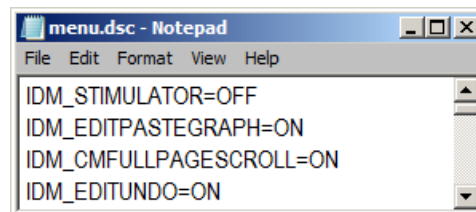
4.   Save the changes to the menu.dsc file and close it.

5.   Restart BSL *PRO*.

6.   Check the menu listing.

> To reactivate a menu item set to OFF, just repeat the above procedure and type õONö for the desired menu item.
>
> To revert a customized menu.dsc to the factory default, choose Display > Preferences > Other and select õCreate default menu configuration file.ö After choosing õyesøin the subsequent dialog, the application must be closed and relaunched in order for the change to take effect.

Note: Application menu customization has a corresponding effect on contextual menu display. If a contextual menu item does not have a corresponding application menu item, the menu customization file identifier will begin with õIDM_CM.ö

Appendix F ô About Electrodes

The purpose of an electrode is to act as a õconnectorö between the Subjectøs skin (where electrical signals are easiest to detect) and the MP UNIT acquisition unit (via the SS2L lead cable). If an electrode makes good contact with the skin, the signals that are generated will be relatively accurate.

Although they sound complex, electrodes are very simple devices that consist of a small piece of metal designed to make indirect contact with the skin and a larger adhesive plastic disk. Each electrode is about 1 inch (2.5 cm) in diameter, and is sticky on one side so it will adhere to the skin. The **electrode lead** (cable with connector end) is the interface between the electrode and the MP acquisition unit.
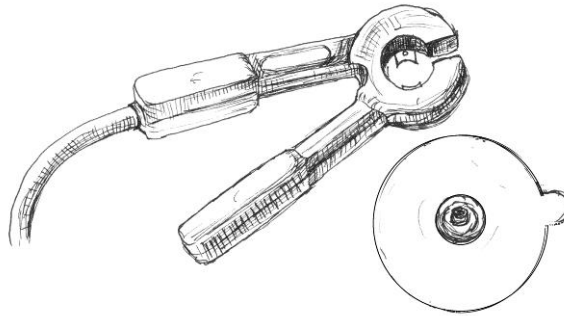
Electrode lead connector and electrode

Looking closely at the electrode, observe that there is a small piece of plastic mesh filled with a bluish gel. Since gel conducts electricity (better than skin, in fact) and is more flexible than the metal part of the electrode. Skin can flex and change shape somewhat without losing the electrical connection with the metal part of the electrode.

BIOPAC disposable electrodes are standard disposable electrodes and are widely used in clinical, research, and teaching applications. These electrodes come in strips of ten, and itøs not advisable to remove an electrode from the backing until ready to use.

The following directions will assist in obtaining the data from the electrodes by explaining how electrodes work and how to attach the electrodes and electrode leads to obtain the best signal.

Electrode placement

There are two basic methods of electrode placement: monopolar and bipolar.

➢ In a **monopolar** recording, an active electrode is placed over the region of interest and a õreferenceö electrode is attached to a more distant part of the body.

➢ In a **bipolar** recording, the voltage difference between two electrodes, placed over the regions of interest, is measured with respect to the third õreferenceö electrode. Leads I, II, and III are standard bipolar electrode configurations, and are explained in more detail when used in a Lesson.

Preparing the Electrode Site

One way to improve electrode connections is to gently rub the area where the electrode is to be placed. This is known as **abrading** the skin, and removes a   thin layer of dead skin from the surface of the skin. Since dead skin doesnøt conduct electricity very well, removing it improves the connection between   the electrode and the skin. An **ELPAD** electrode pad (included with the Biopac Student Lab) can be used to abrade the selected surface.

EXCEPTION: If aquiring **EDA** data, never abrade the skin beforehand.
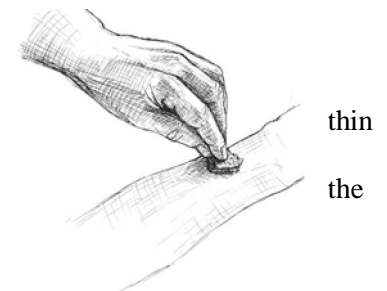
Attaching electrodes

To attach an electrode, peel the electrode from its backing and place it on the area indicated in the lesson. Once in place, press down firmly on the electrode with two fingers and rock the electrode back and forth for a few seconds. This will ensure that it is adhering to the skin as much as possible.
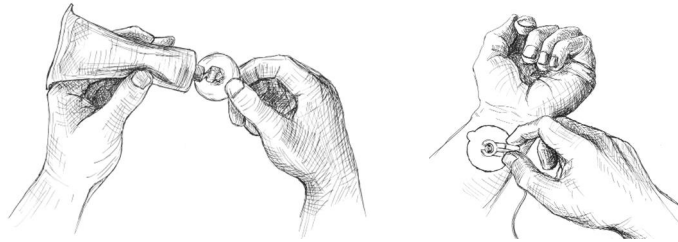
➢ T o help insure that the electrode will make good electrical contact with the skin, it may be helpful to squeeze a drop or two of **electrode gel** onto either the surface of the skin or onto the electrode (without allowing any to get on the adhesive).

Connecting the Electrode Lead

Each electrode lead cable is a different color and each pinch connector on the end of the cable needs to be attached to a specific electrode. Note that the connector is polarized and needs to be clipped on such that the metal extensions inside the clip are on the down side to make surface contact with the electrode. The pinch connectors work like a small clothespin, but will only latch onto the nipple of the electrode from one side of the connector. Follow the figure provided in the lesson to ensure that each lead cable is connected to the proper electrode.

Reducing Electrode "Noise"

If an electrode does not adhere well to the skin, the signal plotted on the screen may appear õfuzzy.ö This is referred to as õ**noise**,ö and although it always exists to some degree, it is best to reduce noise as much as possible. Electrodes have no moving parts, so there is nothing that needs to be done to get an electrode to õworkö but there are several things that are helpful for reducing noise when electrodes are connected:

* Place the electrodes where there is the least amount of hair and/or choose the subject with the least amount of hair. A common problem is that something on the surface of the skin is interfering with the electrode contact. If there is too much hair (for instance) between the outer layer of skin and the electrode, the electrical activity taking place below the surface of the skin may not be detected.
* Make sure that everything is connected properly.
* Attach the electrodes a few minutes before they are to be used. The best results are achieved by putting the electrodes in place about five minutes before beginning to record data. This gives the electrodes time to establish contact with the surface of the skin.
* Position the electrode lead cables such that they are not pulling on the electrodes. Connect the electrode cable clip (where the cable meets the three individual colored wires) to a convenient location (can be on the Subjectøs clothes). This will relieve cable strain.
* The Subject should not be in contact with nearby metal objects (faucets, pipes, etc.), and should remove any wrist or ankle bracelets.

Removing Electrodes

Once the lesson has been completed, disconnect the electrode cable pinch connectors, peel the electrode off the skin, and dispose of the electrode (BIOPAC electrodes are not reusable). Wash the electrode gel residue from the skin, using soap and water. The electrodes may leave a slight ring on the skin for a few hours. This is normal, and does not indicate that anything is wrong.

Electrode Check

MP3X units include an Electrode Check port on the front panel. Use this diagnostic tool with the BSL *PRO* software to determine if the electrodes are properly attached to the subject (see page 158).

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