OPERATOR'S MANUAL - IZOD MACHINE

Prepared by: 2018 - MNE 520 - Dr. Guven

Impact Test Setup to Measure Fracture Toughness of Materials

Abdullah Almarri

Arnaud Debraine

Gregory Nelson

Stephanie Fulenwider

Senior Design - Capstone Project

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Chapter 1

Operation Instructions

1.1 INSTALL SOFTWARE ON NEW COMPUTER

1.1.1 Install Anaconda on Windows

NOTE: All information in this section is taken from:
`https://conda.io/docs/user-guide/install/index.html`

1. **DOWNLOAD Anaconda for Python 3**: `https://www.anaconda.com/download/`
2. Double-click the .exe file
3. Follow the instructions on the screen. Accept default options if unsure about any settings
4. Open **Anaconda Prompt**
5. Test your installation by typing: **conda list** a list of packages should appear
6. Type **conda update conda** to update Anaconda.

1.1.2 Import Arduino Environment

NOTE: All information in this section is taken from:
`https://conda.io/docs/user-guide/tasks/manage-environments.html`

Fig. 1.1

1. Extract **IZOD.zip** where you wish to run the software
2. open **Anaconda Prompt**
3. Navigate to the adequate directory using **cd**:
   Type: **cd "PASTE PATH HERE"**
   Example: **cd "C:\Users\Adebraine\Documents\AA - VCU\A - Senior Design\IZOD"**
4. type **conda env create -f arduino.yml**
5. Ready to start the software

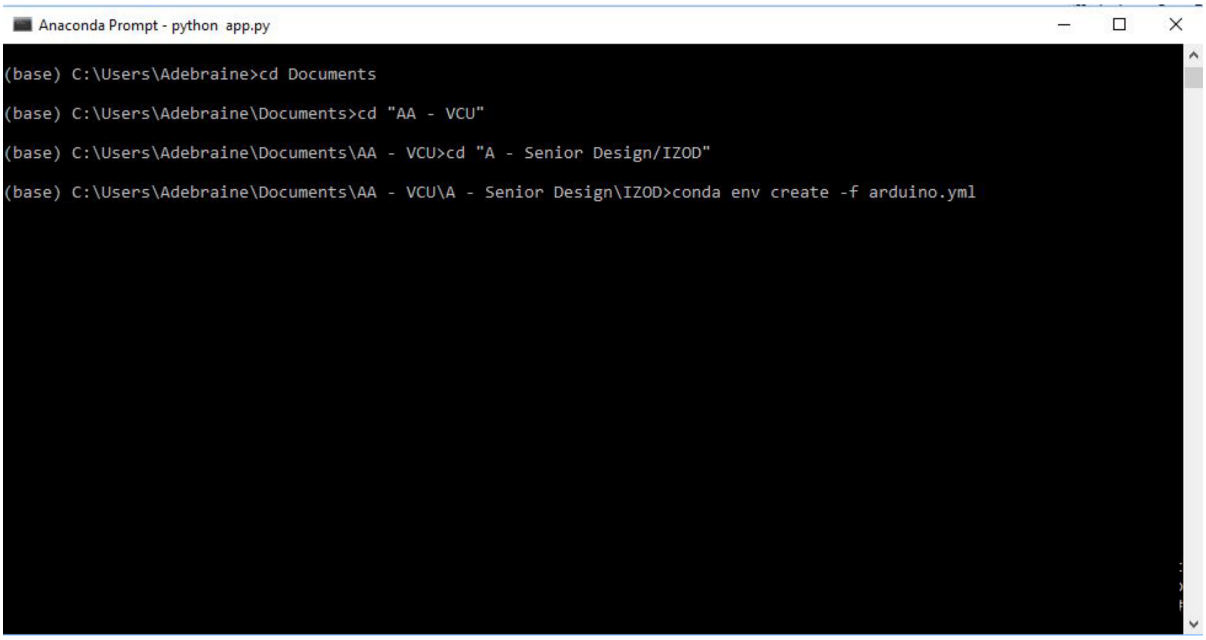

Figure 1.1: Install Arduino Environment

1.2 START SOFTWARE

1.2.1 On Windows Using Anaconda Prompt

OPTION 1: Using Spyder (Fig. 1.2 & 1.3)

1. Connect the Arduino USB to the computer
2. Start **Anaconda Prompt**
3. Activate the **arduino environment**:
   Type **activate arduino**
4. Navigate to the adequate directory using **cd**:
   Type: **cd "PASTE PATH HERE"**
   Example: **cd "C:\Users\Adebraine\Documents\AA - VCU\A - Senior Design\IZOD"**
5. Launch **Spyder**
6. Open **app.py**
7. press **F5** or Click **Run**

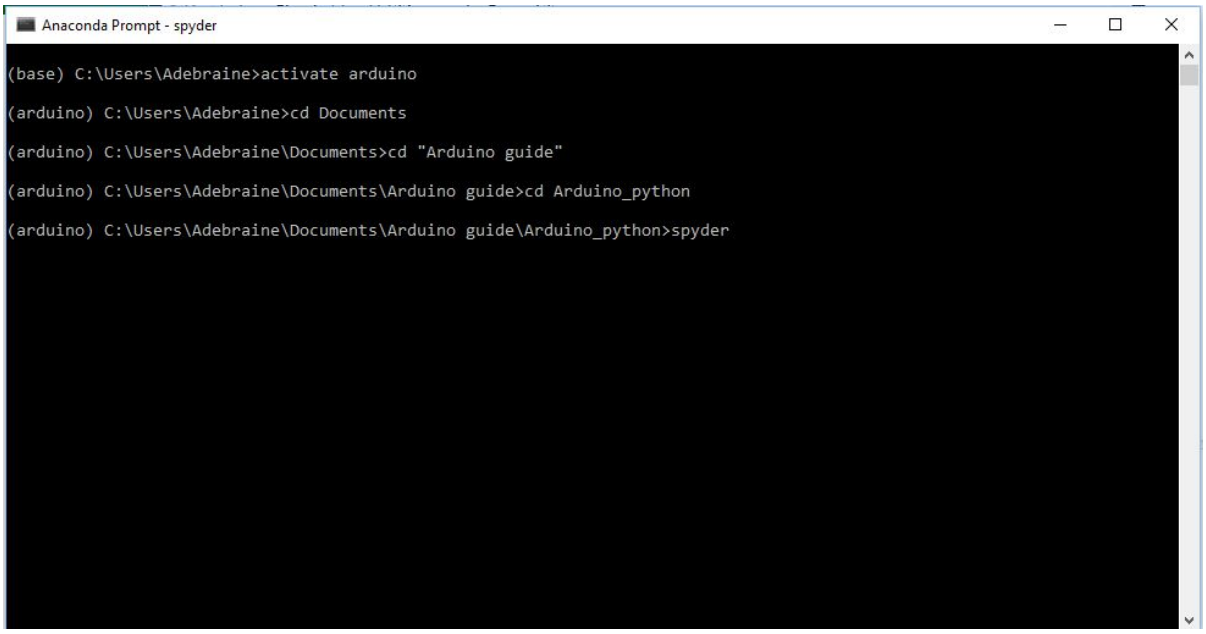

Figure 1.2: Start Spyder Using Anaconda Prompt

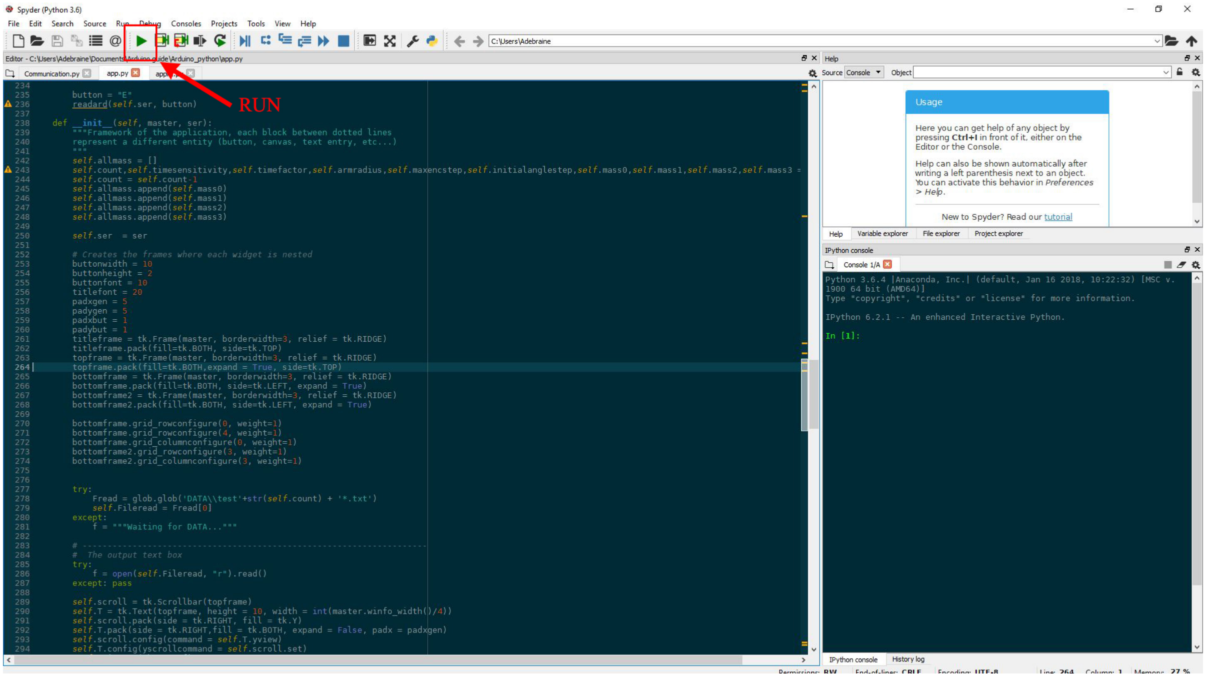

Figure 1.3: Start Software from Spyder

OPTION 2: Direct Launch through Anaconda Prompt(Fig. 1.4)

1. Connect the Arduino USB to the computer
2. Start **Anaconda Prompt**
3. Activate the **arduino environment**:
   Type **activate arduino**
4. Navigate to the adequate directory using **cd**:
   Type: **cd "PASTE PATH HERE"**
   Example: **cd "C:\Users\Adebraine\Documents\AA - VCU\A - Senior Design\IZOD"**
5. Launch the Software:
   Type **python app.py**

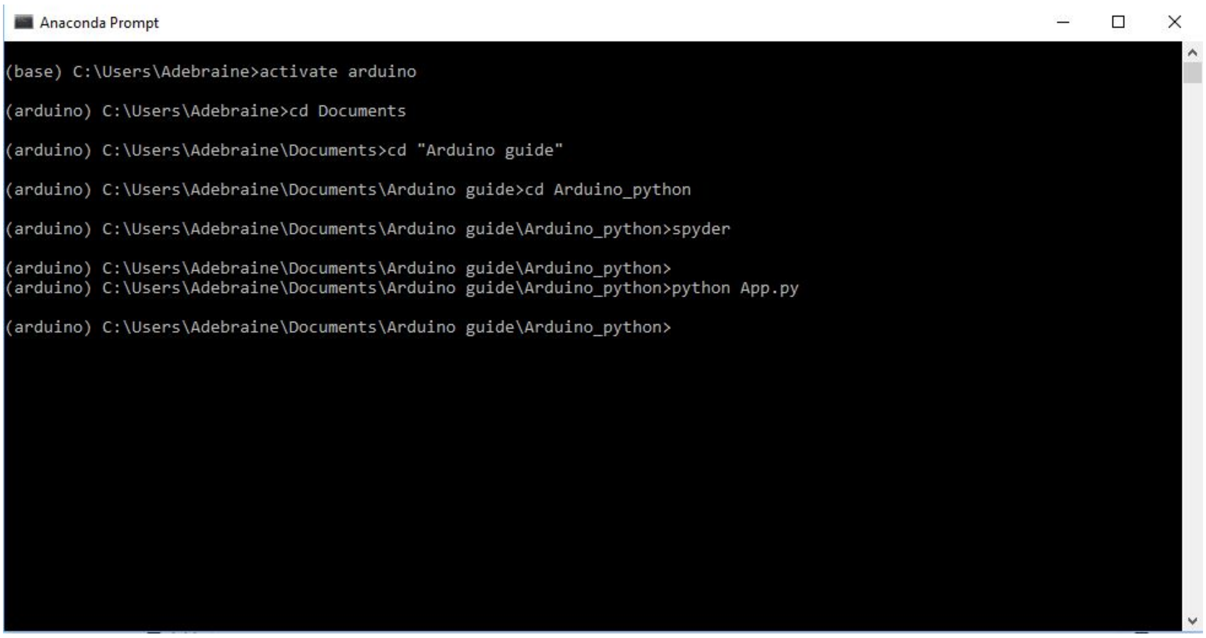

Figure 1.4: Start Software from Anaconda Prompt

1.2.2 On Raspbian Using Terminal

Fig. 1.5 & 1.6

1. Open the Terminal

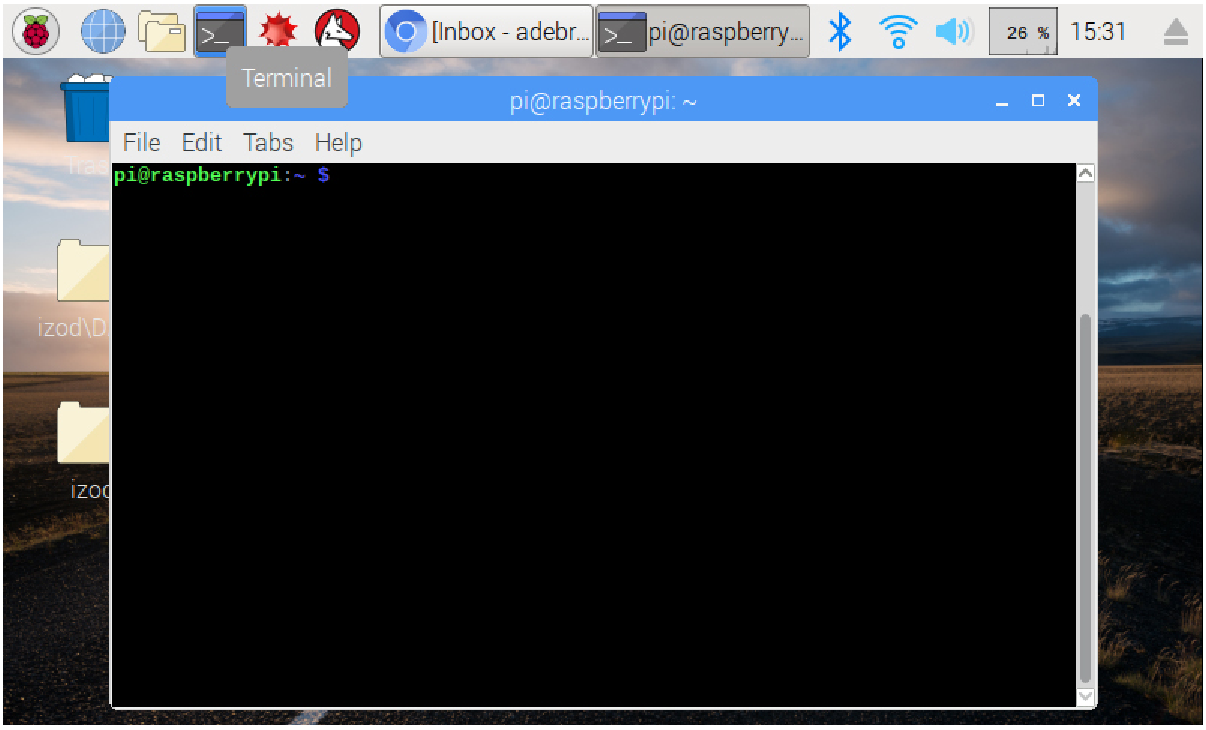

Figure 1.5: Open Terminal

2. Navigate to the adequate directory using **cd**:
   Type: **cd Desktop/izod**

3. Launch the Software:
   Type **python appPI.py**

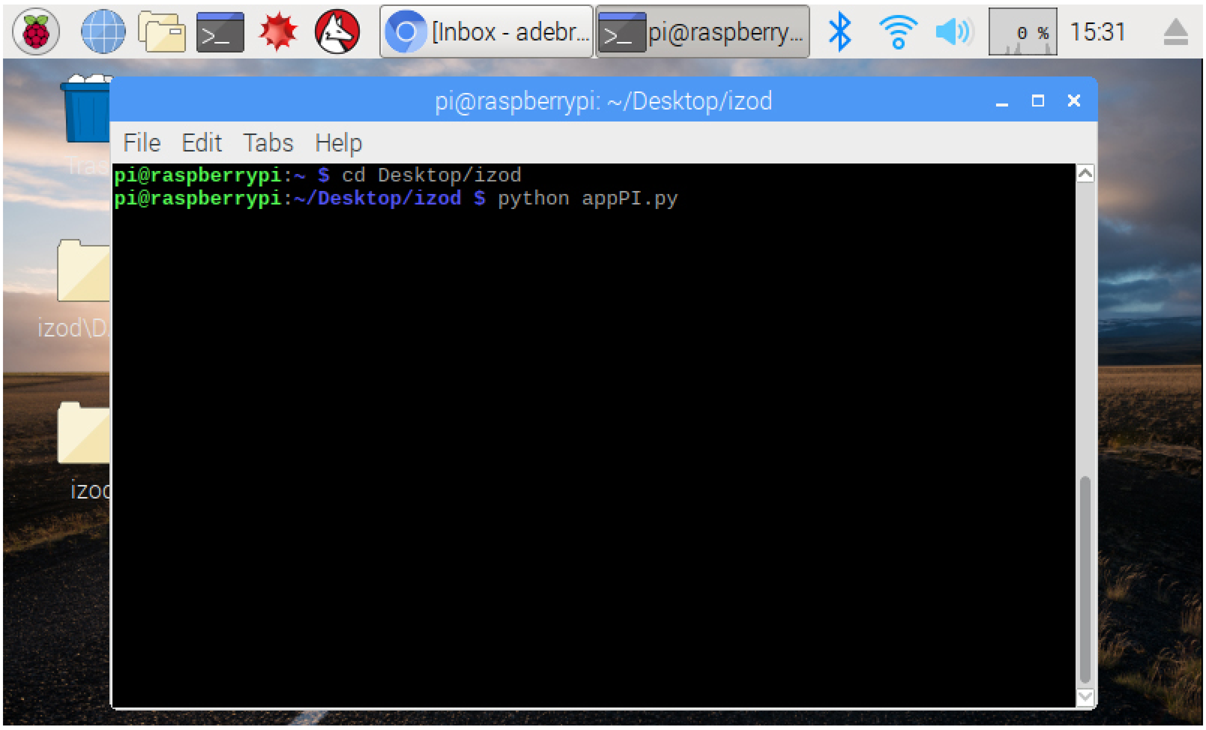

Figure 1.6: Start Software from Terminal

1.3 FIND ZERO POSITION

1. Press **CALIBRATION**
2. The arm will move a few degrees, disengage the magnet and wait until next command is given
3. Wait until the hammer stops moving
4. Press **CALIBRATION** again
5. the software will record the current position of the hammer before moving and set it as **ZERO**
6. The arm will come down and move the hammer to the position recorded in the prior step

1.4 Load a Specimen

1. Press **LOADING**
2. the arm will lift the hammer 30 degrees and wait until next command is given
3. Pressing **LOADING** again will return the hammer to the **ZERO** position or pressing **RUN** will perform a test

1.5 PERFORM A TEST

NOTE: Can be done from the LOADING position or from the ZERO position

1. Press **RUN**
2. the arm will lift the hammer to the required 610mm +/- 2mm vertical height and disengage the magnet
3. The hammer will come down and the software will record DATA for the first swing.
4. DATA is then automatically transformed, displayed on the GUI and saved in a text file

1.6 RESET ARM POSITION

NOTE: Only press the RESET button when the hammer is not moving to avoid damages

1. Press **RESET**

2. The arm engages the magnet and comes down to the **ZERO** position

1.7 Software Interface Details

1.7.1 Windows Desktop Version

1. **FILE** Let's the user access the **CHANGE DIRECTORY** function to decide where the next Output text files will be saved
2. The Accelerometer output graph
3. Functions to manipulate and save the above graph
4. The Previous Test results (Identical to the output text file)
5. User input functions to enter **BEFORE** a test is performed, see below
6. User input function to enter **AFTER** a test is performed, see below

Figure 1.7: Windows GUI

User Inputs BEFORE a Test is Performed:

NOTE: Make sure to properly press **ENTER** after writing anything in the different text boxes.

- **Test File Name**: Let's the user edit the default output text file name.
  Default format: **IZOD**{**File count**}**_Date_**{**MM_DD_YYYY**}**_Time_**{**HH_MM_SS**}
  Example: **IZOD6_Date_05_06_2018_Time_11_17_41**
  Edited format: {**User Input**}**_IZOD**{**File count**}**_Date_**{**MM_DD_YYYY**}**_Time_**{**HH_MM_SS**}
  Example: **USERINPUT_IZOD6_Date_05_06_2018_Time_11_17_41**

- **Operator Name**: Let's the user add the name of the operator to the output text file
  Appears in the text file as: **Operator Name: User Input**
  Example: **Operator Name: Dr. Guven**

- **Added Mass**: Choose between 4 default options: No added mass, small plates, medium plates, and large plates

- **Specimen Material**: Let's the user add the specimen material to the output text file
  Appears in the text file as: **Specimen Material: User Input**
  Example: **Specimen Material: ABS**

- **Specimen Width (mm)**: Let's the user specify the width of the specimen
  Appears in the text file as: **Specimen Width (mm): User Input**
  Example: **Specimen Width (mm): 12.3**

- **Specimen Depth (mm)**: Let's the user specify the Depth of the specimen at the notch
  Appears in the text file as: **Specimen Depth (mm): User Input**
  Example: **Specimen Depth (mm): 12.3**

User Inputs AFTER a test is performed:

NOTE: Pressing **ENTER** does **NOT** save the note but allows the user to add a multi-line note.

1. **Operator Note**: Let's the user add a note to the previous test's output text file
   Appears in the text file as: **Operator Note: User Input**
   Example: **Operator Note: Full break**

2. Press **PRINT** to print the above note to the text file

1.7.2 Raspbian Touchscreen Version

Refer to 1.6.1 for User Inputs Instructions

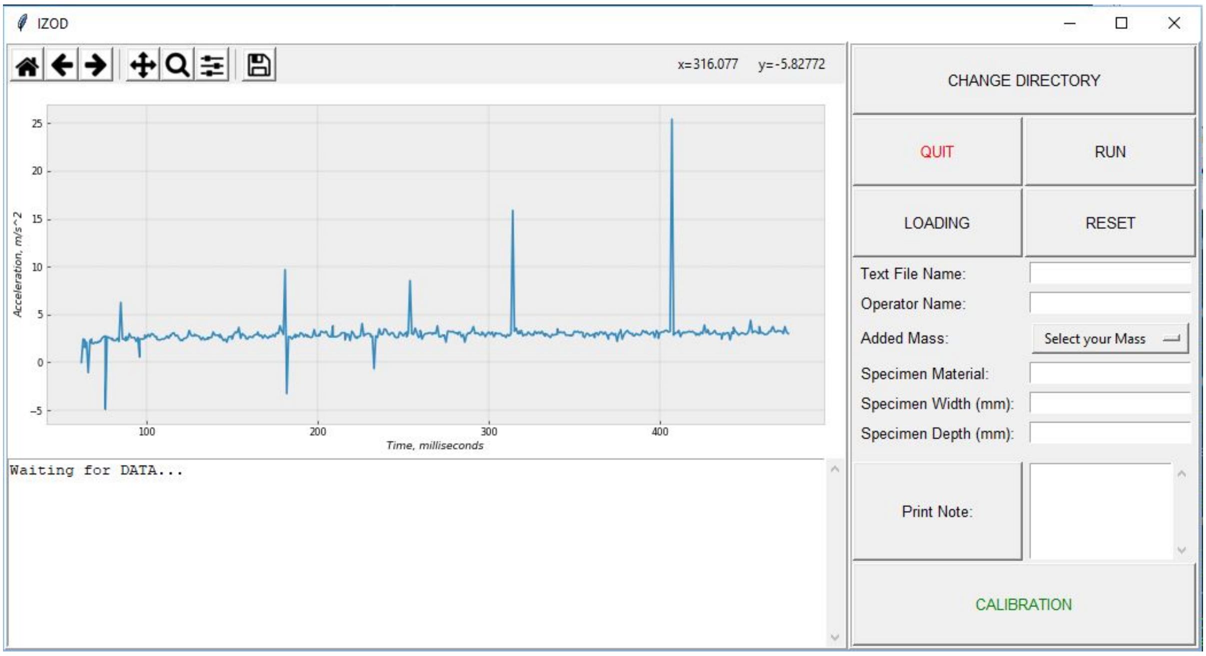

Figure 1.8: Raspbian Touchscreen GUI

1.8 TEXT FILE OUTPUT DETAILS

The text file will display **N/A** if the user did not enter required inputs.
The data is also saved below a dashed line in four columns:

- Time corresponding to the encoder data point in milliseconds
- Position of the hammer from 0 to 10,000 corresponding to 0 to 360 degrees.
- Time corresponding to the accelerometer data point in milliseconds
- accelerometer data point in *g*

```
Sun, 06, May, 2018, 12:24:09
File Number:    9
Operator Name: Dr. Guven

Operator Notes: ASTM Classification Example:
C = Complete Break
H = Hinge Break
P = Partial Break
NB = Non-Break

Mass Selected:  Medium Mass
Specimen Width (mm):
Specimen Depth (mm):

OUTPUT:
Initial Angle (degrees):    134.1
Final Angle (degrees):  132.732

Initial Height (mm):    610.3895419239126
Final Height (mm):  604.1475636734372
Height Difference (mm): 6.241978250475427

Initial Potential Energy (J):   12.3399084340486
Final Potential Energy (J): 12.213717805330731
Energy Difference (J):  0.12619062871786824
Impact Resistance (J/m):    N/A
Impact Strength (Full break) (J/m^2):   N/A

----------------------------------------

T_enc(ms)   Enc_data(raw)   T_acc(ms)   Acc_data(g)
0.0 601.0   262.0   0.0
0.0 602.0   263.0   1.3838013838013827
0.0 603.0   264.0   1.6280016280016278
0.0 604.0   265.0   1.7908017908017895
0.0 605.0   265.0   1.953601953601951
```

Figure 1.9: Output Text File

Chapter 2

Troubleshooting

2.1 Swap Computer/Touchscreen

Unplugging the Arduino USB cable from the Raspberry Pi and plugging it into a computer that has the IZOD software installed allows the user to change the device that operates the machine.

2.2 SWAP WEIGHTS

IMPORTANT: Each plate has its corresponding set of screws. Selecting the wrong set of screws can lead to weights falling off, especially the large plates.
The user can switch the weights attached to the machine or remove all weights and select the corresponding option on the GUI.

2.3 Invert Touchscreen Display

Fig. 2.1 & 2.2

1. Open **Terminal**
2. Type **sudo nano /boot/config.txt**
3. Type **lcd_rotate=0** or **lcd_rotate=2** depending on what is already there (DO NOT PRESS ENTER)
4. Press **CTRL + X**
5. Press **Y**
6. Press **CTRL + T**
7. Press **ARROW DOWN** until you reach **config.txt** then press **ENTER**
8. type **sudo reboot**

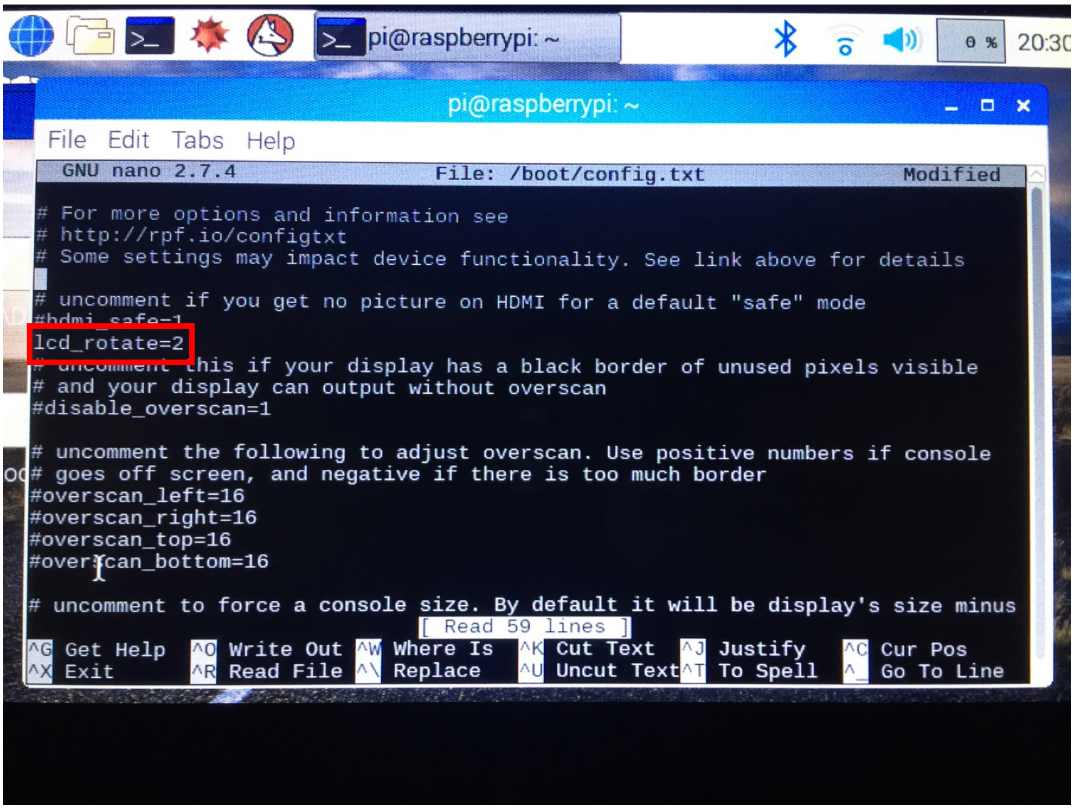

Figure 2.1: Invert Touchscreen Display 1

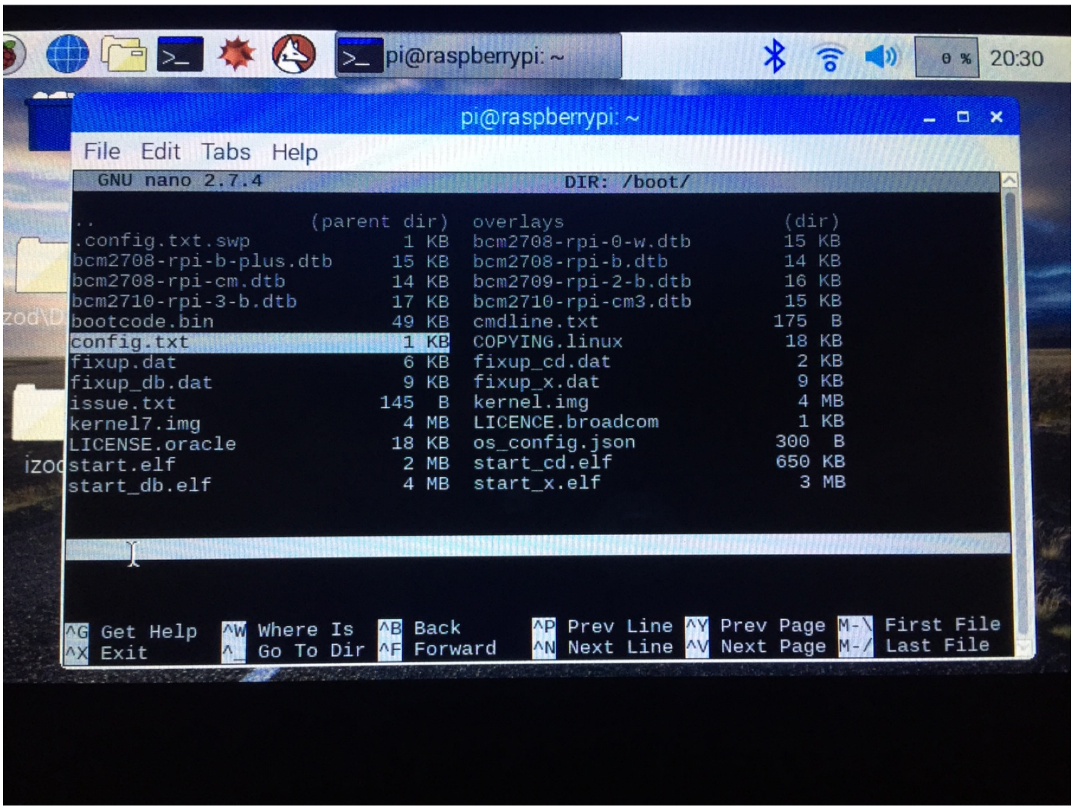

Figure 2.2: Invert Touchscreen Display 2

2.4 Incorrect Arm Starting Position

2.4.1 Arm Before ZERO Position

If the arm is located between the **ZERO** position and the **INITIAL MAXIMUM HEIGHT** position upon starting the software. **Fig. 2.3**

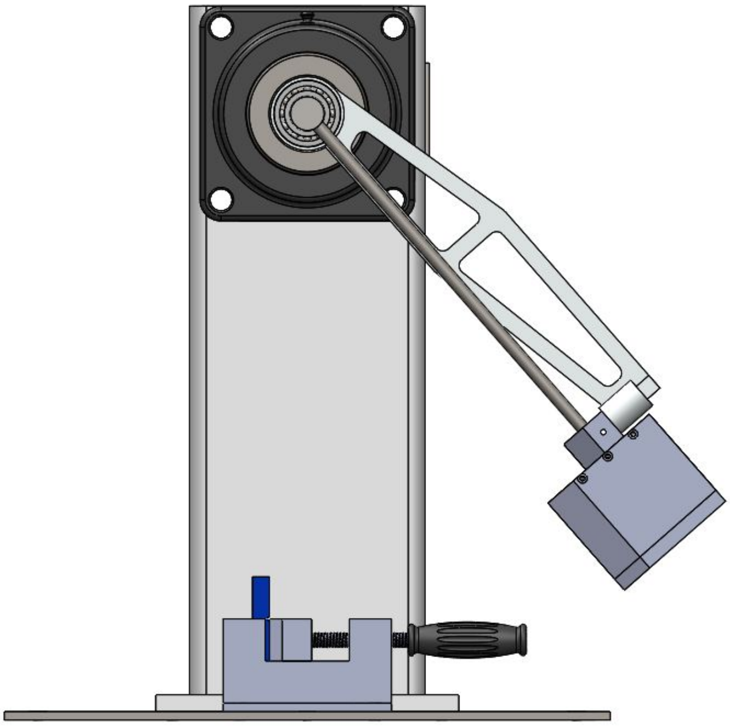

Figure 2.3: Arm before ZERO position

1. Press **CALIBRATION** on the GUI
2. Wait for the hammer to stabilize at the **ZERO** position (Full stop)
3. Press **CALIBRATION** again
4. Immediately move the hammer to the magnet on the arm.

2.4.2 Arm After ZERO Position

If the arm is located between the **ZERO** position and the **FINAL MAXIMUM HEIGHT** position upon starting the software. **Fig. 2.4**

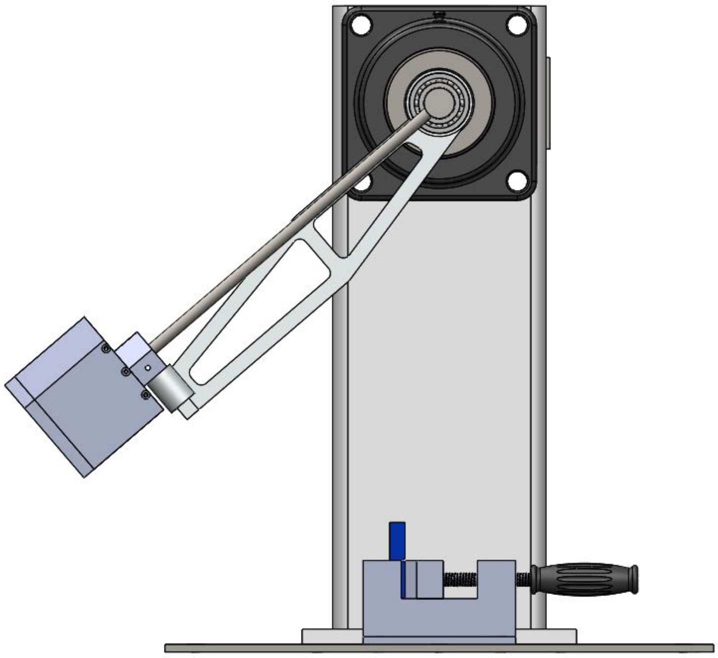

Figure 2.4: Arm after ZERO position

1. Press **CALIBRATION** on the GUI
2. Wait for the arm to stop
3. Press **CALIBRATION**
4. Wait for the arm to stop
5. Repeat until the hammer reaches a position close to the **ZERO** position
6. Follow the calibration procedure, Section 1.3

2.5 Unresponsive Software Buttons/Arduino Communication Malfunction

Typically, when the software is unresponsive or if it isn't able to communicate with the arduino it will return an error like the following:

could not open port 'com8': FileNotFoundError(2, 'The system cannot find the file specified.', None, 2)

It can be solved by first shutting down the software and unplugging/replugging the USB connected to the Arduino from either the Raspberry Pi or the Computer used for operation.

2.6 Bypass Software Interface

The machine can be operated while bypassing the software, however the output text file is minimal. See **Fig. 2.5** for an example of the Output text file for this method.

1. Open **Terminal** on Raspbian or **Anaconda Prompt** on Windows
2. Type **python Communication.py**
3. Type **B**,**C**,**D**,**E**,**Q** adequately following:
   (a) **B**: **RUN**
   (b) **C**: **RESET**
   (c) **D**: **LOADING**
   (d) **E**: **CALIBRATION**
   (e) **Q**: **QUIT**

```
Sun, 06, May, 2018, 14:39:43
File Number:    0
Initial Angle (degrees):    134.316
Final Angle (degrees):  132.624

Initial Height (mm):    611.3621557922141
Final Height (mm):  603.6487994224118
Height Difference (mm): 7.713356369802341
```

Figure 2.5: Software Bypass Output Text File

2.7 Reset File Count to Default

To reset the file count to default, delete *preferences.txt* in the IZOD Directory. This will reset file count to 0 but also reset all values in *preferences.txt* to default.

2.8 Modify Constants (Weight, Arm Length, etc...)

Open *preferences.txt* to modify constant parameters.

NOTE: Do NOT modify File Count

2.9 Anaconda Starter Guide

ANACONDA

ANACONDA DISTRIBUTION STARTER GUIDE

See full documentation for Anaconda Distribution
docs.anaconda.com/anaconda/

BEFORE YOU START	
Why do I need Anaconda Distribution?	Installing Python in a terminal is no joy. Many scientific packages require a specific version of Python to run, and it's difficult to keep them from interacting with each other. It is even harder to keep them updated. Anaconda Distribution makes getting and maintaining these packages quick and easy.
What is Anaconda Distribution?	It is an open source, easy-to-install high performance Python and R distribution, with the conda package and environment manager and collection of 1,000+ open source packages with free community support.
Then what is Miniconda?	It's Anaconda Distribution without the collection of 1,000+ open source packages. With Miniconda you install only the packages you want with the conda command, `conda install PACKAGENAME` **Example:** `conda install anaconda-navigator`
GET IT	
Will it work on my machine?	Yes, Anaconda Distribution is available for Windows, macOS or Linux x86 or POWER8, 32- or 64-bit, 3GB HD available. Miniconda is the same but needs only 400 MB HD.
Quick install it	docs.anaconda.com/anaconda/install
Get your conda cheat sheet	conda.io/docs/using/cheatsheet.html
Take the test drive	conda.io/docs/test-drive.html

NOW PLAY WITH THE WORLD'S MOST AWESOME SCIENTIFIC PACKAGES

Included in Anaconda 4.4+, or get with "`conda install PACKAGENAME`"

1. **NumPy**
   numpy.org
   N-dimensional array for numerical computation
2. **SciPy**
   scipy.org
   Scientific computing library for Python
3. **Matplotlib**
   matplotlib.org
   2D Plotting library for Python
4. **Pandas**
   pandas.pydata.org
   Powerful Python data structures and data analysis toolkit
5. **Seaborn**
   seaborn.pydata.org/
   Statistical graphics library for Python
6. **Bokeh**
   bokeh.pydata.org
   Interactive web visualization library
7. **Scikit-Learn**
   scikit-learn.org/stable
   Python modules for machine learning and data mining
8. **NLTK**
   nltk.org
   Natural language toolkit
9. **Jupyter Notebook**
   jupyter.org
   Web app that allows you to create and share documents that contain live code, equations, visualizations and explanatory text
10. **R essentials**
    conda.pydata.org/docs/r-with-conda.html
    R with 80+ of the most used R packages for data science
    "`conda install r-essentials`"
    R package list
    docs.anaconda.com/anaconda/rlanguage-pkg-docs

ANACONDA

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ANACONDA

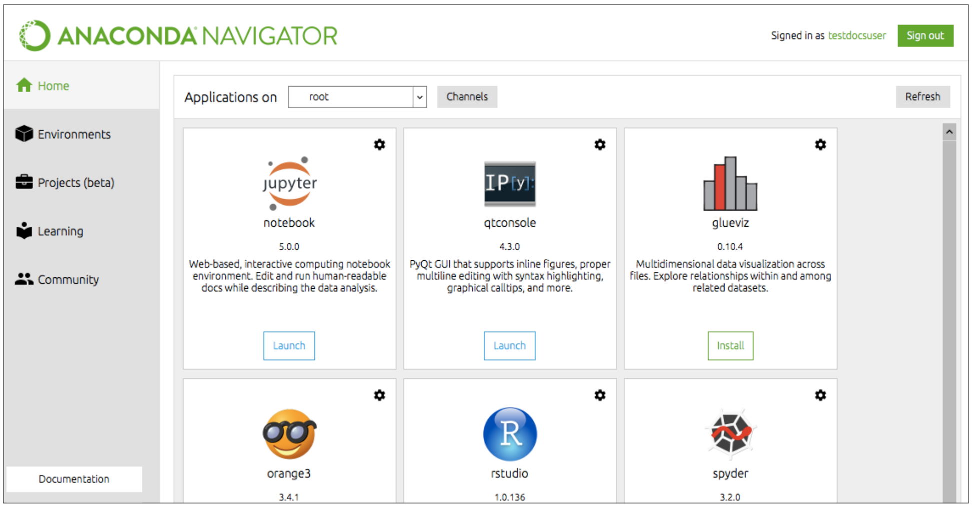
ANACONDA NAVIGATOR CHEAT SHEET

See full documentation for Anaconda Navigator
docs.anaconda.com/anaconda/navigator/

Before you Start	
What is Anaconda Navigator?	Anaconda Navigator is an easy way to use graphical Python programs without having to use command line commands.

Get It	
Will it work on my machine?	Anaconda Navigator is available for Windows, macOS or Linux, 32- or 64-bit, 3GB HD available. Navigator is automatically installed when you install Anaconda Distribution.
Follow the graphical install instructions	docs.anaconda.com/anaconda/install
Open Anaconda Navigator	After install, look on your desktop or programs menu for Anaconda Navigator and click it.

NOW PLAY WITH THE WORLD'S MOST AWESOME SCIENTIFIC PACKAGES



MORE RESOURCES	
Free email group support	http://bit.ly/anaconda-community
Paid support	anaconda.com/anaconda-support
Training	anaconda.com/training
Consulting	anaconda.com/anaconda-consulting

Follow us on Twitter @anacondainc and join the #AnacondaCrew!

Connect with talented, like-minded data scientists and developers while contributing to the open source movement. Visit anaconda.com/community.

ANACONDA

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8/20/2017

2.10 Conda Cheat Sheet

CONDA

CONDA CHEAT SHEET

Command line package and environment manager

Learn to use conda in 30 minutes at **bit.ly/tryconda**

TIP: Anaconda Navigator is a graphical interface to use conda. Double-click the Navigator icon on your desktop or in a Terminal or at the Anaconda prompt, type `anaconda-navigator`

Conda basics	
Verify conda is installed, check version number	`conda info`
Update conda to the current version	`conda update conda`
Install a package included in Anaconda	`conda install PACKAGENAME`
Run a package after install, example Spyder*	`spyder`
Update any installed program	`conda update PACKAGENAME`
Command line help	`COMMANDNAME --help` `conda install --help`

*Must be installed and have a deployable command, usually PACKAGENAME

Using environments	
Create a new environment named py35, install Python 3.5	`conda create --name py35 python=3.5`
Activate the new environment to use it	`WINDOWS: activate py35` `LINUX, macOS: source activate py35`
Get a list of all my environments, active environment is shown with *	`conda env list`
Make exact copy of an environment	`conda create --clone py35 --name py35-2`
List all packages and versions installed in active environment	`conda list`
List the history of each change to the current environment	`conda list --revisions`
Restore environment to a previous revision	`conda install --revision 2`
Save environment to a text file	`conda list --explicit > bio-env.txt`
Delete an environment and everything in it	`conda env remove --name bio-env`
Deactivate the current environment	`WINDOWS: deactivate` `macOS, LINUX: source deactivate`
Create environment from a text file	`conda env create --file bio-env.txt`
Stack commands: create a new environment, name it bio-env and install the biopython package	`conda create --name bio-env biopython`

Finding conda packages	
Use conda to search for a package	`conda search PACKAGENAME`
See list of all packages in Anaconda	https://docs.anaconda.com/anaconda/packages/pkg-docs

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CONTINUED ON BACK →

Installing and updating packages	
Install a new package (Jupyter Notebook) in the active environment	`conda install jupyter`
Run an installed package (Jupyter Notebook)	`jupyter-notebook`
Install a new package (toolz) in a different environment (bio-env)	`conda install --name bio-env toolz`
Update a package in the current environment	`conda update scikit-learn`
Install a package (boltons) from a specific channel (conda-forge)	`conda install --channel conda-forge boltons`
Install a package directly from PyPI into the current active environment using pip	`pip install boltons`
Remove one or more packages (toolz, boltons) from a specific environment (bio-env)	`conda remove --name bio-env toolz boltons`

Managing multiple versions of Python	
Install different version of Python in a new environment named py34	`conda create --name py34 python=3.4`
Switch to the new environment that has a different version of Python	Windows: `activate py34` Linux, macOS: `source activate py34`
Show the locations of all versions of Python that are currently in the path **NOTE**: The first version of Python in the list will be executed.	Windows: `where python` Linux, macOS: `which -a python`
Show version information for the current active Python	`python --version`

Specifying version numbers

Ways to specify a package version number for use with conda create or conda install commands, and in meta.yaml files.

Constraint type	Specification	Result
Fuzzy	`numpy=1.11`	1.11.0, 1.11.1, 1.11.2, 1.11.18 etc.
Exact	`numpy==1.11`	1.11.0
Greater than or equal to	`"numpy>=1.11"`	1.11.0 or higher
OR	`"numpy=1.11.1|1.11.3"`	1.11.1, 1.11.3
AND	`"numpy>=1.8,<2"`	1.8, 1.9, not 2.0

NOTE: Quotation marks must be used when your specification contains a space or any of these characters: > < | *

MORE RESOURCES

Free Community Support	groups.google.com/a/continuum.io/forum/#!forum/conda
Online Documentation	conda.io/docs
Command Reference	conda.io/docs/commands
Paid Support Options	anaconda.com/support
Anaconda Onsite Training Courses	anaconda.com/training
Anaconda Consulting Services	anaconda.com/consulting

Follow us on Twitter @anacondainc and join the #AnacondaCrew!
Connect with other talented, like-minded data scientists and developers while contributing to the open source movement. Visit anaconda.com/community

ANACONDA.

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8/20/2017 conda cheat sheet Version 4.3.24

Chapter 3

Electrical Components

3.1 Arduino DUE

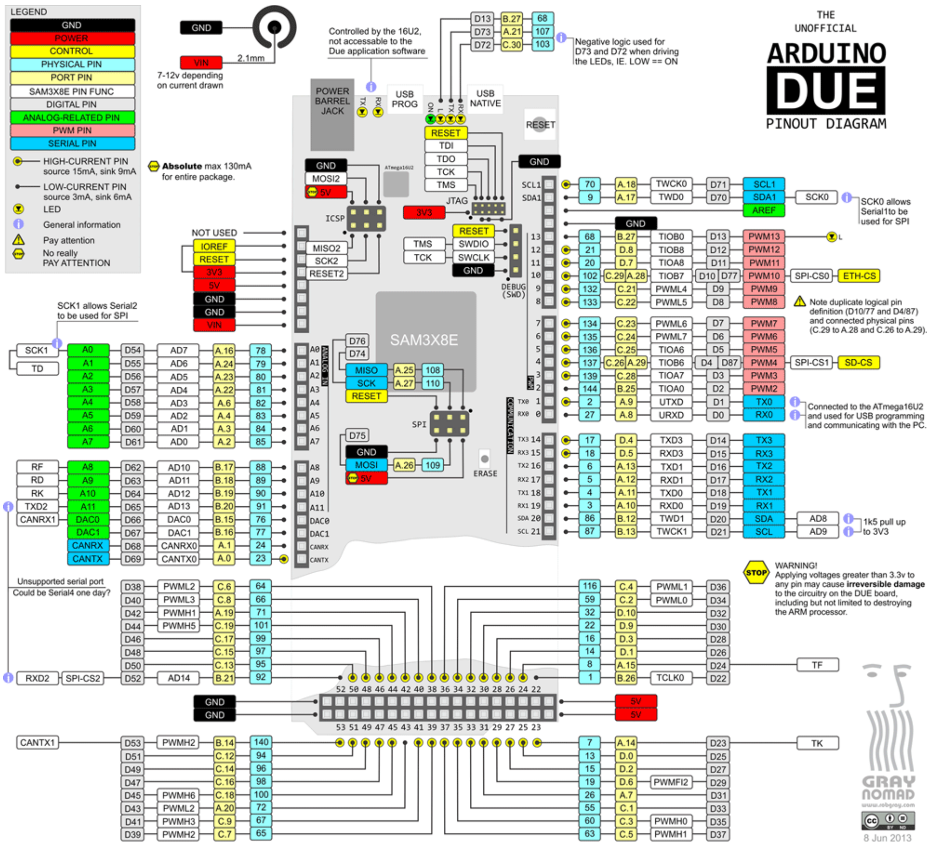

Figure 3.1: Arduino DUE Schematics

3.2 RASPBERRY PI 3

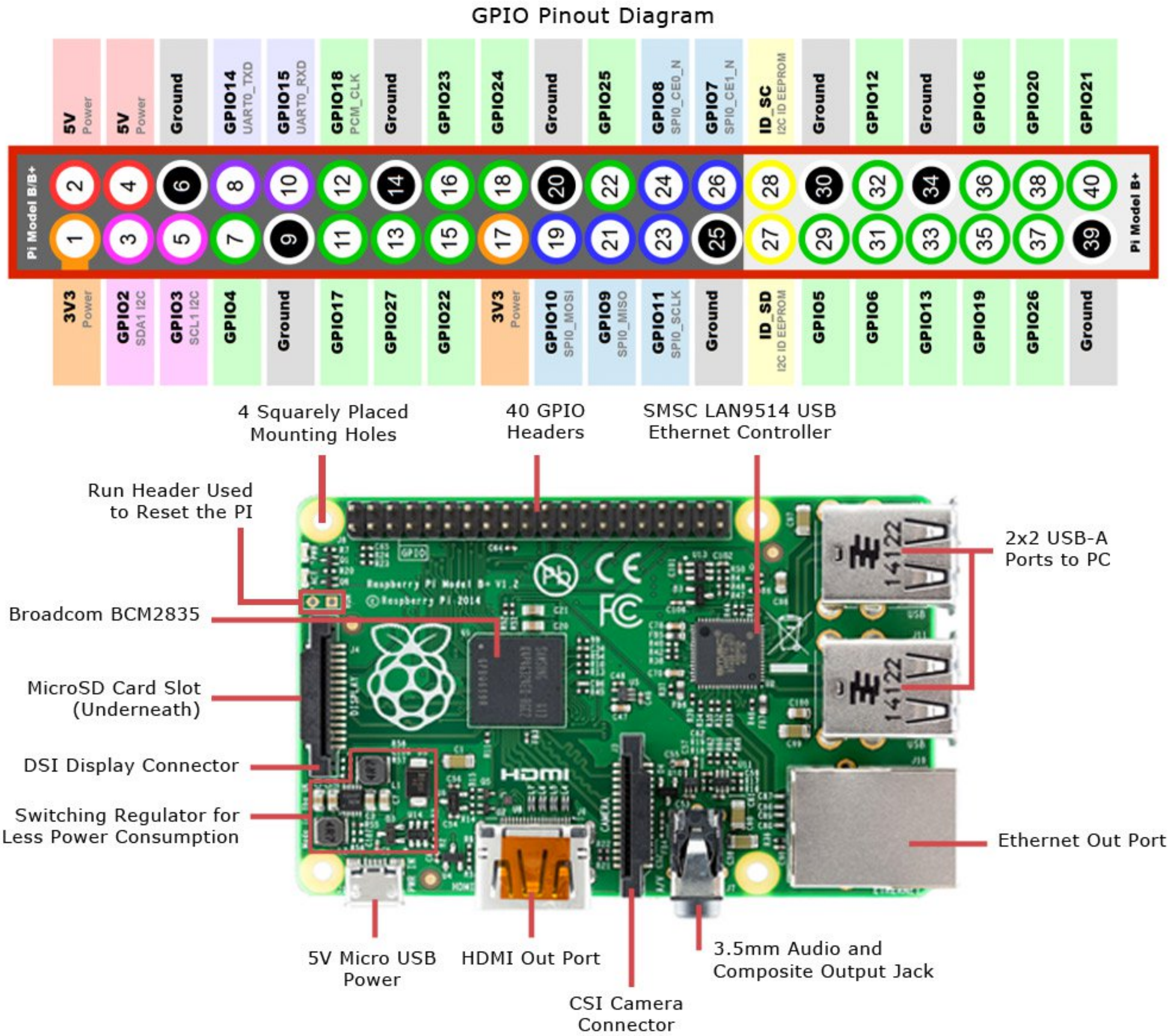

Figure 3.2: Raspberry Pi 3 Schematics

3.3 L298N V3 MOTOR CONTROLLER

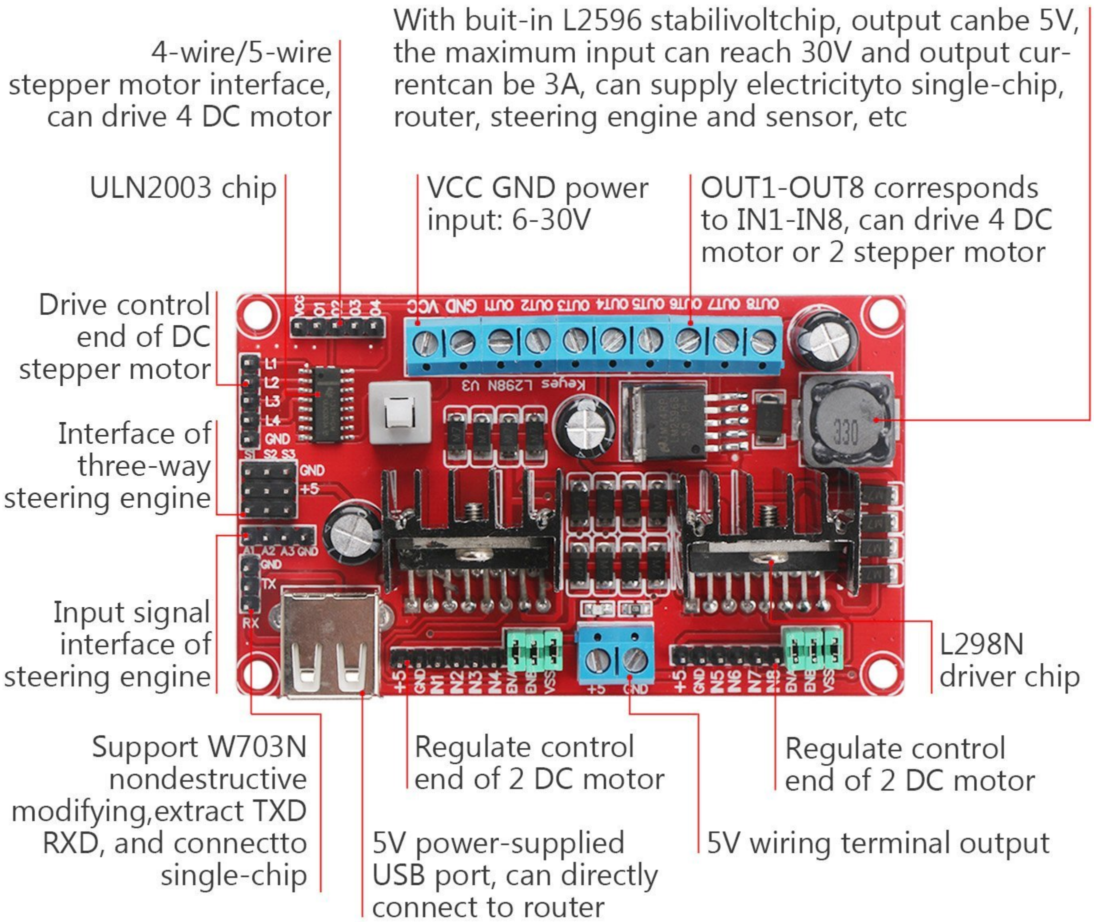

Figure 3.3: L298N v3 Schematics

3.4 DYTRAN 4110C CURRENT SOURCE

OG4110.DOC
REV A 7-17-96

OPERATING INSTRUCTIONS

SINGLE CHANNEL MODEL 4110C & 4-CHANNEL 4110B

LINE-POWERED CURRENT SOURCE

POWER UNITS WITH LED ARRAY METER

NOTE:
Model 4110C is a single channel unit and features BNC connectors for both Sensor and Output and a LED array monitor meter at the front panel.
Model 4114B has four channels and has 10-32 Sensor and BNC output connectors. This unit also features the LED array voltmeter.

Operating principles and most specifications are similar for these two units.

THIS MANUAL INCLUDES:
1) Specifications, Models 4110C and 4114B
2) Operatign instructions, Models 4110C and 4114B
3) Outline/installation drawings 127-4110C & 127-4114B

. 1

3.4. DYTRAN 4110C CURRENT SOURCE

SPECIFICATIONS
MODELS 4110C SINGLE CHANNEL & 4114B 4-CHANNEL LIVM
LINE-POWERED CURRENT SOURCE POWER UNITS

SPECIFICATIONS		VALUE	UNITS
SENSOR DRIVE CURRENT ADJUSTMENT RANGE		2 to 20	mA
COMPLIANCE (SUPPLY) VOLTAGE		+24	VDC
VOLTAGE GAIN		1	UNITY
DE-COUPLING CAPACITOR		10	μF
PULLDOWN RESISTOR		1	MEGOHM
COUPLING TIME CONSTANT, NO LOAD		10	SECONDS
W/1 MEGOHM LOAD		1	SECONDS
LOWER -3db FREQUENCY, NO LOAD		.016	Hz
W/1 MEGOHM LOAD		.03	Hz
HIGH FREQUENCY RESPONSE:		DETERMINED BY SENSOR, CABLE LENGTH AND SENSOR DRIVE CURRENT.	
BACKGROUND ELECTRICAL NOISE, WIDEBAND		150	μV RMS
SENSOR CONNECTOR, REAR PANEL,	MODEL 4110C	BNC	JACK
	MODEL 4114B	10-32 (4)	JACK
OUTPUT CONNECTOR, REAR PANEL,	ALL MODELS	BNC	JACK
POWER CORD, 3-WIRE W/GND		6	FT
POWER REQUIRED: [1]			
MODEL 4110C		1.1	VA
MODEL 4114		4.4	VA
SIZE, H x W x D [2]	BOTH MODELS	5.5 x 1.6 x 8.0	IN
WEIGHT	BOTH MODELS	32/907	OZ/GRAMS

[1] 115 VAC, 50-60 Hz FOR STANDARD MODELS. EXPORT ["E"] VERSIONS REQUIRE 230 VAC, 50-60Hz.

[2] RACK MOUNTING: UP TO 10 UNITS MAY BE MOUNTED IN 19 IN. WIDE MODEL 4200 RACK ADAPTOR. UNIT IS SECURED IN RACK BY MEANS OF A CAPTIVATED 10-32 THUMB SCREW AT THE BOTTOM OF THE FRONT PANEL.

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3.4. DYTRAN 4110C CURRENT SOURCE

OPERATING INSTRUCTIONS
MODELS 4110C AND 4114B LINE POWERED
LIVM* CURRENT SOURCE POWER UNITS

* **LIVM** is Dytran's trade mark for its line of **L**ow **I**mpedance **V**oltage **M**ode piezoelectric sensors with built-in impedance converting electronics operating in the two-wire mode.

INTRODUCTION

Dytran Models **4110C & 4114B** are line-operated constant current power units designed to power LIVM voltage mode sensors and in-line charge amplifiers, such as series 4751A & 4705A. These power units provide 2 to 20 mA of constant current at +24 VDC compliance voltage.

Model 4110C is a single-channel unit with BNC Sensor and Output jacks.

Mod. 4114B is a 4-channel unit with four 10-32 Sensor jacks and four BNC Output jacks. (Model 4114B is not available with BNC Sensor jacks.) All electrical connectors are mounted on the rear panel of all models

Aside from the number of channels, operation of these two units is similar.

Both models are exactly the same size and may be used as stand-alone "desktop" units or may be rack mounted in an available 19 in. wide rack adaptor, Model 4200. When rack mounted, the outer case is removed. Up to 10 units may be inserted into the rack adaptor. The units are secured by means of a captivated thumbscrew at the bottom of the front panel.

The standard versions of these units operate from 115 VAC line power while the "E" (export) versions operate from 230 VAC.

DESCRIPTION

(Refer to outline/installation drawings 127-4110C & 127-4114B).

Both models contain highly regulated +24 VDC power supplies coupled to adjustable constant current circuits.

The constant current circuits consist of clamped-base PNP transistors with variable emitter resistor to adjust the current.

The current output of these circuits is user-settable over the range of 2 to 20 mA. The constant current is supplied to the sensors via the rear-panel "Sensor" jacks.

LIVM sensors operate with a single two-wire cable, i.e., power and signal are conducted over the same wire. When the sensors are supplied with constant current, they self-bias at approx. +10 VDC. The sensor signal is superimposed on the DC bias voltage of the sensor amplifier.

Inside the power unit, the DC bias of the sensor amplifier is blocked by a 10 μF coupling capacitor and is coupled to the Output jacks(s). The sensor bias voltage is continuously monitored by the front-panel LED array DC voltmeter which serves as a handy trouble shooting tool. (More on this topic later in the section "The Bias-monitoring Voltmeter".)

Model 4114B has a four-position rotary selector switch which selects any one of the four channels for monitoring without disturbing the function of the channel selected.

OPERATION

Refer to Figure 1.

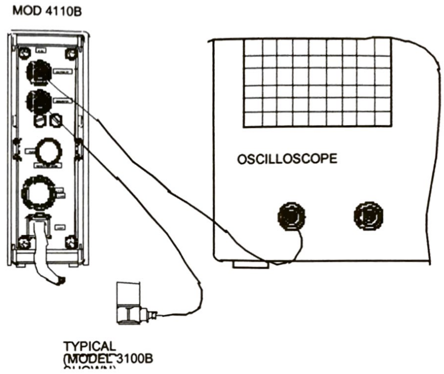


Figure 1
Typical System Interconnect

Connect the LIVM sensor to the rear panel "Sensor" jack.

Cable model 6010AXX (XX is the length in feet) 10-32 to 10-32, will connect sensors with 10-32 miniature connectors to the 4114B while Model

6011AXX cable will connect 10-32 sensor connectors to the BNC "Sensor" jacks on the 4110C.

Connect the "Output" jack(s) to the readout instrument using Model 6020AXX BNC/BNC cables.

Plug the line cord into a source of 115 VAC power (230 VAC for the "E" versions). The front panel "PWR" indicator lamp will glow and the LED array voltmeter will indicate approx. mid-scale if sensor and cables are functioning normally.

Allow several minutes for coupling capacitors to charge and proceed with measurements.

If the "PWR" lamp does not glow, check the fuse and replace if necessary. Use only the exact replacement fuse, 3AG 312.250 1/4 AMP. The fuse holder is located at the rear panel.

NOTE: Remember to unplug the unit while changing the fuse to avoid electrical shocks.

THE BIAS-MONITORING VOLTMETER

The voltmeter on the front panel of these power units can be used as a handy trouble shooting aid as explained here. The meter on Model 4110C continuously monitors the single channel while a rotary switch on Model 4114B selects one of four channels for monitoring.

NOTE: <u>Normal operation of the measurement circuit is **NOT** affected by monitoring.</u>

As previously stated, the front-panel voltmeter continuously monitors the DC voltage output of the constant current circuit at the "Sensor" jack.

With no sensor connected, the meter will measure the "open circuit" compliance voltage, +24 Volts. The meter will indicate full scale or "open". under this condition

Consequently, should the sensor cable or sensor built-in amplifier become **open,** the meter will indicate this by reading **full scale** as if no sensor was connected.

Normal operation of sensor and cable is indicated by a **mid-scale** meter reading which reflects the +10 volt bias of the sensor amplifier.

If a **short** should occur across sensor or cable connector or if the sensor itself is shorted, the meter will indicate **zero volts or "short"**. If this condition is indicated, check cable and sensor connectors for metal filings or chips which may short across contacts. Wipe connectors with stiff-bristled brushes and/or paper wipes and/or blow off with compressed air to dislodge shorting particles.

CHANGING THE CONSTANT CURRENT SETTINGS.

Sensor drive current on all units is factory set at 5 mA. This is a nominal setting which will take care of 90% of the measurement needs.

In certain circumstances, it may be desirable to change this value. For example, if the sensor must drive very long cables at high frequencies, 5 mA may not be enough drive current. Conversely, if the sensor is to be used at very high temperatures, at the upper limit of the specification, it may be necessary to reduce the drive current to keep the junction temperature of the IC sensor amplifier below maximum. Also, lowest sensor noise is obtained with lower drive currents.

For any of the above reasons. it may be necessary to change the drive current setting(s). Sensor drive current is adjustable for Model 4110C and for each channel, individually for Model 4114B, over the range from 2 to 20 mA.

To reset the value of the sensor drive current, proceed as follows:

1) Remove the right hand side cover (viewed from the front) by removing the single securing screw toward the rear of the cover. Slide the cover rearward to remove.

CAUTION: AVOID TOUCHING THE FUSE DURING THIS OPERATION TO AVOID SERIOUS ELECTRICAL SHOCK.

2) On the printed circuit board, locate the current setting potentiometers. (Refer to the outline/installation drawings for the locations of the current setting pots.

The single channel 4110C has only one constant current circuit while 4114B has four.

3) Connect a milliammeter from sensor jack center pin to the outer shell. (The milliammeter should have a full scale range of at least 20 mA.)

Adjusting the sensor drive current.

<u>**CAUTION:** Use a non-metallic screwdriver when making the following adjustment when power is applied. Touching the AC power input fuse terminal or transformer contacts could result in a dangerous electrical shock. Also,</u>

. 4

shorting solid state components with a metal tool can destroy them instantly.

4) Select the appropriate potentiometer (pot.). referring to the outline/installation drawing, and while monitoring the current as in step 3, adjust the drive current setting as required. Although it may be possible to do so, **do not exceed a 20 mA setting.**

FAST RISE TIME PULSES AND LONG CABLES

When driving very long cables with short rise time pulses (as with blast or shock tube measurements) it has been discovered that it is best to empirically determine the drive current setting for best pulse fidelity since no two sets of test conditions (cable type and length and pulse rise time) are similar.

It may also be necessary to match driving point and line impedances to avoid mismatches which can cause reflections and other disturbances which may impair pulse fidelity.

A low value resistor in series with the sensor line (see figure 2 below) can sometimes be useful in overcoming this difficulty.

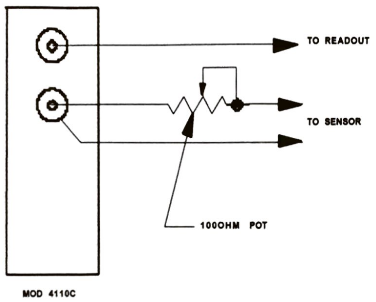


Figure 2
Matching the line impedance.

(Refer to Figure 2), By inserting a 100 Ohm impedance matching potentiometer in series with the line and varying the pot value along with the drive current setting, it is possible to tune the system for best pulse fidelity. The best setting must be arrived at empirically

COUPLING TIME CONSTANT CONSIDERATIONS

The outputs of both models are AC coupled, i.e., the signal is capacitor-coupled from the sensor jack to the output jack. This is so the quiescent output signal level is at zero volts DC.

The value of the coupling capacitor used is 10 uF. The output side of this capacitor is "pulled down" to ground at the sensor jack with a 1 Megohm resistor to "pull" the output voltage close to zero Volts. (This is necessary because of the inherent leakage of tanalytic style capacitors.)

This capacitor and the pull-down resistor (along with the readout load) constitute a first order, high-pass filter. It is this combination of components which may **limit the low frequency performance** of your system. We say "may limit" because the sensor itself may be the limiting factor on the system L.F. response. At any rate, it will be useful to understand the limitations set by these parameters.

The coupling time constant (TC) is the product of the coupling capacitor C_c (10μF) and the total output load including the parallel sum of the pulldown resistor R_p (1 Megohm) and the output load R_l which is the input resistance of your readout instrument. With **no (or negligible) output load,** the coupling TC is:

$$TC = C_c \times R_p = 1\text{ Meg} \times 10\text{uF} = 10\text{ Seconds} \qquad \text{Eq. 1}$$

We may now calculate the theoretical **low frequency response** of the system using the following relationship:

Note: In the following relationship, f_o is the frequency at which the signal is down by **3db** (30%) compared to the mid-range or reference frequency, usually 100 Hz. (f_o is also called the corner frequency.)

$$f_0 = \frac{.16}{TC} = \frac{.16}{10} = .016\text{ Hz.} \qquad \text{Eq. 2}$$

This result tells us that the lower corner frequency, i.e., the frequency at which our signal is 30% down from the reference frequency is .016 Hz. To find the frequency at which the response is **5% down,** simply multiply f_0 by 3,

$$f_{-5\%} = f_0 \times 3 \qquad \text{Eq. 3}$$

$$= .016 \times 3 = .048\text{ Hz}$$

With these equations, it is possible to calculate the -3db and the -5% frequencies for any condition of output load.

Remember, if the **output load is less than 10 Megohms,** calculate the parallel combination of the load resistance and the 1 megohm pulldown resistor and substitute this new value for R_p in equation 1 for most accurate results.

QUASI-STATIC (CLOSE TO DC) OPERATION

For those situations that require longer coupling time constants, a DC coupled power unit is available, the Model 4115. This single channel power unit features a DC coupled level shifting circuit in place of the coupling capacitor which allows direct coupling to the sensor to the output jack. The output of this unit is DC coupled using an op-amp. With this unit, the low frequency response is determined solely by the sensor and not the output load.

A method to bypass the 10μF coupling capacitor and direct couple to the sensor is to take the signal from the Sensor jack instead of the Sensor jack.

This can be accomplished by using a "T" connection at the Sensor connector with one cable going to the sensor and the other to the readout instrument.

The main drawback with this scheme is that the signal will have a +11 Volt DC offset which must be handled by the offset adjustment of the oscilloscope or other readout instrument.

ZERO CLAMP (MODEL 4110C ONLY)

Model 4110C incorporates an output voltage zero clamp circuit which may be switched in or out as desired. This section explains what a zero clamp is and how it can be useful for certain types of measurements.

Piezoelectric sensors are AC devices, i.e., zero voltage reference is not maintained during operation of the measurement system. In most cases, this is not a detriment as with most vibration measurements.

However, in cases where unidirectional repetitive pulses are being measured, such as during impact force measurements or when measuring pressure pulsations for example, it may be important that the baseline DC voltage level of the output signal be maintained. The zero clamp prevents the DC level shifting that would normally occur in any AC couples system, essentially clamping the baseline to zero volts.

THEORY OF OPERATION

Without zero clamping, the output voltage signal from an AC coupled sensor system, e.g., a force sensor measuring repetitive compressive force pulses, may look like figure 3 in the steady state.

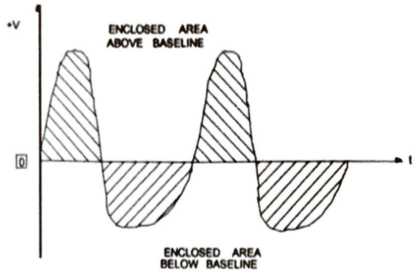


Figure 3
Output signal unclamped

As shown in figure 3, the voltage level will shift downward until the areas enclosed by the waveform are equal above and below the zero baseline.

If the readout device is sensitive to absolute voltage level, such as with peak-reading voltmeters or certain data loggers, it is easy to see that the peak value of the waveform shown in figure 3 will be in error if measured from the zero baseline.

To avoid this problem, the zero clamp circuit was incorporated into the model 4110C.

A SIMPLE ZERO CLAMP

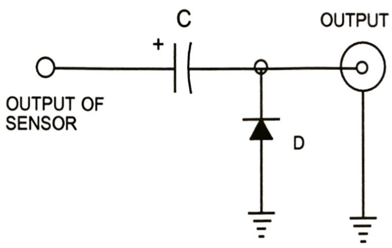


Figure 4
A simple zero clamp

Figure 4 above is a simplified schematic diagram of a simple zero clamp (sometimes called a zero restorer). The coupling capacitor C, blocks the +10 VDC bias from the sensor amplifier but allows the signal information to pass. The diode D, prevents the output from going negative and effectively lifts the

. 6

entire waveform above the zero voltage reference level. Refer to figure 5 below.

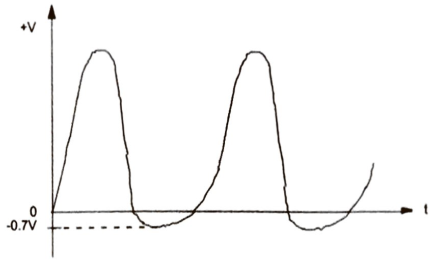


Figure 5
Output signal, simple zero clamp

There is a problem with this arrangement however. The forward voltage drop across the diode D will not allow true zero clamping, i.e., the baseline will settle to a point approximately .7 V below the zero baseline. This could represent a major error during low level measurements where .7 volts is a significant part of the overall signal level. To remove this flaw in the basic zero clamp, it is only necessary to return the diode to a voltage point approximately .7 volts above ground instead of directly to ground.

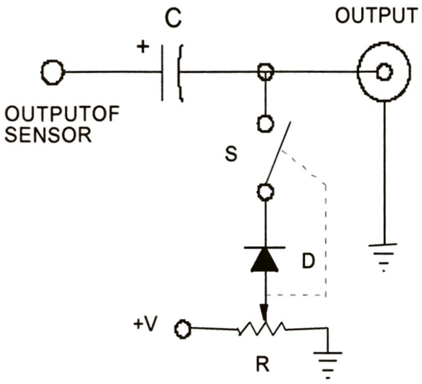


Figure 6
Improved zero clamp

The arrangement shown in Figure 6 allows "fine tuning" of the zero clamp to exactly compensate for the forward voltage drop across the diode to give accurate and precise setting of the zero clamp circuitry, as shown in figure 7.

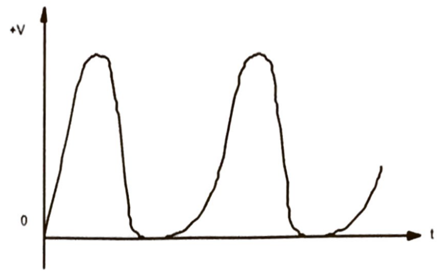


Figure 7
Output precisely clamped

The circuit shown in figure 6 is employed in Model 4110C.

Potentiometer R and switch S are accessible at the rear panel of model 4110C. (See outline/installation drawing 127-4110C for the location of the pot with switch s. o switch the zero clamp in, simply rotate the pot clockwise away from the switch detent. Use the pot to tune in the zero clamp so the baseline is precisely zero.

To switch the zero clamp off, rotate the pot knob fully counter clockwise until a click is heard.

MAINTENANCE AND REPAIR

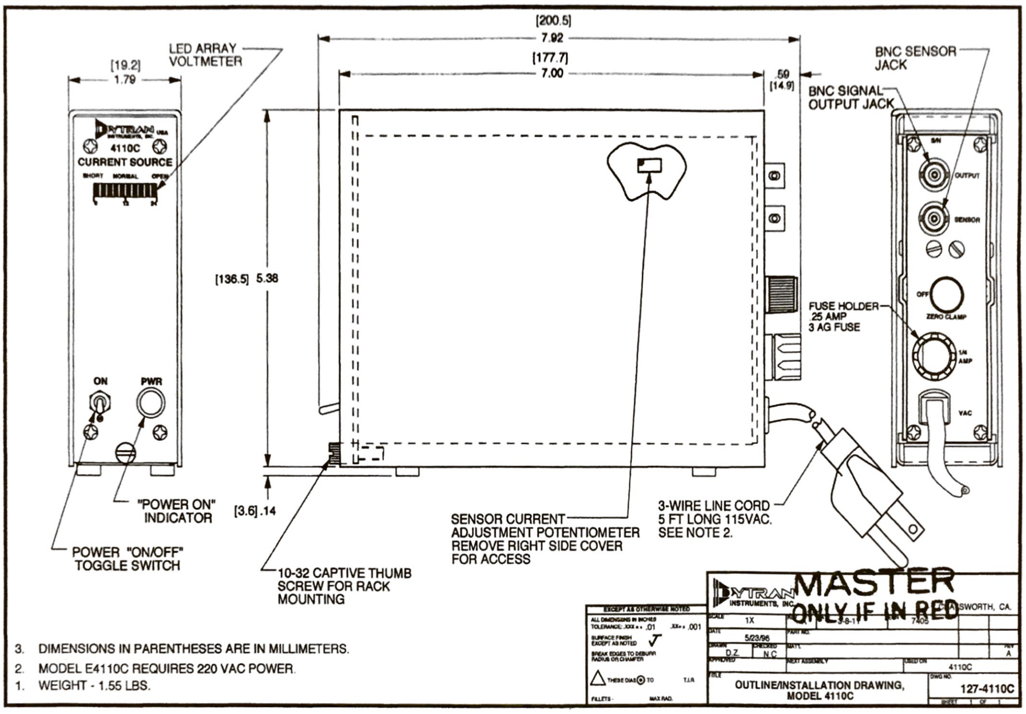
Being solid state devices, no maintenance is needed beyond the replacement of fuses should this become necessary.

Should a problem develop, notify the factory for advice in trouble shooting and for instructions in returning the instrument to the factory should this be necessary. Obtain a Returned Material Authorization (RMA) number.

If the instrument is within warranty (the warranty period is one year from date of receipt) there will be no charge for repair except for postage if there are no signs of abuse which would void the warranty.

For out-of-warranty units, there is no charge for evaluation. We will not proceed with the repair until we obtain the customer's authorization to proceed.

3.4. DYTRAN 4110C CURRENT SOURCE



DYTRAN INSTRUMENTS, INC.
Dynamic Transducers and Systems
21592 Marilla St. • Chatsworth, CA 91311 • Phone 818-700-7818
www.dytran.com • e-mail: info@dytran.com

LOW IMPEDANCE VOLTAGE MODE (LIVM) SYSTEMS, THEORY AND OPERATION

LIVM: WHAT IS IT?

LIVM is Dytran's trademark for our version of **L**ow **I**mpedance **V**oltage **M**ode piezoelectric instruments, i.e., piezo instruments with integral-impedance-converting amplifiers operating from constant current supplies over two wires. **LIVM** instruments are entirely compatible the new industry standard **IEPE** designated systems.

LIVM instruments produced at Dytran include force, pressure and acceleration sensors. Each class of sensors is produced in many varieties for a wide range of applications.

Also falling under the class of **LIVM** instruments are in-line charge amplifiers that utilize the same two-wire constant current operating mode as the **LIVM** sensors.

Operating principles for **LIVM** sensors and in-line amplifiers are similar in that they utilize the same two-wire constant current operating mode. The amplifiers built into the sensors are either MOSFET-input voltage or charge amplifiers or JFET-input charge amplifiers.

All types of **LIVM** amplifiers serve to convert the very high impedance of the piezoelectric crystals to much lower impedance voltage signals that have the capability of driving long cables with little or no signal degradation.

THEORY OF OPERATION

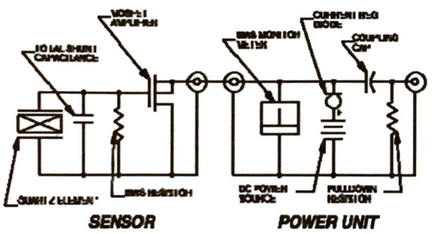


FIGURE 1: TYPICAL LIVM VOLTAGE MODE SYSTEM

Figure 1 is a simplified schematic of a basic LIVM system including the sensor with integral electronics, the cable and the power unit. The sensor amplifier in this case is the unity gain voltage follower. This is the type of amplifier used in most **LIVM** sensors and almost exclusively used with quartz element sensors.

The sensing element (force, pressure or acceleration), usually made with quartz or piezoceramic crystals, is connected directly to the gate of a FET input integrated circuit (IC) amplifier. This amplifier is operated as a source follower and, as such, has unity voltage gain.

The source terminal of the IC is supplied with constant current over the range of 2 to 20 mA at a compliance (supply) voltage of +18 to +30 volts DC. The power unit may take the form of many different configurations from simple battery powered 2 mA units with constant current diode, to line-powered adjustable current power units able to supply 2 to 20 mA of constant current from adjustable constant current circuits.

In either case, the constant current device (current diode or constant current circuit), acts as the source impedance for the unity gain IC built into the sensor or for the in-line charge amplifier.

Under quiescent conditions, the IC will bias itself at approximately +10 volts DC at the input (source) terminal of the sensor. (Some special variations will bias at different voltages depending upon the specific application). This sensor bias voltage is monitored and displayed, on most Dytran power units, and this feature serves as a handy trouble-shooting tool, serving as an indicator for normal or abnormal operation. (More on this topic in a following section, "The fault monitoring monitor as a trouble-shooting tool").

The sensor signal, produced by the measurand acting upon the piezo element, is superimposed upon the sensor bias voltage and appears at the "Sensor" jack of the power unit. At this point, the DC bias portion of the signal is blocked by a coupling capacitor and the AC (signal) portion is coupled directly to the "Output" jack of the power unit.

The Output jack may then be connected directly to the input of readout instruments (oscilloscopes, spectrum analyzers, AC meters, frequency counters, etc.). The very low output impedance of the **LIVM** sensor (about 150 Ohms) makes the effect of most readout instruments on the signal, negligible.

Be aware that the coupling capacitor in the power unit (usually 10 μF) and the impedance of the readout load constitute a high-pass filter that may set the low frequency response of the system below the LF response built into the sensor. In most accelerometer applications, the 10 μF capacitor provides ample time constant to allow vibration measurements down to fractions of a Hz.

Dytran also manufactures DC-coupled power unit for **LIVM** sensors that utilizes an active variable voltage level amplifier circuit to "buck out" the DC bias voltage of the sensor. One such unit, model 4115B, supplies constant current to the sensor and direct-couples the sensor to the output jack eliminating the coupling capacitor. This feature allows the user to take full advantage of the long time constant built into the sensor and precludes the effect of readout instrument load on the low frequency response of the system. Model 4115B is especially useful for very long-duration (quasi-static) measurements especially with force and pressure sensors.

OPERATION, GENERAL

Special note: LIVM sensors depend on the power unit to supply a fixed amount of current to the sensor IC. These IC circuits will absorb any amount of current supplied until they exceed their power rating and burn up. For this reason, never apply power to an **LIVM** sensor without this current limiting protection. This precludes the connection of **LIVM** sensors directly to batteries, DC power units and many types of resistance measuring devices. Never measure the continuity of an LIVM sensor with any type of Ohmmeter. This type of measurement is redundant and may lead to destruction of the sensor. To determine if the IC is intact, use the monitor meter on the front panel of your Dytran power unit. This topic is covered in the following section, "The fault monitoring meter as a trouble-shooting tool".

1

3.4. DYTRAN 4110C CURRENT SOURCE

After installing the sensor in accordance with instructions in the operating guide (manual) supplied with each sensor, connect the sensor to the power unit's "Sensor" jack. This jack, in most cases, is a BNC coaxial connector. You should have been supplied with the proper cable to connect the sensor to the power unit you have selected. If you were not and/or do not have such a cable, contact the factory for help.

It is important to carefully support the sensor cable, especially in situations where there is movement between the sensor and its surroundings. This practice will prolong cable life and will diminish or preclude the effects of triboelectric (cable generated) noise on the signal.

THE FAULT-MONITOR METER: A TROUBLE -SHOOTING TOOL

Most Dytran power units incorporate a dc voltmeter on the front panel that measures the DC bias voltage at the sensor terminal. Measuring this voltage supplies information about the "health" of the measurement system. The three conditions it can identify are 1) normal operation, 2) shorted cable or sensor or faulty power unit and 3) open sensor or cable connection. We will examine each possibility here.

NOTE: The fault-monitor meter may be the LED style shown on the left, Fig. 2, or the D'Arsonval panel meter style shown on the right, Fig. 2.

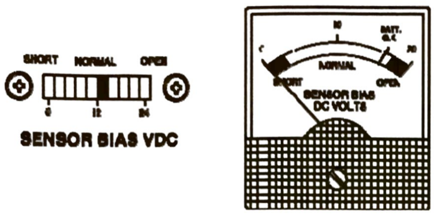


FIGURE 2: TYPICAL FAULT MONITOR METERS

NORMAL OPERATION

Under most normal operating conditions, the monitor meter will indicate approx. mid-scale (+10 to +13 volts DC) when the sensor is connected. Many of the meter faces have a "Normal" area delineated to indicate that the sensor is functioning and the cable from sensor to power unit is neither open nor shorted. It is possible that certain failure modes of the sensor can produce "Normal" indications but these modes are very rare. In most cases, if the meter reads in the "Normal" area, the system is viable.

As a further quick check on normal operation, with some sensors such as pressure and force sensors, pressing on the diaphragm or force sensitive surface with a finger can cause the monitor meter pointer to deflect showing that the sensor is "alive". With some higher sensitivity accelerometers, shaking them by hand can deflect the monitor meter enough to show the sensor is functioning.

OPEN SENSOR OR CABLE (FULL SCALE METER READING)

If the sensor amplifier is blown or the cable connecting sensor to power unit is open, the monitor meter will read in the "OPEN" area of the scale since the current source in the power unit has no load. To check if the problem is in the sensor, disconnect the sensor from its cable (leaving the other end connected to the power unit), and short across the open end of the cable with a metallic object while observing the meter. If the meter does not indicate zero ("short") while the sensor end of the cable is shorted, the cable is open. Replace the cable and try the sensor again, looking for the "Normal" indication.

If the meter reads zero when the short is applied, the cable is OK but the sensor is open. If another sensor is available, try it to verify the finding.

SHORTED SENSOR OR CABLE ("SHORT" METER READING)

If the fault-monitor meter reads in the "Short" area after connecting the sensor, this means that there is a short in the cable or sensor.

This condition cannot damage the power unit since the constant current circuit in the power unit limits the maximum current. Sometimes, shards of metal can scrape off of the cable connector of the 10-32 cables and these may short across the sensor connection. Check for this. Cleaning with a stiff-bristled brush will dislodge such metal shards.

If a short is still indicated, then the problem is with the cable or the power unit. Disconnect the cable from the power unit and observe the meter reading. If the meter reads full scale, the power unit is OK and the problem is a shorted cable or sensor. Replace the cable to verify.

MAINTENANCE AND REPAIR

Because of their small size and sealed construction, field maintenance of **LIVM** sensors is limited to cleaning of connectors and maintenance of mounting surfaces.

Clean connectors with a cloth or paper wipe dipped in solvents such as alcohol, Freon, etc. For hermetically sealed units, acetone may be used also. Acetone is not recommended for non-hermetic units.

Clean epoxy from the mounting surfaces of accelerometers, if necessary, with acetone or other solvents to dissolve and remove epoxies and other adhesives.

If the problem you are having is poor low frequency response and the sensor is not hermetically sealed, baking in a 250° oven for one hour will often get rid of moisture that may have condensed and shorted across the crystals which would shortened the discharge time constant.

If you cannot solve the problem, call the factory for assistance in trouble-shooting the system or for instructions for returning the instrument for evaluation and/or possible repair.

If the instrument is to be returned, you will be issued a Returned Material Authorization (RMA) number by the service department to help speed the instrument through the evaluation process. Do not return an instrument without first contacting the factory.

2

3.5 NEMA17 100:1 STEPPER MOTOR

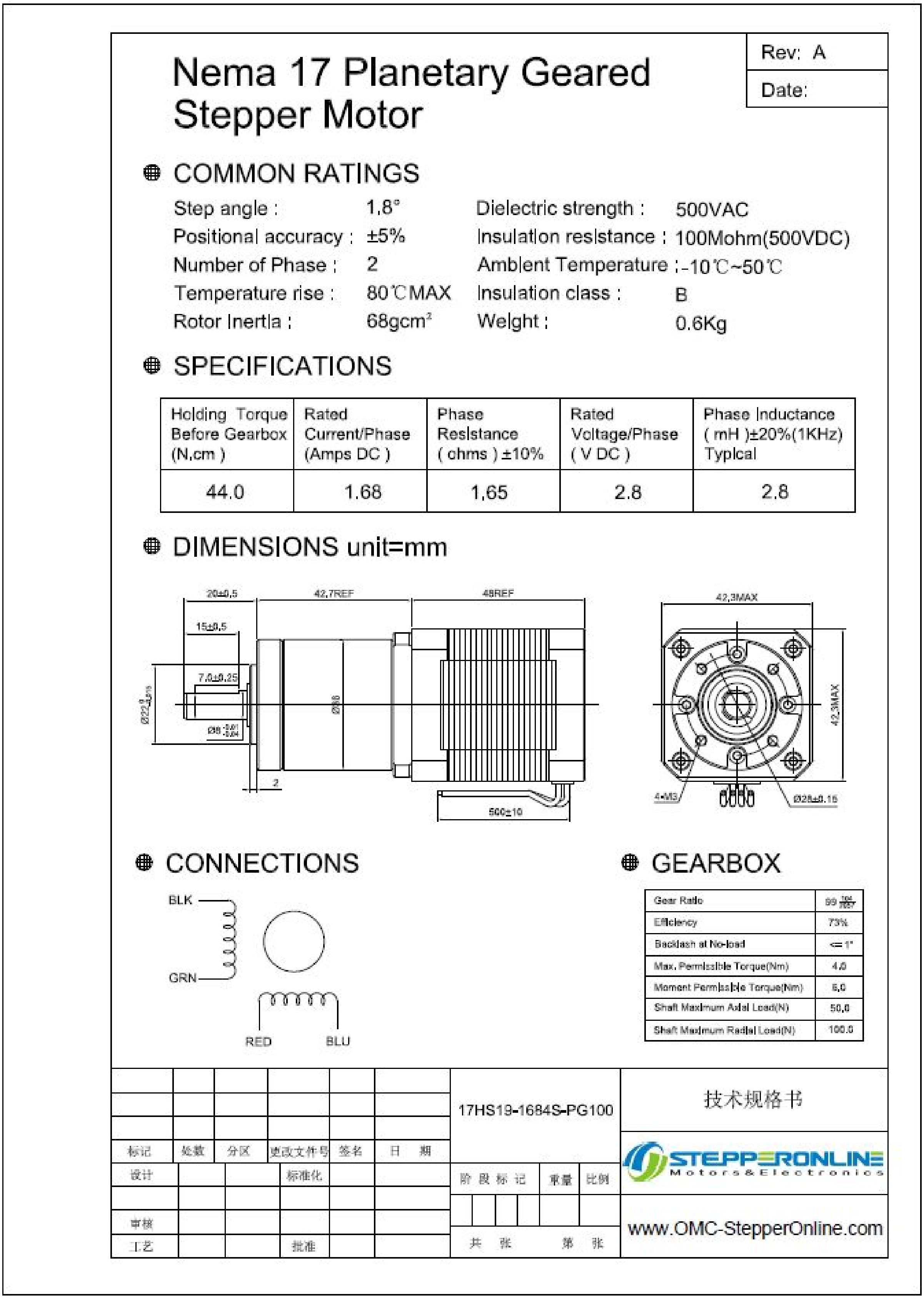
Electrical Specification:
* Manufacturer Part Number: 17HS19-1684S-PG100
* Motor Type: Bipolar Stepper
* Step Angle: 0.018 deg.
* Holding Torque: 4Nm
* Rated Current/phase: 1.68A
* Phase Resistance: 1.65ohms
* Inductance: 2.8mH+/-20%(1KHz)

Gearbox Specifications:
* Gearbox Type: Planetary
* Gear Ratio: 99.05:1
* Efficiency: 73%
* Backlash at No-load: <=1 deg.
* Max.Permissible Torque: 4Nm(566oz-in)
* Moment Permissible Torque: 6Nm(850oz-in)
* Shaft Maximum Axial Load: 50N
* Shaft Maximum Radial Load: 100N

Physical Specifications:
* Frame Size: 42 x 42mm
* Motor Length: 48mm
* Gearbox Length: 42.7mm
* Shaft Diameter: 8mm
* Shaft Length: 20mm
* D-cut Length: 15mm
* Number of Leads: 4
* Lead Length: 500mm
* Weight: 630g

Connection:
Black(A+), Green(A-), Red(B+), Blue(B-)

3.5. NEMA17 100:1 STEPPER MOTOR



Nema 17 Planetary Geared Stepper Motor

Rev: A	
Date:	

COMMON RATINGS

Step angle :	1.8°	Dielectric strength :	500VAC
Positional accuracy :	±5%	Insulation resistance :	100Mohm(500VDC)
Number of Phase :	2	Ambient Temperature :	-10℃~50℃
Temperature rise :	80℃MAX	Insulation class :	B
Rotor Inertia :	68gcm²	Weight :	0.6Kg

SPECIFICATIONS

Holding Torque Before Gearbox (N.cm)	Rated Current/Phase (Amps DC)	Phase Resistance (ohms) ±10%	Rated Voltage/Phase (V DC)	Phase Inductance (mH)±20%(1KHz) Typical
44.0	1.68	1.65	2.8	2.8

DIMENSIONS unit=mm

CONNECTIONS

GEARBOX

Gear Ratio	$99\frac{104}{1057}$
Efficiency	73%
Backlash at No-load	<=1°
Max. Permissible Torque(Nm)	4.0
Moment Permissible Torque(Nm)	6.0
Shaft Maximum Axial Load(N)	50.0
Shaft Maximum Radial Load(N)	100.0

标记	处数	分区	更改文件号	签名	日 期	17HS19-1684S-PG100	技术规格书
设计		标准化				阶 段 标 记 / 重量 / 比例	STEPPERONLINE Motors&Electronics
审核							
工艺		批准				共 张 第 张	www.OMC-StepperOnline.com

Figure 3.4: NEMA 17 Schematics

3.6 Encoder

Wachendorff Automation GmbH & Co. KG
Industriestraße 7 • D-65366 Geisenheim
Tel.: +49 (0) 67 22 / 99 65 -25 • Fax: +49 (0) 67 22 / 99 65 -70
E-Mail: wdg@wachendorff.de • www.wachendorff-automation.com

Encoder WDG 58B

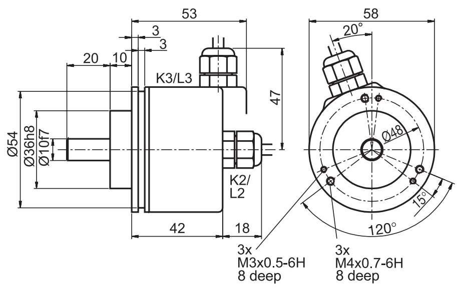
- Rugged industrial standard encoder
- Up to 25000 PPR by use of high grad electronics
- Protection to IP67, shaft sealed to IP65
- Maximum mechanical and electrical safety
- Full connection protection with 10 VDC up to 30 VDC
- With light reserve warning
- Optional: -40 °C up to +80 °C
  Protection to IP67 all around

www.wachendorff-automation.com/wdg58b

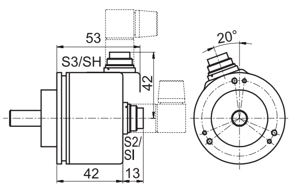
Available PPR	up to 25000 PPR	
Mechanical Data		
Housing		
- Clamping flange:	Aluminium	
- Cap:	Aluminium, powder coated	
- Cam mounting:	pitch 69 mm	
Shaft	Ø 10 mm	
- Material:	stainless steel	
- Permitted load on shaft end:	max. 220 N radial max. 120 N axial	
- Starting torque:	approx. 1 Ncm at ambient temperature	
Bearings		
- Type:	2 precision ball bearings	
- Service life:	1 x 10^{9} revs. at 100 % rated shaft load 1 x 10^{10} revs. at 40 % rated shaft load 1 x 10^{11} revs. at 20 % rated shaft load	
Max. operating speed:	8000 rpm	
Weight:	approx. 250 g	
Connections:	cable or connector	
Protection rating: (EN 60529)	IP67, shaft sealed to IP65	
Operating temperature:	-20 °C up to +80 °C, 1 Vss: -10 °C up to +70 °C	
Storage temperature:	-30 °C up to +80 °C	
Machinery Directive:	**basic data safety integrity level**	
$MTTF_d$:	200 a	
Mission time (T_M):	25 a	
Nominale service life ($L_{10}h$):	1 x 10^{11} revss. at 8000 rpm and 20 % rated shaft load	
Diagnostic coverage (DC):	0 %	
Electrical Data		
Power supply/ Open circuit current consuption:	4.75 VDC up to 5.5 VDC: 5 VDC up to 30 VDC: 10 VDC up to 30 VDC:	max. 100 mA max. 70 mA max. 100 mA
Output circuit:	TTL, RS422 compatible HTL 1 Vss Sin/Cos	
Pulse frequency:	TTL ≤ 5000 PPR: HTL ≤ 5000 PPR: TTL > 5000 PPR: HTL > 5000 PPR: 1 Vss Sin/Cos:	max. 200 kHz max. 200 kHz max. 2 MHz max. 600 kHz max. 100 kHz
Channels:	AB, ABN and inverted signals	
Load:	max. 40 mA / channel, @ 1 Vss Sin/Cos: 120 Ohm termination	
Circuit protection:	circuit type F24, G24, H24, I24, P24, R24 only	
Accuracy:	Phase offset: pulse-/pause-ratio:	90° ± max. 7.5 % of the pulse length 50 % ± max. 7 %

Further technical information on:
www.wachendorff-automation.com/gtd
Matching accessories on: www.wachendorff-automation.com/acs

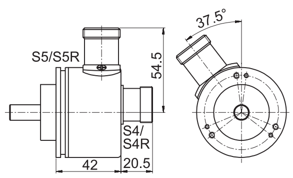
Cable connection K2, K3, L2, L3 with 2 m cable



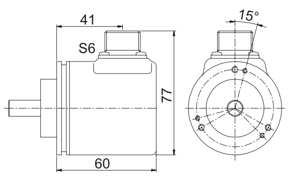
Connector (M16x0.75) SI, SH, 5-, 6-, 8-, 12-pin and S2, S3, 7-pin



Connector (M23) S4, S5, S4R, S5R, 12-pin



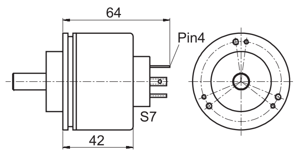
MIL-connector S6, 6-pin



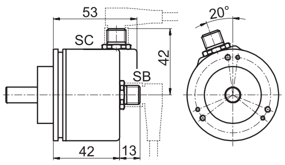
27.04.2010 / Specifications without engagement, subject to errors and modifications.

1 of 2

Valve-connector S7, 4-pin



Sensor-connector (M12x1) SB, SC, 4-, 5-, 8-, 12-pin

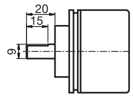


All dimensional specifications in mm.

Options:

Low-temperature:
The encoder WDG 58B with the output circuit types F24, G24, H24, I24, P24, R24, F05, G05, I05, P05, 245 and 645 is also available with the extended temperature range -40 °C up to +80 °C (measured at the flange). When ordering please add the suffix code - ACA.

Shaft with flat:
The encoder WDG 58B can be supplied with a shaft with flat. When ordering please add the suffix code - AAF.



Drawing 58B-AAF

Low-friction bearings:
The encoder WDG 58B is also available as a particularly smooth-running low-friction encoder. The starting torque is thereby changed to $\leq$ 0.1 Ncm and the protection class at the shaft input to IP50. When ordering please add the suffix code - AAC.

Shafts sealed to IP67 (not for 1 Vss Sin/Cos):
The encoder WDG 58B can be supplied in a full IP67 version. When ordering please add the suffix code - AAO.

Max. RPM	Permitted Shaft-Loading axial	radial	Max. PPR	Starting-torque
3500 rpm	100 N	110 N	2500 PPR	approx. 4 Ncm

Amended specifications for shaft sealed to IP67.

Cable length:
The encoder WDG 58B can be supplied with more than 2 m cable. The maximum cable length depends on the supply voltage and the frequency; see "General Technical Data": www.wachendorff-automation.com/gtd
Please extend the standard order code with a three figure number, specifying the cable length in decimetres.
Example: 3 m cable = 030

Ordering information: **Please see our general technical data at: www.wachendorff-automation.com/gtd**

Output circuit:

Reso-lution PPR	Power supply VDC	Output circuit	Light reserve warning	Order Key
up to 1024	5 - 30	HTL	-	H30
		HTL inverted	-	R30
up to 5000	4,75 - 5,5	TTL	●	G05
			-	H05
		TTL, RS422 comp., inverted	●	I05
			-	R05
	10 - 30	HTL	●	G24
			-	H24
		HTL inverted	●	I24
			-	R24
		TTL, RS422 comp., inv.	●	245
10000 up to 25000	4,75 - 5,5	TTL	-	F05
		TTL, RS422 comp., inv.	-	P05
	10 - 30	HTL	-	F24
		HTL inverted	-	P24
		TTL, RS422 comp., inv.	-	645
up to 2048	4,75 - 5,5	1 Vss Sin/Cos	-	SIN

Channels: AB, ABN (SIN: AB)

Pulses per revolution PPR:
2, 10, 15, 20, 24, 25, 30, 36, 40, 48, 50, 60, 64, 72, 87, 90, 100, 120, 125, 127, 128, 150, 160, 180, 200, 216, 240, 250, 254, 256, 300, 314, 320, 360, 400, 500, 512, 571, 600, 625, 720, 750, 768, 800, 810, 900, 1000, 1024, 1200, 1250, 1270, 1440, 1500, 1800, 2000, 2048, 2400, 2500, 3000, 3600, 4000, 4096, 4685, 5000, 10000, 12500, 20000, 25000.

1 Vss Sin/Cos 1024 PPR and 2048 PPR only
Other PPRs on request

Electrical connections:

Order key	Outgoing	Description	$\overline{ABN}$ inv.
Cable: (Length 2 m standard)			
K2	axial	shield not connected	●
L2		shield connected to encoder housing	●
K3	radial	shield not connected	●
L3		shield connected to encoder housing	●
Connector:			
SI5	axial	5-pin, connector	-
SH5	radial		
SI6	axial	6-pin, connector	-
SH6	radial		
SI8	axial	8-pin, connector	●
SH8	radial		
SI12	axial	12-pin, connector	●
SH12	radial		
S2	axial	7-pin, connector	-
S3	radial		
S4/S4R	axial	12-pin, connector	●
S5/S5R	radial	(R = clockwise pin count)	
S6	axial	6-pin, MIL-connector	-
S7	radial	4-pin, Valve-connector	-
SB4	axial	4-pin, M12-sensor-connector	-
SC4	radial		
SB5	axial	5-pin, M12-sensor-connector	-
SC5	radial		
SB8	axial	8-pin, M12-sensor-connector	●
SC8	radial		
SB12	axial	12-pin, M12-sensor-connector	●
SC12	radial		

Options:

Empty	=	Without option
ACA	=	Low-temperature -40 °C up to +80 °C
AAF	=	Shaft with flat
AAC	=	Low-friction bearings
AAO	=	Shaft sealed to IP67
In decimetres	=	Cable length

Order No.:

Example	WDG 58B	5000	ABN	G24	K2	
Your encoder	WDG 58B					

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3.7 ELECTRO-MAGNET

BUYMAGNETS.COM
A Bunting® Magnetics Co.

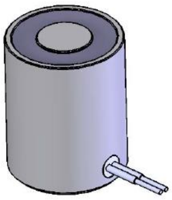
Technical Data Sheet

Round Electromagnets, Flat-Faced

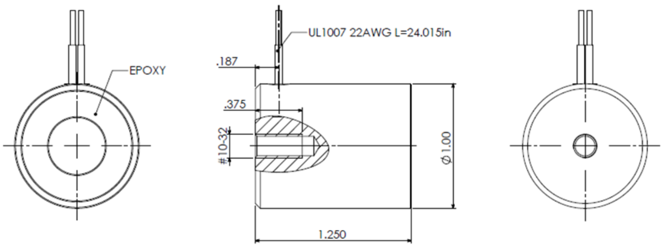
BuyMagnets.com Round electromagnets handle ferrous materials safely and securely. Electromagnets provide an efficient and economical solution for handling and holding parts. Available in a number of shapes and sizes, our electromagnets require little maintenance and can be used in a variety of manual and automated applications. (Special sizes upon request).

Product Specifications

Shape: **Round**



Part No.	Diameter(A)	Height (B)	Thread (C)	Thread Depth (D)	DC Volts	Watts	Pull Force	Wt.	Price
BDE-1012-12	1.00	1.250	10-32	.375	12	4.5	20	2.60oz	$20.00



- All Measurements are in inches (unless otherwise noted)
- Direction of Magnetization (DOM) is through the thickness unless noted
- Unless otherwise specified, magnets will be furnished in magnetized condition
- Holding forces are approximate. These are average values obtained under laboratory conditions. Size, shape, and material of the test piece may affect actual pull forces

1150 Howard Street • Elk Grove Village, IL 60007 • 800-232-4359 or 847-593-2060

3.8 DYTRAN ACCELEROMETERS

3.8.1 General Accelerometer Specifications

DYTRAN INSTRUMENTS, INC.
Dynamic Transducers and Systems
21592 Marilla St. • Chatsworth, CA 91311 • Phone 818-700-7818
www.dytran.com • e-mail: info@dytran.com

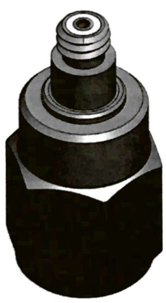
OG3056D
REV A, ECN 10060, 06/21/13
REV B, ECN 11394, 11/04/14
REV C, ECN 12135, 07/27/15

OPERATING GUIDE

SERIES 3056D

IEPE ACCELEROMETERS 5, 10, 20, 50, 100, 200 & 500 mV/g

TOP CONNECTOR, HERMETICALLY SEALED AND BASE ISOLATED



NOTE:
Series 3056D features hermetically sealed construction and electrically isolated case for "off-ground" performance. Hermeticity is obtained by all-welded construction and glass-to-metal sealed connector. Case material is titanium. Base ground isolation is by an electrically isolated threaded insert located in the base of the instrument. Signal ground return is electrically isolated from the mounting surface.

This guide contains:
1) Operating instructions, Series 3056D.
2) Outline/installation drawing, Series 3056D
3) Specifications, Series 3056D

NOTE: IEPE is an acronym for Integrated Electronics Piezoelectric types of low impedance voltage mode sensors with built-in amplifiers operating from constant current sources over two wires. **IEPE** instruments are compatible with other comparable systems labeled **LIVM™**

1

OPERATING INSTRUCTIONS MODEL SERIES 3056D
IEPE ACCELEROMETER

INTRODUCTION

The Dytran Model Series 3056D consists of seven top connector accelerometers, differing only in sensitivity. The 3056D1 is 10 mV/g, 3056D2 is 100 mV/g, 3056D3 is 500 mV/g, 3056D4 is 20 mV/g, 3056D5 is 50 mV/g, 3056D6 IS 200 mV/g, and 3056D7 is 5mV/g.

These accelerometers features IEPE operation. The self-generating seismic element, utilizing piezoceramic crystals in planar shear mode, convert acceleration to an analogous electrostatic charge mode signal. This very high impedance signal is fed to the gate of a tiny on-board IC JFET charge amplifier which drops the output impedance level ten orders of magnitude allowing this instrument to drive long cables without appreciable effect on sensitivity and frequency response.

Simple constant current type power units supply power to operate the integral charge amplifier and separate the signal from the DC bias of the internal amplifier. Coaxial cables or even twisted pair wire may be used to connect accelerometer to power units. Power and signal are conducted over the same two-wire cable.

Model series 3056D also features signal ground isolation from the mounting surface to avoid annoying ground loops and hermetic sealing for normal operation in moist and dirty environments.

DESCRIPTION

Figure 1, following, is a representative cross section of series 3056D.

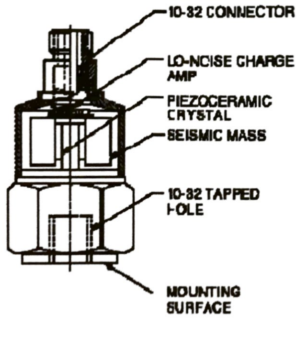


Figure 1-Cross section, series 3056D

The seismic masses, made from a very dense tungsten alloy, and are tightly preloaded against the ceramic crystals by means of a special preload screw, under hundreds of pounds of force. This is so there is absolutely no relative motion between mass, crystals and base keeping the non-linearity low and the natural frequency high.

The force from acceleration (vibration or shock) acting upon the mounting base, is transferred to the seismic mass through the crystals, stressing the crystals in shear mode and producing an electrostatic charge signal analogous to the input acceleration. This charge is impressed across the gate of the JFET IC charge amplifier.

Because the IC is a 2-wire IEPE charge amplifier, the dynamic voltage signal is impressed across the sensor connector which is the same point into which the constant current from the power unit is applied. (See Figure 2 below)

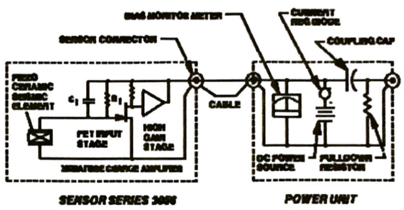


Figure 2-Electro-mechanical schematic, accelerometer and power unit system.

When constant current from the IEPE power unit is applied to the accelerometer amplifier input terminal, the amplifier "turns on" at approx. +10 Volts DC quiescent bias level. When the accelerometer senses acceleration, the resultant signal is superimposed upon this bias voltage.

In the power unit, in its simplest form, a capacitor blocks the DC bias and allows the dynamic signal voltage to be separated and brought out to an "output" jack on the power unit. At this point the signal may be connected directly to almost any type of readout instrument such as DVM's, oscilloscopes, data collectors, spectrum analyzers, etc. The approximate 100 Ohm output impedance of the signal allows the driving of long cables without adverse effects on sensitivity or frequency response.

2

Referring to figure 2, the feedback resistor R_f in conjunction with feedback capacitance C_f, forms a first order high-pass filter which sets the low frequency response of the accelerometer in accordance with the following equation:

$$f_{-3db} = \frac{.16}{R_f C_f} \qquad \text{(eq.1)}$$

where:

f_{-3db} = lower -3db frequency (Hz)

R_f = resistance value R (Ohms)

C_f = total feedback capacitance C (Farads)

RC = discharge time constant TC (Seconds)

Equation 1 above, defines the frequency at which the accelerometer sensitivity will be 3db down when compared to the reference sensitivity measured at 100 Hz.

The discharge time constant for all Models is 0.50 seconds yielding a lower -3db frequency of 0.3 Hz, from equation 1.

As rule of thumb, the lower -5% frequency is three times the -3db frequency or 1 Hz.

INSTALLATION

(Refer to Outline/Installation drawing 127-3056D) To install Model 3056D, is necessary to prepare (or find) a flat mounting area of approximately 0.5 inch diameter. Ideally, the mounting surface should be flat to .001 in. TIR. The flat mounting surface ensures intimate contact between accelerometer base and mounting surface for best high frequency transmissibility, thus accuracy.

At the center of the mounting area, drill and tap a 10-32 mounting port in accordance with instructions on drawing 127-3056D. Clean the area to remove all traces of machining chips, burrs, etc.

Next, thread the Mod. 6200 mounting stud into the base of the 3056D. The stud should enter easily and thread in up to the raised collar of the stud by hand. This collar prevents the stud from bottoming inside the tapped hole in the 3056D where it could possibly cause stresses in the base structure which could, in turn, cause anomalous behavior of the accelerometer at higher frequencies.

After seating the stud, spread a light coating of silicone grease, or other lubricant, on either of the mating surfaces and thread the accelerometer/stud combination into the tapped hole by hand, until the accelerometer base seats against the mounting surface. Check to see that the mating surfaces are meeting properly, i.e., that they are meeting flush and that there is not an angle formed between the two surfaces indicating that they are not co-planar. If this condition is observed, torquing the accelerometer down will strain the base causing possible poor frequency response and even erroneous reference sensitivity. Inspect the perpendicularity of the tapped hole.

If the hand tight meeting between the two surfaces is satisfactory, torque the 3056D to the mating surface with 7 to 10 lb-inches of torque, preferably measuring the torque with a torque wrench torquing on the hex surface only.

Proper torque will ensure the best high frequency performance from the instrument as well as repeatability of sensitivity when mounting and remounting. Too much torque could damage the ground isolation base.

Connect the cable (typically Models 6010AXX or 6011AXX) to the accelerometer snugging up the threaded lock ring tightly by hand.

NOTE: Do not use a pliers or vise grips on the knurled lock ring. This could damage the connector of the 3056D and/or the cable connector.

To avoid stressing the cables which could lead to early failure, especially under larger excursions of the test object, it is good practice to tie the cable down to a fixed surface near the mounting area at a point approximately one inch from the accelerometer.

If there is excessive motion between the accelerometer and the nearest tie point, allow a strain loop of cable to let relative motion occur without stressing the cable.

3.8. DYTRAN ACCELEROMETERS

Connect the other end of the cable to the "Sensor" jack of the Dytran power unit (Models 4102, 4103, 4110, 4114, etc.) and switch the power on.

Observe the monitor voltmeter located at the front panel of each of the power units. If the meter reads in the mid-scale region, (labeled "Normal"), this tells you that the cables, accelerometer and power unit are functioning normally and you should be able to proceed with the measurement.

Check for shorts in the cables and connectors if the meter reads in the "Short" region. Check for open cables or connections if the meter reads in the "Open" area. In this manner, the meter becomes a trouble-shooting tool for the measurement system.

HIGH FREQUENCY RESPONSE

All piezoelectric accelerometers are basically rigid spring mass systems, i.e., second order systems with essentially zero damping. As a result, these instruments will exhibit a rising characteristic as the resonant frequency is approached. A filter incorporated into Model 3056D compensates for this rise.

The frequency at which the sensitivity may increases or decrease by 5% is approximately 10,000 Hz, the frequency to which the 3056D series is calibrated. The accelerometer is usable above this frequency but to use it above 10,000 Hz, it must be calibrated at the specific frequencies of intended use because sensitivity deviations will increase drastically as you greatly exceed this high frequency calibration limit. Consult the factory for special calibrations required above 10kHz.

CAUTIONS

1) Do not store or use the 3056D above 250 degrees F. To do so can damage the IC amplifier.
2) Do not allow cables to vibrate unrestrained. This will eventually destroy the cable and could lead to system inaccuracies.
3) Avoid dropping or striking the accelerometer, especially against rigid materials such as concrete and metals. While Model 3056D is protected against shock induced overloads, the very high overloads induced by dropping can do permanent damage to the IC amplifier or to the mechanical structure of the accelerometer. This type of damage is not covered by the warranty.

MAINTENANCE AND REPAIR

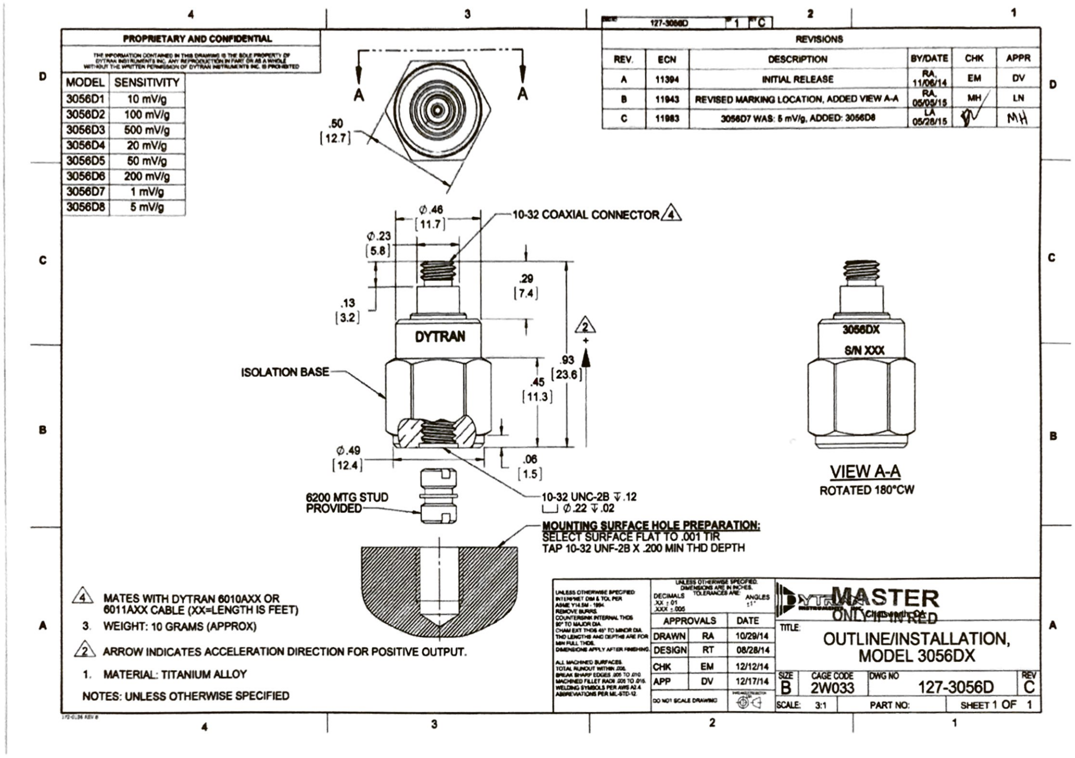
The welded construction of the series 3056D precludes field repair.

Should the electrical connector become contaminated with moisture, oil, grease, etc., the entire instrument may be immersed in degreasing solvents to remove the contaminants. After degreasing, place the instrument in a 200°F to 250°F oven for one hour to remove all traces of the solvent.

Should a problem be encountered with the operation of the instrument, contact the factory for trouble shooting advice. Often our service engineers may point out something which may have been overlooked and which may save the expense and time of returning the 3056D to the factory.

If the instrument must be returned, the service department will issue you a **R**eturned **M**aterials **A**uthorization (**RMA**) number to aid in tracking the repair through the system. Do not send the instrument back without first obtaining an RMA number. At this time you will be advised of the preferred shipping method. A short note describing the problem, included with the returned instrument, will aid in trouble shooting at the factory and will be appreciated.

We will not proceed with a non-warranty repair without first calling to notify you of the expected charges. There is no charge for evaluation of the unit.


PROPRIETARY AND CONFIDENTIAL
MODEL SENSITIVITY
3056D1 10 mV/g
3056D2 100 mV/g
3056D3 500 mV/g
3056D4 20 mV/g
3056D5 50 mV/g
3056D6 200 mV/g
3056D7 1 mV/g
3056D8 5 mV/g
REVISIONS
REV. ECN DESCRIPTION BY/DATE CHK APPR
A 11394 INITIAL RELEASE RA, 11/06/14 EM DV
B 11943 REVISED MARKING LOCATION, ADDED VIEW A-A RA, 05/05/15 MH LN
C 11983 3056D7 WAS: 5 mV/g, ADDED: 3056D8 LA 05/26/15 MH
A
A
.50
[12.7]
10-32 COAXIAL CONNECTOR 4
Ø.46
[11.7]
Ø.23
[5.8]
.29
[7.4]
.13
[3.2]
DYTRAN
ISOLATION BASE
.93
[23.6]
.45
[11.3]
Ø.49
[12.4]
.06
[1.5]
6200 MTG STUD
PROVIDED
10-32 UNC-2B ↧.12
⌴ Ø.22 ↧.02
MOUNTING SURFACE HOLE PREPARATION:
SELECT SURFACE FLAT TO .001 TIR
TAP 10-32 UNF-2B X .200 MIN THD DEPTH
3056DX
S/N XXX
VIEW A-A
ROTATED 180°CW
4 MATES WITH DYTRAN 6010AXX OR 6011AXX CABLE (XX=LENGTH IS FEET)
3. WEIGHT: 10 GRAMS (APPROX)
2 ARROW INDICATES ACCELERATION DIRECTION FOR POSITIVE OUTPUT.
1. MATERIAL: TITANIUM ALLOY
NOTES: UNLESS OTHERWISE SPECIFIED
APPROVALS DATE
DRAWN RA 10/29/14
DESIGN RT 08/28/14
CHK EM 12/12/14
APP DV 12/17/14
MASTER
TITLE:
OUTLINE/INSTALLATION,
MODEL 3056DX
SIZE B
CAGE CODE 2W033
DWG NO 127-3056D
REV C
SCALE: 3:1
PART NO:
SHEET 1 OF 1

3.8.2 3056B4-15742

Dytran Instruments, Inc.
21592 Marilla St. Chatsworth, CA 91311 Ph: 818-700-7818 Fax 818-700-7880
www.dytran.com email: info@dytran.com

ACCREDITED Calibration Laboratory CERT#2672.01

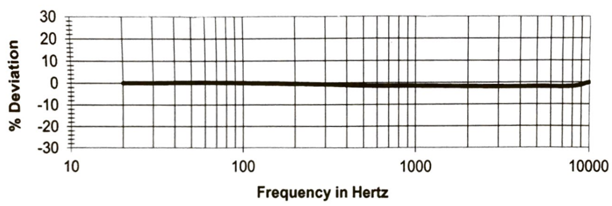
CALIBRATION CERTIFICATE
VOLTAGE MODE ACCELEROMETER

CUSTOMER: VIRGINIA COMMONWEALTH UNIVERSITY		TEST REPORT #: 15742	
PURCHASE ORDER #: VCU-QUAD	SALES ORDER #:	PROCEDURE: TP3002	
MODEL: 3056B4	SERIAL #: 15742	RANGE, F.S. (g's): +/- 250	
NEW UNIT	RE-CALIBRATION [1] X	AS RECEIVED CODE 4	AS RETURNED CODE 8
REF. SENSITIVITY (mV/g) [2]: 20.28		TEMP (°C): 24	HUMIDITY (%): 35

FREQUENCY RESPONSE [3]

FREQUENCY (Hz)	SENSITIVITY (mV/g)	FREQUENCY (Hz)	SENSITIVITY (mV/g)
20	20.29	500	20.00
30	20.29	1000	19.97
50	20.32	3000	19.89
100	20.28	5000	19.89
300	20.12	8000	19.91
TRANSVERSE SENSITIVITY (%):	6.8	10000	20.27
DISCHARGE TIME CONSTANT (sec):	1.1	BIAS VOLTAGE (VDC):	12.2

Amplitude Response



REMARKS: LIMITED CALIBRATION - HIGH TRANSVERSE SENSITIVITY

TEST EQUIPMENT LIST - CALIBRATION STATION # 10

DII #	MANUFACTURER	MODEL	SERIAL #	DESCRIPTION	CAL DATE	DUE DATE
1654	NATIONAL INST.	PCI-4461	1801C33	DATA ACQUISTION CARD	03/01/17	03/01/19
1867	DYTRAN INST.	3010M14	1772	ACCELEROMETER	02/20/17	05/20/18

[1] AS RECEIVED / AS RETURNED CODES:
1 = IN TOLERANCE, NO ADJUSTMENTS
2 = IN TOLERANCE, BUT ADJUSTED
3 = OUT OF TOLERANCE < 5%
4 = OUT OF TOLERANCE > 5%
5 = REPAIR REQUIRED
6 = REPAIRED AND CALIBRATED
7 = UNIT NON-REPAIRABLE, RECOMMEND REPLACEMENT
8 = UNIT SERVICEABLE WITH CURRENT CALIBRATION DATA
[2] THE REFERENCE SENSITIVITY IS MEASURED AT 100 Hz, 1G RMS.
[3] THIS CALIBRATION WAS PERFORMED IN ACCORDANCE WITH ANSI/NCSL Z540-1-1994, ISO 10012-1, ISO/IEC17025 USING THE BACK-TO-BACK COMPARISON METHOD PER ISA RP37.2 AND IS TRACEABLE TO THE NIST THROUGH TEST REPORT # 0695 DUE 05/20/2018.
ESTIMATED UNCERTAINTY OF CALIBRATION: 1.6% FROM 20-100 Hz, 1.4% FROM 100-2500 Hz, 2.8% FROM 2.5kHz-10 kHz. APPLIES TO FREQUENCY RESPONSE ONLY.
THIS CERTIFICATE SHALL NOT BE REPRODUCED EXCEPT IN FULL, WITHOUT THE WRITTEN PERMISSION FROM DYTRAN INSTRUMENTS, INC.

CALIBRATION TECHNICIAN: CHENCHIN YEH

TEST DATE : 04/13/18

RECOMMENDED RECALL DATE :

3.8.3 3056B4-15819

DYTRAN INSTRUMENTS, INC.

Dytran Instruments, Inc.
21592 Marilla St. Chatsworth, CA 91311 Ph: 818-700-7818 Fax 818-700-7880
www.dytran.com email: info@dytran.com

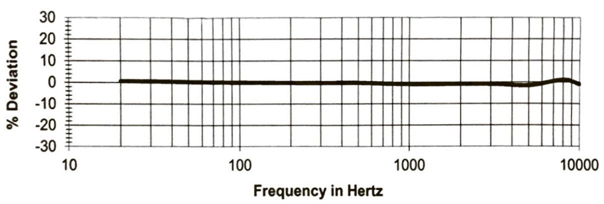
ilac-MRA | A2LA ACCREDITED Calibration Laboratory CERT#2672.01

CALIBRATION CERTIFICATE
VOLTAGE MODE ACCELEROMETER

CUSTOMER:	*VIRGINIA COMMONWEALTH UNIVERSITY*	TEST REPORT #:	*15819*
PURCHASE ORDER #:	*VCU-QUAD*	SALES ORDER #:	PROCEDURE: *TP3002*
MODEL: *3056B4*	SERIAL #: *15819*	RANGE, F.S. (g's):	*+/- 250*
NEW UNIT	RE-CALIBRATION [1] X	AS RECEIVED CODE 1	AS RETURNED CODE 1
REF. SENSITIVITY (mV/g) [2]: *19.01*		TEMP (°C): *24*	HUMIDITY (%): *35*

FREQUENCY RESPONSE [3]

FREQUENCY (Hz)	SENSITIVITY (mV/g)	FREQUENCY (Hz)	SENSITIVITY (mV/g)
20	*19.13*	500	*18.97*
30	*19.12*	1000	*18.85*
50	*19.07*	3000	*18.85*
100	*19.01*	5000	*18.72*
300	*18.97*	8000	*19.22*
TRANSVERSE SENSITIVITY (%):	*3.9*	10000	*18.83*
DISCHARGE TIME CONSTANT (sec):	*1.0*	BIAS VOLTAGE (VDC):	*12.2*



REMARKS:

TEST EQUIPMENT LIST - CALIBRATION STATION # 10

DII #	MANUFACTURER	MODEL	SERIAL #	DESCRIPTION	CAL DATE	DUE DATE
1654	*NATIONAL INST.*	*PCI-4461*	*1801C33*	*DATA ACQUISTION CARD*	*03/01/17*	*03/01/19*
1867	*DYTRAN INST.*	*3010M14*	*1772*	*ACCELEROMETER*	*02/20/17*	*05/20/18*

[1] AS RECEIVED / AS RETURNED CODES:
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- 4 = OUT OF TOLERANCE > 5%
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- 6 = REPAIRED AND CALIBRATED
- 7 = UNIT NON-REPAIRABLE, RECOMMEND REPLACEMENT
- 8 = UNIT SERVICEABLE WITH CURRENT CALIBRATION DATA

[2] THE REFERENCE SENSITIVITY IS MEASURED AT 100 Hz, 1G RMS.

[3] THIS CALIBRATION WAS PERFORMED IN ACCORDANCE WITH ANSI/NCSL Z540-1-1994, ISO 10012-1, ISO/IEC17025 USING THE BACK-TO-BACK COMPARISON METHOD PER ISA RP37.2 AND IS TRACEABLE TO THE NIST THROUGH TEST REPORT # 0695 DUE 05/20/2018.

ESTIMATED UNCERTAINTY OF CALIBRATION: 1.6% FROM 20-100 Hz, 1.4% FROM 100-2500 Hz, 2.8% FROM 2.5kHz-10 kHz. APPLIES TO FREQUENCY RESPONSE ONLY.

CALIBRATION TECHNICIAN: *CHENCHIN YEH*

TEST DATE : *04/13/18*

RECOMMENDED RECALL DATE :

3.8.4 3056B1-15849

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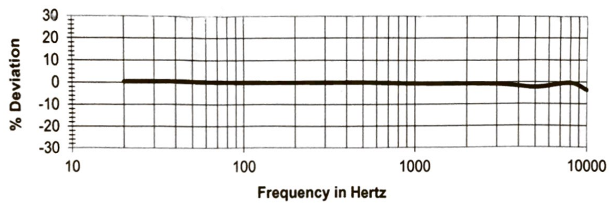
CALIBRATION CERTIFICATE
VOLTAGE MODE ACCELEROMETER

CUSTOMER: *VIRGINIA COMMONWEALTH UNIVERSITY*		**TEST REPORT #:** *15849*	
PURCHASE ORDER #: *VCU-QUAD*	**SALES ORDER #:**	**PROCEDURE:** *TP3002*	
MODEL: *3056B1*	**SERIAL #:** *15849*	**RANGE, F.S. (g's):** *+/- 500*	
NEW UNIT	**RE-CALIBRATION [1]** X	**AS RECEIVED CODE** 4	**AS RETURNED CODE** 8
REF. SENSITIVITY (mV/g) [2]: *9.99*		**TEMP (°C):** *23*	**HUMIDITY (%):** *35*

FREQUENCY RESPONSE [3]

FREQUENCY (Hz)	SENSITIVITY (mV/g)	FREQUENCY (Hz)	SENSITIVITY (mV/g)
20	10.03	500	9.98
30	10.03	1000	9.94
50	10.01	3000	9.90
100	9.99	5000	9.75
300	9.98	8000	9.94
TRANSVERSE SENSITIVITY (%):	5.3	10000	9.62
DISCHARGE TIME CONSTANT (sec):	1.0	**BIAS VOLTAGE (VDC):**	12.0

Amplitude Response



REMARKS: *LIMITED CALIBRATION - SENSITIVITY AND TRANSVERSE SENSITIVITY OUT OF TOLERANCE*

TEST EQUIPMENT LIST - CALIBRATION STATION # 10

DII #	MANUFACTURER	MODEL	SERIAL #	DESCRIPTION	CAL DATE	DUE DATE
1654	NATIONAL INST.	PCI-4461	1801C33	DATA ACQUISTION CARD	03/01/17	03/01/19
1867	DYTRAN INST.	3010M14	1772	ACCELEROMETER	02/20/17	05/20/18

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8 = UNIT SERVICEABLE WITH CURRENT CALIBRATION DATA

[2] THE REFERENCE SENSITIVITY IS MEASURED AT 100 Hz, 1G RMS.

[3] THIS CALIBRATION WAS PERFORMED IN ACCORDANCE WITH ANSI/NCSL Z540-1-1994, ISO 10012-1, ISO/IEC17025 USING THE BACK-TO-BACK COMPARISON METHOD PER ISA RP37.2 AND IS TRACEABLE TO THE NIST THROUGH TEST REPORT # 0695 DUE 05/20/2018.

ESTIMATED UNCERTAINTY OF CALIBRATION: 1.6% FROM 20-100 Hz, 1.4% FROM 100-2500 Hz, 2.8% FROM 2.5kHz-10 kHz. APPLIES TO FREQUENCY RESPONSE ONLY.

CALIBRATION TECHNICIAN: ***CHENCHIN YEH***

TEST DATE : *04/13/18*

RECOMMENDED RECALL DATE :

3.8.5 3056B1-15909

DYTRAN INSTRUMENTS, INC.

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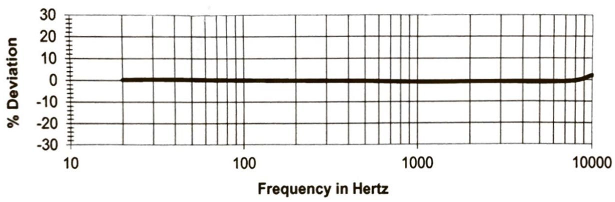
CALIBRATION CERTIFICATE
VOLTAGE MODE ACCELEROMETER

CUSTOMER: *VIRGINIA COMMONWEALTH UNIVERSITY*		TEST REPORT #: *15909*	
PURCHASE ORDER #: *VCU-QUAD*	SALES ORDER #:		PROCEDURE: *TP3002*
MODEL: *3056B1*	SERIAL #: *15909*	RANGE, F.S. (g's): *+/- 500*	
NEW UNIT	RE-CALIBRATION [1] X	AS RECEIVED CODE 4	AS RETURNED CODE 8
REF. SENSITIVITY (mV/g) [2]: *10.75*		TEMP (°C): *23*	HUMIDITY (%): *35*

FREQUENCY RESPONSE [3]

FREQUENCY (Hz)	SENSITIVITY (mV/g)	FREQUENCY (Hz)	SENSITIVITY (mV/g)
20	10.78	500	10.71
30	10.79	1000	10.67
50	10.78	3000	10.67
100	10.75	5000	10.64
300	10.73	8000	10.72
TRANSVERSE SENSITIVITY (%):	1.1	10000	10.98
DISCHARGE TIME CONSTANT (sec):	0.9	BIAS VOLTAGE (VDC):	12.2

Amplitude Response



REMARKS: *LIMITED CALIBRATION - SENSITIVITY OUT OF TOLERANCE*

TEST EQUIPMENT LIST - CALIBRATION STATION # 10

DII #	MANUFACTURER	MODEL	SERIAL #	DESCRIPTION	CAL DATE	DUE DATE
1654	NATIONAL INST.	PCI-4461	1801C33	DATA ACQUISTION CARD	03/01/17	03/01/19
1867	DYTRAN INST.	3010M14	1772	ACCELEROMETER	02/20/17	05/20/18

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8 = UNIT SERVICEABLE WITH CURRENT CALIBRATION DATA

[2] THE REFERENCE SENSITIVITY IS MEASURED AT 100 Hz, 1G RMS.

[3] THIS CALIBRATION WAS PERFORMED IN ACCORDANCE WITH ANSI/NCSL Z540-1-1994, ISO 10012-1, ISO/IEC17025 USING THE BACK-TO-BACK COMPARISON METHOD PER ISA RP37.2 AND IS TRACEABLE TO THE NIST THROUGH TEST REPORT # 0695 DUE 05/20/2018.

ESTIMATED UNCERTAINTY OF CALIBRATION: 1.6% FROM 20-100 Hz, 1.4% FROM 100-2500 Hz, 2.8% FROM 2.5kHz-10 kHz. APPLIES TO FREQUENCY RESPONSE ONLY.

CALIBRATION TECHNICIAN: **CHENCHIN YEH**

TEST DATE : *04/13/18*

RECOMMENDED RECALL DATE :

3.8.6 3056D4-18611

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21592 Marilla St. Chatsworth, CA 91311 Ph 818-700-7818 Fax 818-700-7880
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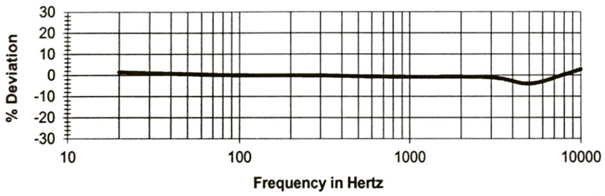
CALIBRATION CERTIFICATE
VOLTAGE MODE ACCELEROMETER

CUSTOMER: VIRGINIA COMMONWEALTH UNIV		TEST REPORT #: 18611	
PURCHASE ORDER #: ONLINE ORDER# 81	SALES ORDER #: 192329		PROCEDURE: TP3002
MODEL: 3056D4	SERIAL #: 18611	RANGE, F.S. (g's): +/- 250	
NEW UNIT X	RE-CALIBRATION [1]	AS RECEIVED CODE	AS RETURNED CODE
REF. SENSITIVITY (mV/g) [2]: 19.76		TEMP (°C): 23	HUMIDITY (%): 36

FREQUENCY RESPONSE [3]

FREQUENCY (Hz)	SENSITIVITY (mV/g)	FREQUENCY (Hz)	SENSITIVITY (mV/g)
20	20.06	500	19.67
30	19.97	1000	19.62
50	19.88	3000	19.56
100	19.76	5000	18.97
300	19.74	8000	19.83
TRANSVERSE SENSITIVITY (%):	3.0	10000	20.32
DISCHARGE TIME CONSTANT (sec):	1.1	BIAS VOLTAGE (VDC):	11.9



REMARKS:

TEST EQUIPMENT LIST - CALIBRATION STATION # 9

DII #	MANUFACTURER	MODEL	SERIAL #	DESCRIPTION	CAL DATE	DUE DATE
1867	DYTRAN INST.	3010M14	1772	ACCELEROMETER	02/20/17	05/20/18
1776	NATIONAL INST.	PCI-4461	1878F95	DATA ACQUISITION CARD	08/18/17	08/18/19

[1] AS RECEIVED / AS RETURNED CODES:
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5 = REPAIR REQUIRED
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7 = UNIT NON-REPAIRABLE, RECOMMEND REPLACEMENT
8 = UNIT SERVICEABLE WITH CURRENT CALIBRATION DATA

[2] THE REFERENCE SENSITIVITY IS MEASURED AT 100 Hz, 1G RMS.

[3] THIS CALIBRATION WAS PERFORMED IN ACCORDANCE WITH ANSI/NCSL Z540-1-1994, ISO 10012-1, ISO/IEC17025 USING THE BACK-TO-BACK COMPARISON METHOD PER ISA RP37.2 AND IS TRACEABLE TO THE NIST THROUGH TEST REPORT # 0695 DUE 05/20/2018

ESTIMATED UNCERTAINTY OF CALIBRATION: 1.6% FROM 20-100 Hz, 1.4% FROM 100-2500 Hz, 2.8% FROM 2.5kHz-10 kHz. APPLIES TO FREQUENCY RESPONSE ONLY.

THIS CERTIFICATE SHALL NOT BE REPRODUCED EXCEPT IN FULL, WITHOUT THE WRITTEN PERMISSION FROM DYTRAN INSTRUMENTS, INC.

CALIBRATION TECHNICIAN: DAVID NUTE

26 CAL

TEST DATE : 04/20/18

RECOMMENDED RECALL DATE : 04/20/19

3.9 Wiring/Electrical Circuit

Chapter 4

ASTM Methodologies

NOTE: Information directly extracted from ASTM D256
Refer to ASTM D256 for more in-depth details.

4.1 Measuring Effective Weight of the Hammer

Swing the pendulum to a horizontal position and support it by the striking edge in this position with a vertical bar. Allow the other end of this bar to rest at the center of a load pan on a balanced scale. Subtract the weight of the bar from the total weight to find the effective weight of the pendulum. The effective pendulum weight should be within 0.4% of the required weight for that pendulum capacity. If weight must be added or removed, take care to balance the added or removed weight without affecting the center of percussion relative to the striking edge. It is not advisable to add weight to the opposite side of the bearing axis from the striking edge to decrease the effective weight of the pendulum since the distributed mass can lead to large energy losses from vibration of the pendulum.

4.2 Measuring Effective Length of the Hammer

The distance from the axis of support to the center of percussion may be determined experimentally from the period of small amplitude oscillations of the pendulum by means of the following equation:

$L = (g/(4\pi^2)p^2$

where:

L = distance from the axis of support to the center of percussion, m or (ft)

g = local gravitational acceleration (known to an accuracy of one part in one thousand), m/s^2 or (ft/s^2), $\pi = 3.1416$ $(4\pi^2 = 39.48)$

p = period, s, of a single complete swing (to and fro) determined by averaging at least 20 consecutive and uninterrupted swings. The angle of swing shall be less than 5 degrees each side of center.

4.3 Specimen Failure Types

The type of failure for each specimen shall be recorded as one of the four categories listed as follows:

1. C = Complete Break: A break where the specimen separates into two or more pieces.
2. H = Hinge Break: An incomplete break, such that one part of the specimen cannot support itself above the horizontal when the other part is held vertically (less than 90Âř included angle).
3. P = Partial Break: An incomplete break that does not meet the definition for a hinge break but has fractured at least 90% of the distance between the vertex of the notch and the opposite side.
4. NB = Non-Break: An incomplete break where the fracture extends less than 90% of the distance between the vertex of the notch and the opposite side.

4.4 SPECIMEN DIMENSIONS FOR IZOD-TYPE TEST

1. A = 10.16 +/− 0.05 mm or 0.400 +/− 0.002 in
2. B = 31.8 +/− 1.0 mm or 1.25 +/− 0.04 in
3. C = 63.5 +/− 2.0 mm or 2.50 +/− 0.08 in
4. D = 0.25R +/− 0.05 mm or 0.010R +/− 0.002 in
5. E = 12.70 +/− 0.20 mm or 0.500 +/− 0.008 in

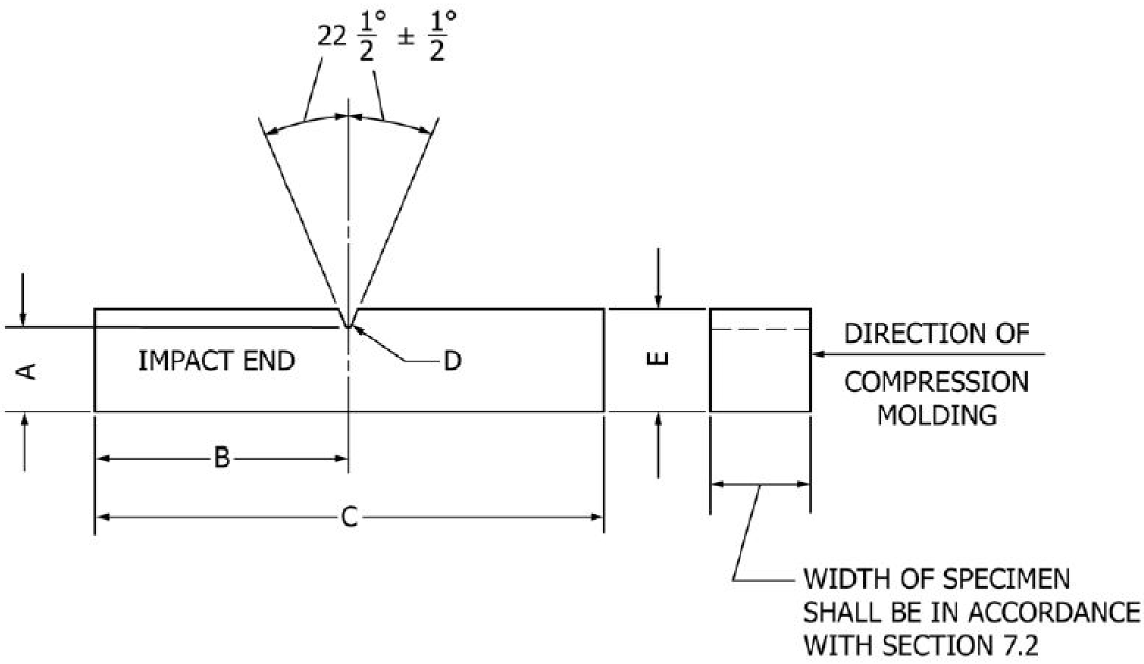

Figure 4.1: Specimen Dimensions