

LAMBDA VF-5™

TUNABLE OPTICAL FILTER CHANGER
CONTROL SYSTEM

OPERATION MANUAL

REV. 1.04 (20120409)



SUTTER INSTRUMENT

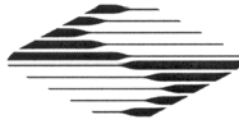
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CE EU Declaration of Conformity

Application of Council Directives:
2014/30/EU (EMC), 2014/35/EU (LVD), and 2011/65/EU (RoHS 2)

Manufacturer's Name: Sutter Instrument Company

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Equipment Tested: Lambda VF-5 Wavelength-Tunable Optical Filter Switching System

Model(s): Controller: VF5-E (Lambda 10-B with VF-5 firmware)
Variable Filter Enclosure: VF5-M (five variable filters); includes W620009 driver cable

Conforms to Standards: EMC Emissions: EN 61326-1:2013, including:
EN 55011: 2009 Class A;
EN 61000-3-2:2015, & EN 61000-3-3:2014
EMC Immunity: EN 61000-4-2:2009, EN 61000-4-3:2011,
EN 61000-4-4:2012, EN 61000-4-5:2014,
EN 61000-4-6:2014, EN 61000-4-8:2010, &
EN 61000-4-11:2004
LVD (Safety): EN 61010-1:2010

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SI_EMC_LBVF-5_20160713

Sutter Instrument Company hereby declares that the equipment specified above was tested and conforms to the EU Directives and Standards listed above, and further certifies conformation to the requirements of the European Union's Restriction on Hazardous Substances in Electronic Equipment Directive 2011/65/EU (RoHS 2).

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DISCLAIMER

The Lambda VF-5 Variable Optical Filter Switcher is designed for the specific use of changing filters and bandwidth into and out of an optical pathway and no other use is recommended.

This instrument is designed for use in a laboratory environment. It is not intended, nor should it be used in human experimentation or applied to humans in any way. This is not a medical device.


Do not open or attempt to repair the instrument. Extreme heat and high voltages are present and could cause injury.

Do not allow unauthorized and/or untrained operative to use this device.

Any misuse will be the sole responsibility of the user/owner and Sutter Instrument Company assumes no implied or inferred liability for direct or consequential damages from this instrument if it is operated or used in any way other than for which it is designed.



SAFETY WARNINGS AND PRECAUTIONS

Electrical

- Operate the Lambda VF-5 using 110-120 V AC, 60 Hz, or 220-240 V AC., 50 Hz line voltage. This instrument is designed for connection to a standard laboratory power outlet (Overvoltage Category II), and because it is a microprocessor--controlled device, it should be accorded the same system wiring precautions as any 'computer type' system. A surge protector and power regulator are recommended.
-  Fuse Replacement: Replace only with the same type and rating:
T1.0A, 250V, Time Delay (IEC 60127-2, Sheet III)
(Examples: Bussmann GDC-1A or S506-1R (RoHS); or
Littelfuse 218 001 or 218.001.P (RoHS))



A spare fuse is located in the power input module. Please refer to the fuse-replacement appendix for more details on fuse ratings and for instructions on how to change the fuse.

Avoiding Electrical Shock and Fire-related Injury

-  Always use the grounded power supply cord set provided to connect the system to a grounded outlet (3-prong). This is required to protect you from injury in the event that an electrical hazard occurs.
- Do not disassemble the system. Refer servicing to qualified personnel.
-  To prevent fire or shock hazard do not expose the unit to rain or moisture.

Optical Radiation

This system is designed for use in conjunction with high-intensity light sources. Failure to comply with any of the following precautions may result in injury to the users of this device as well as those working in the general area near the device.


-  Never look into the optical pathway of the high intensity light sources typically used with this instrument. Doing so can cause permanent eye damage.
-  The high-intensity light sources typically used with this instrument also produce a significant amount of heat. Direct contact with the housing of those instruments can cause serious burns.

Electromagnetic Interference

To comply with FDA and CE electromagnetic immunity and interference standards; and to reduce the electromagnetic coupling between this and other equipment in your lab always use the type and length of interconnect cables provided with the unit for the interconnection of the filter wheel, host computer via serial RS-232 or parallel interface, or other equipment via TTL connections (see the TECHNICAL SPECIFICATIONS appendix for more details).

Operational

Failure to comply with any of the following precautions may damage this device.

- This instrument is designed for operation in a laboratory environment (Pollution Degree I).
- This unit is not designed for operation at altitudes above 2000 meters nor was it tested for safety above 2000 meters.
-  **DO NOT CONNECT OR DISCONNECT THE CABLES BETWEEN THE CONTROLLER AND THE MECHANICAL UNIT (FILTER WHEEL) WHILE POWER IS ON.**

Please allow at least 20 seconds after turning the unit off before disconnecting the mechanical units. Failure to do this may result in damage to the electronics.


-  Operate only in a location where there is a free flow of fresh air on all sides. **NEVER ALLOW THE FREE FLOW OF AIR TO BE RESTRICTED.**

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1. GENERAL INFORMATION

1.1 Introduction

The Lambda VF-5 is a filter wheel and shutter control system designed for rapid change and aperture control of wavelength, and comprises a controller and a filter wheel that is placed in the optical pathway(s) of your existing experimental setup. Next is a description on how this manual is organized and the manner in which its use is intended, followed by a general and functional description of the system.

1.1.1 How to Use this Manual

This manual is organized in a manner that is best suited for the typical manner in which the reader would learn about the system, and then install, operate, and maintain it. Prior to the table of contents of this manual is a series of cautionary and warning notes that should be read first. This chapter (Chapter 1) provides an overall description of the system, leaving more in-depth technical information towards the end of the chapter. The next chapter describes how to install the system, followed by one or more chapters that provide operation instructions, and ending with a chapter on maintenance. Following the final chapter are several appendices that provide supplemental information. The installation chapter covers everything related to installation, from unpacking the equipment as received, through to ensuring that everything is correctly installed and is operating correctly. The operation chapters cover the two basic types of user interaction with the system: Manual (local) control and external computer control. Please take the time to read these instructions to assure the safe and proper use of this instrument.

1.1.2 Technical Support

Unlimited technical support is provided by Sutter Instrument Company at no charge to our customers. Our technical support staff is available between the hours of 8:00 AM and 5:00 PM (Pacific Time) at (415) 883-0128. You may also E-mail your queries to info@sutter.com.

1.2 General Description

The **LAMBDA VF-5** is a microprocessor controlled, high-speed filter wheel designed for microscopy and other applications that require rapid and accurate wavelength switching. The Lambda VF-5 controller can control one filter wheel and features both USB and serial input for remote control.

The VersaChrome filters from Semrock have excellent band-pass characteristics for which Semrock is known, and the center wavelength can be tuned over a significant range by adjusting the angle of incidence of the light. Sutter has combined this filter technology with a mechanical system that allows a rapid selection of any center wavelength in the range of 5 filters. This device selects the correct filter and sets the required tilt to obtain the center wavelength requested using a special version of the Sutter Lambda 10-B filter controller. Control can be via the keypad, serial port input or USB input. Until a full manual is produced this supplement will be used with the manual of the Lambda 10-B.

Each of the filters in the Versachrome line is designed to have the center wavelength of the band pass selected by tilting the filter relative to the light path. It is well known that the

center wavelength of a band pass interference filter depends on the angle of incidence of light, and this is sometimes used to make minor adjustments in wavelength. The coating design of the Versachrome filters allows tilting up to 60 degrees without loss of the excellent band pass characteristics so that the center wavelength can be shifted 60 to 100 nanometers. (The amount of shift depends on the filter).

The maximum design angle for tilt is 60 degrees. As the tilt is increased the center wavelength is shifted to shorter wavelengths but the width of the band pass does not change. The relationship between angle and center wavelength is not linear. The first several degrees of tilt have little effect, but the change is roughly 1 nm per degree of tilt as you approach the maximum tilt. The required tilt angle for each nanometer has been programmed into the microprocessor for each filter in the Versachrome series. If you specify a valid center wavelength for one of the loaded filters the controller will automatically turn the wheel to the correct filter and tilt the wheel to the appropriate angle.

If you prefer, you can instead specify the angle of tilt in steps of 0.225 degrees. The number of steps must be in the range of 0 to 267. You can also directly select the filter to use. If you select a combination of filter and angle that is used for a nanometer value command the display will show the nanometer value. If the angle does not correspond exactly to a programmed nanometer value for the current filter the controller will display the closest whole nanometer wavelength with the ^ symbol to show that it is not the standard micro step value for that wavelength.

The wheel has 5 positions for filters. In order to allow for possible future expansion the standard Sutter 10 position filter commands have been used. As a result, the available filter positions in this 5 position version have the values 0,2,4,6 and 8. The default position at power on is filter 0 with a tilt of 0 degrees.

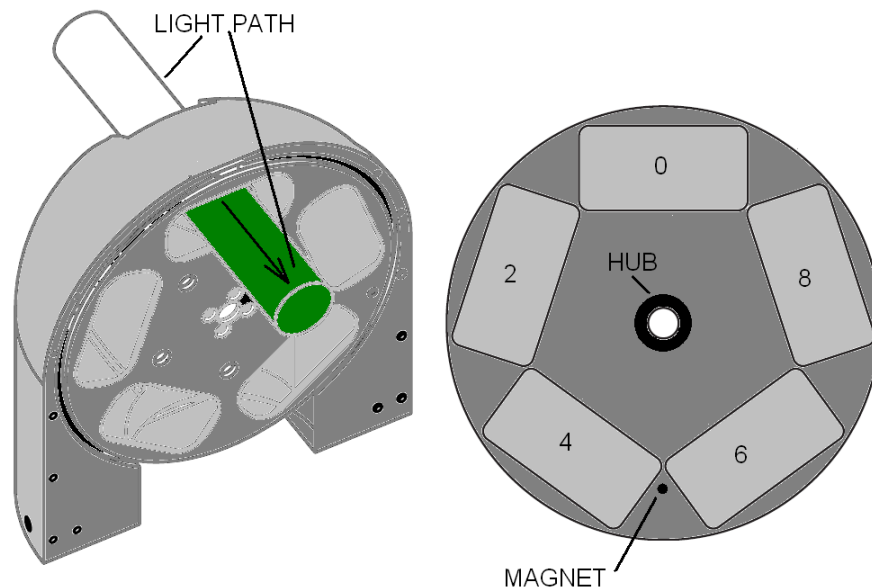


Figure 1-1 Anatomy of the Lambda VF-5 filter wheel.

The mechanical system has two step motor subsystems. One motor rotates the filter wheel so that the desired filter is located in the optical path. The second motor rotates the entire

wheel subsystem in order to tilt the selected filter to the correct angle for the desired center wavelength. Both subsystems have sensors for establishing the correct initial position and verifying moves that are made in response to commands.

The following VersaChrome¹ tunable optical filters are available for use with the Lambda VF-5:

Table 1-1. List of supported tunable filters.

Filter Type	Wavelength Range	Bandwidth	Part Number
Tunable	338-380nm	16nm	CO-O573380
Tunable	390-440nm	16nm	CO-O573440
Tunable	440-490nm	15nm	CO-O573490
Tunable	490-550nm	15nm	CO-O573550
Tunable	550-620nm	14nm	CO-O573620
Tunable	620-700nm	13nm	CO-O573700
Tunable	700-800nm	12nm	CO-O573800

The system is connected to the controller via a DB-25 connector. Although there is protection against hot connection or disconnection of the cables it is important to avoid connection or disconnection of these cables when the power is on.

At power on the tilt subsystem is rotated to 0 degrees, as indicated by an optical sensor. Once the correct tilt is established the wheel rotates to the 0 filter position. The unit powers up in the USB port mode. The local key can be used to select the manual mode, which allows keypad control. Serial port control is normally established by sending the correct command over the serial port, but can also be selected as the default mode using the keypad in the manual mode. The display at power-on should be similar to the example below:

```

W: 25MM F0 SP1 L
S: WL-380 nm T3

```

This display is an adaptation of the original 10B version that controls a filter wheel and shutter. The direct control of the filter wheel in the VF-5 is identical to that of a Lambda 10 series filter wheel, so the top line, starting with W: for wheel, indicates that this is the 25 mm aperture version, Filter 0 is selected, filter changing speed 1 (SP1) is selected, and the controller is in the local mode (L). The power-on display will show a U for USB control. In this case the LOCAL key was pressed to switch to the local mode.

The second line of the display indicates the current center wavelength selected in nm (WL-380 nm). At power-on the indicated value should be equal to the center wavelength at a tilt of 0 degrees for the filter loaded in filter position 0.

The selected speed for the tilt is also displayed (T3). The value following the T can be 0-3. As with the filter wheel, 0 is the fastest speed.

The filters are installed oriented so that the best optical performance is obtained with light directed into the optical port on the silver colored side of the housing and emerging from the

¹ VersaChrome[®] is a registered trademark of Semrock[®]

optical port on the blue colored side of the housing. For best results the input light should be well collimated. Light that is not well collimated will broaden the bandpass of the filters.

The controller can run the filter wheel under remote control through a USB or serial input using the same simple protocol as the original Lambda 10-B controller with some differences in commands. The USB port uses a command set similar to the serial input. Some important considerations about using a combination of input sources (e.g., the keypad and the Serial port) are discussed in the Operations – External Control section of this manual.

The following instructions are meant to help you set up the Lambda VF-5 and familiarize you with the manual mode of filter selection. More detail on controller functionality, filter installation and remote communications can be found in other sections of this manual.

The following instructions are meant to help you set up the Lambda VF-5 and become familiar with the manual mode of filter selection. Further details on controller functionality and remote communications can be found in other sections of this manual.

1.2.1 Systems

1.3 Filter Wheel

1.3.1 Mechanical Description

The basic components of the filter wheel mechanical assembly are shown below in the following two figures. The only components that are to be removed by the user are the drop-in or slide-in filter holders and the plug in the loading port. At no time should the user remove the cover plate from the wheel housing.

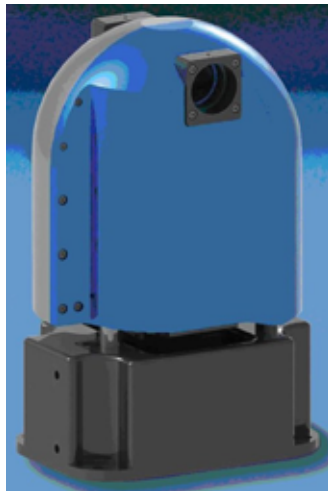


Figure 1-2. Lambda VF-5 Filter Wheel

1.3.2 Filter Wheels

Description. **Note that you must only use filter wheels manufactured by Sutter Instrument Company.** All filter wheel options are listed in Sutter Instrument's catalogue and web site (<http://www.sutter.com>), and in the following list.

- 5-position VersaChrome filter LBVF-5(?).

wheel

1.3.2.1 Mechanical Description

The basic components of the filter wheel mechanical assembly are shown in following figures. The only components that are to be removed by the user are the drop-in or slide-in filter holders and the plug in the loading port.

1.3.3 Filter Wheel Adapters

Most microscopes, cameras, light sources and other optical instruments to which the Lambda VF-5 Filter Wheel may be interfaced will require some sort of adapter to link the devices. Adapters for interfacing the Filter Wheel to most instruments are available from Sutter Instrument Company or can be custom built by Sutter. **Suitable adapters are available from other sources, as well, but Sutter Instrument Company assumes no responsibility for the performance, suitability and safety of adapters built by the user or other manufacturers.**

1.3.4 Cables

1.4 Controller

1.4.1 Principles of Operation

The Lambda VF-5 controller can be operated locally (manually) from the controller keypad or remotely from a computer through either the parallel or serial port. These three operational modes (manual, USB and serial) are functionally identical. Each allows the user to select:

- **Filter position**
- **Filter switching speed**
- **Filter angle**

The remainder of this chapter provides a detailed description of the controller's rear panel connectors and front panel controls. Information needed to connect the power cord and filter wheel(s) is found in the **FIRST TIME USE** chapter. Instructions on operation of the controller and manual keypad control of the filter wheel(s) are presented in the **MANUAL CONTROL** chapter. The **REMOTE CONTROL** chapter explains control of the unit from a remote device, as well as supplying some technical details relevant to local operation. Technical details, which are not required for operation but which may help you understand the behavior of the unit, are found in **APPENDIX A: Stepping Motor Operation**.

1.4.2 Rear Panel Connectors

All electrical connections are all made on the rear panel of the Lambda VF-5. See the **FIRST TIME USE** chapter for details on connecting the power cord and filter wheel cable(s).

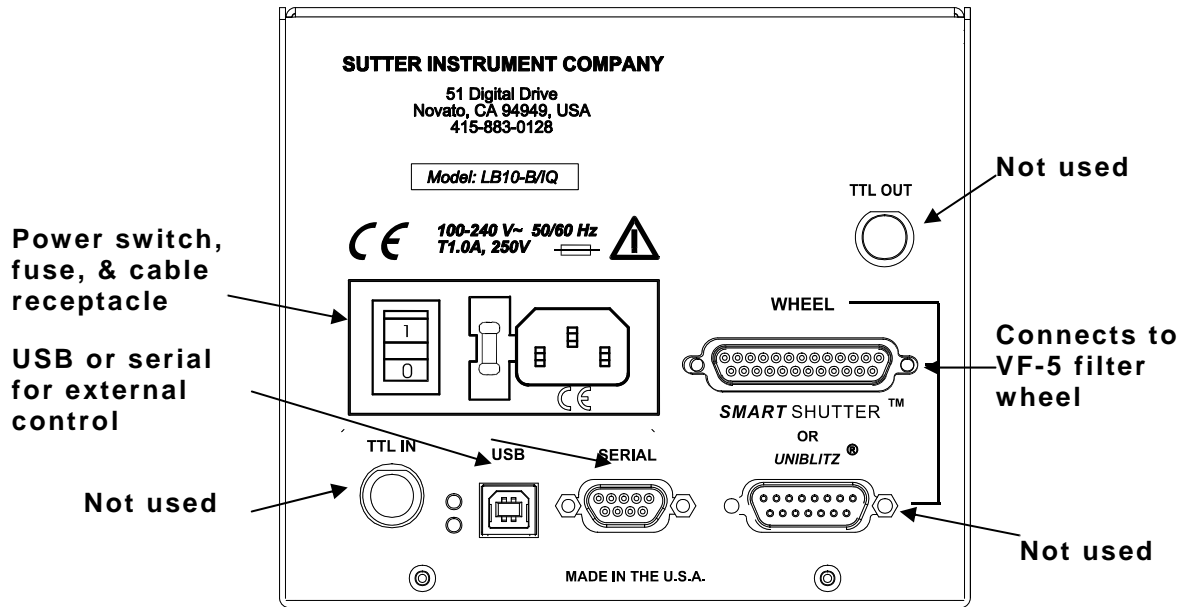


Figure 1-3. Electrical connections.

FILTER WHEEL POSITION AND ANGLE CONTROL – A 25 pin, DSUB connector used to link the Lambda VF-5 controller with the VF-5 filter wheel.

USB PORT – A USB Type B receptacle used to connect the Lambda VF-5 controller as a USB device to a USB port of a host computer.

SERIAL PORT – A 9 pin, DSUB connector used for establishing a serial interface between the Lambda VF-5 and a remote device (computer) using the cable provided. This cable should not be used simultaneously with the parallel port cable.

POWER SWITCH – This turns on the system power.

LINE POWER – This socket is used to connect the power cord to the Lambda VF-5.

FUSE LABEL – Information found here includes the model number of this instrument, appropriate supply voltage and the type of fuse required for the supply voltage.

FUSE – Fuse compartment containing the supply voltage fuse and an extra fuse. Replace blown fuses with a fuse of the appropriate value as given on the fuse label (back panel of the controller) or on the TECHNICAL SPECIFICATIONS page in this manual.

1.4.3 Front Panel Controls

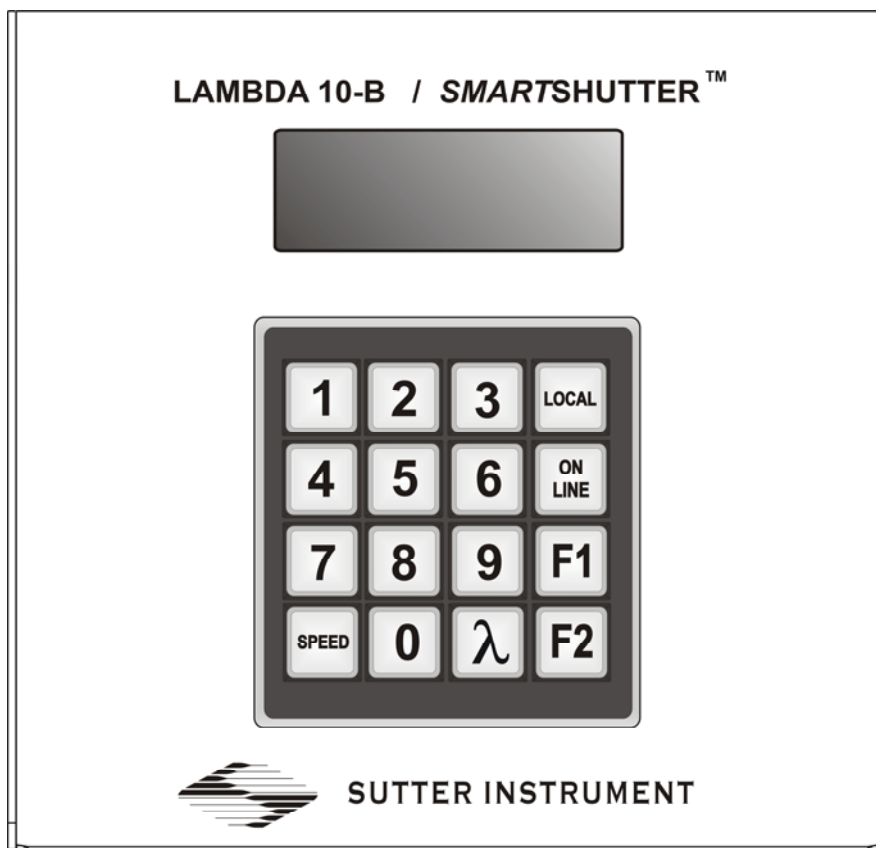


Figure 1-4. Lambda VF-5 front panel controls.

1.4.3.1 Keypad

There are 16 keys on the Lambda VF-5 keypad.

Numerical keys 0 through 9: These keys are used to manually select filter positions and, with the # key, to choose between the eight pre-set speeds

LOCAL: Takes the controller off-line

ON LINE: Puts the controller on-line

F1: Go to main menu.

F2: Used as “Enter” for neutral density shutter steps.>

SPEED: This key is used to access the rotational speed selection mode. When followed by the

λ key, the tilt speed selection mode is accessed.

λ : Used for switching to specified wavelengths.

Keys are read while depressed but the appropriate action will occur only when the key is released. If a key is pressed while a move is in progress but released after the move is over, the key will read normally. Keys pressed and released while a move is in progress are ignored.

1.4.3.2 Display

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After the copyright screen, the unit display should be similar to the following if the controller has already been initialized with the base wavelength of each variable filter installed on the filter wheel.

**W: 25MM F0 SP3 U
S: WL-490 nm**

The start menu shown

**W: 25MM F0 SP3 L
S: WL-490 nm**

If the Lambda VF-5 controller has not been initialized for the first time or if the controller has been reset, the following screen will display for about 5 seconds,

**ENTER FILTER POS
NO. 0-9 FOR VF..**

... and then the following menu is displayed.

**F1-BROWSE 999- *
F2-ENT 000-EXIT**

Please refer to the Initialization section in the Installation chapter for instructions on how to initialize the Lambda VF-5 controller for the specific set of variable filters mounted on the filter wheel that is now attached to the controller. Once the controller has been properly initialized, the controller will display the standard top-level start menu after the unit has been powered up and the copyright and firmware version screen has been displayed.

1.6 Functional Description

1.6.1 Stepping Motor Operation

Stepping motors are not as familiar to most people as the common DC motor, but there are some similarities. The DC motor consists of an armature, an electromagnet mounted on a rotating shaft, which is located inside a permanent magnet. Current is supplied to the electromagnet through brushes that rub on contacts on the armature. When the

electromagnet is energized, the armature rotates to align the poles of the electromagnet with the opposite poles of the permanent magnet. Of course, before this can occur, the rotation of the armature changes the contact plates rubbing on the brushes so that the current is reversed. This causes the poles of the electromagnet to reverse, establishing a force for continued rotation. This switching action is called commutation.

In a stepping motor, the rotating element, called a rotor, is generally a permanent magnet while the fixed element, the stator, is the electromagnet. The key difference between stepping motors and DC motors, however, is the method of commutation. The DC motor commutates automatically as it rotates. Thus the timing of the commutation is determined by the speed of rotation, which may vary with the load or applied power. The commutation of the stepping motor is set by external electronics, forcing the motor to rotate at a predetermined rate. If the load is such that the motor does not have the force to produce the correct rate of rotation, the rotation will become erratic and may even reverse.

The force exerted between two magnet poles is proportional to the square of the distance between the poles. A motor with a single electromagnet and only two poles would exhibit considerable loss of power when the distance between the poles of the permanent magnet and the electromagnet was greatest. It is understandable that, in most practical DC motors, the armature has more than 2 poles. This allows the commutation to occur over a smaller angle of rotation, so that the active poles can always be relatively close to the poles of the permanent magnet.

Stepping motors are also made with multiple poles on both the rotor and stator; the exact arrangement determines the number of steps per revolution. The motor used in the **LAMBDA VF-5** has 200 steps per revolution (1.8 degrees per step). There are usually two windings in the stator, and reversing the current on one of the windings produces a single step of rotation. Reversing the current on the second winding will then produce another step. If the first winding is then reversed again, returning to its original value, a third step will result. Finally, reversing the second winding, so that both windings are back to their original state, will produce a fourth step. This pattern may then be repeated to continue rotation in the same direction. Reversing the sequence produces steps of rotation in the opposite direction.

The rate and distance of rotation is determined by the rate and number of commutation steps. As long as the current is held constant in both windings, the rotor will not rotate. This makes the stepping motor ideal for producing fast start and stop movements. Some limitations should be considered: Given that there are only four states of the control electronics (2 polarities for each of the 2 windings) but 200 steps per revolution, it follows that, for each of these 4 states, there are 50 possible rotary positions. In order to establish the absolute position an external sensor must be added. Absolute position only needs to be determined once so long as the subsequent moves occur without errors.

Correct operation of stepping motors, which is outlined above, is not always obtained. If the motor lacks the torque to accelerate and decelerate the load at the rate indicated by the control electronics, the resulting move may differ from that commanded by the control electronics. For instance, if enough external force is applied, the motor shaft may be rotated even though the command signal has not changed. For small rotations (less than 3.6 degrees), the motor shaft will return to the correct position if the force is removed. For larger rotations, the shaft will stop at the nearest of the 50 correct positions for that command signal when the external force is removed.

2. INSTALLATION

2.1 Unpacking

The Lambda VF-5 and associated hardware comes packed in a single carton. The following is a list of the components found there. If you believe that any of these components are missing or show obvious signs of damage from shipping, please contact the factory.

- A VF-5 Filter Wheel Dome containing five (5) VersaChrome filters, each with a predetermined base wavelength.
- LAMBDA VF-5 controller
- One 15-pin cable and one 25-pin-to-two-9-pin-split cable. Both the 15-pin and one 9-pin split of 25-to-two-9-pin cable connect to the filter wheel. The unused 9-pin split must have a terminator attached.
- USB interface cable (optionally for connecting to a host computer for remote control).
- 9-Pin serial interface cable (optionally for connecting to a host computer for remote control).
- Power cord.
- Manual.
- Microscope adapters (if ordered).

The Lambda VF-5 is shipped to you in a prefabricated foam mold. Please take note of this method of packaging. Should it ever be necessary to ship the Lambda VF-5 to another location, the same method of packaging should be employed. Additional packing material may be purchased from Sutter Instruments Company.

IMPORTANT: Improper packaging is a form of abuse and, as such, can be responsible for voiding the warranty where shipping damage is sustained because of such packing.

2.2 Pre-Installation Instructions

2.2.1 Vibrations

The Lambda VF-5 filter wheel system was designed to produce fast filter changes with a minimum of vibration. The microprocessor controls the trajectory of each move using microsteps with programmed acceleration and deceleration profiles. The result is a system so smooth that customers using the Lambda 10 for the first time have called to report that their wheel isn't turning simply because they could not hear or feel anything.

Although the Lambda VF-5 is smooth and quiet, even the slightest vibration can produce problems for the electrophysiologist. Vibration can come from several sources. The most pronounced effects normally come from the high-speed shutter, if that option has been included. The shutter produces a very sharp impulse which is best avoided by finding another way of turning the light on and off such as turning to a blanked filter position. When the motor accelerates and decelerates the filter wheel rapidly, the torque applied tends to turn the motor and the Lambda housing in the opposite direction. If the housing is not firmly attached, this may appear as vibration that increases with the selected speed and the weight

of filters loaded. This is not usually a problem if the wheel is firmly mounted to a good solid surface.

Stepping motor-based systems can produce considerable vibration and noise if the rate at which steps are taken excites a system resonance. This problem is greatly reduced by decreasing the step size with microstepping. Even when microstepping is used, it is possible to produce vibration by selecting a speed that is not optimal or by starting a new move within a few milliseconds of the end of the previous move. For example, with only 2 typical filters loaded speed 1 should give a very smooth move that stops with little vibration. Speed 2, 3, and 7 may all produce more vibration at the end of a move with this load even though they are slower speeds.

At a minimum, we recommend that the Lambda VF-5 should be firmly mounted to a solid surface by the support stand, which is included with each unit. Do not depend on the optical coupling between the microscope and the Lambda VF-5 to support and stabilize the Lambda VF-5. This configuration will be adequate in many cases. If there is still too much vibration, the wheel may be mounted using the support stand, but with an air gap between the Lambda VF-5 and the microscope.

The best cure for vibration is isolation. One simple approach is to mount the filter wheel to a wall or a separate table. If the microscope is on an air table, be aware that the microscope might drift relative to a filter wheel mounted on a separate, stable surface. In such cases it may be better to couple the Lambda VF-5 to the microscope with a flexible light guide. Contact Sutter Instrument for detail of our light-guide adapter system.

2.3 Installation Instructions

If you have not yet mounted the filter wheel on the support hardware, please refer to the FIRST TIME USE chapter of this manual for instructions. Now move the mounted filter wheel to the approximate final location and adjust the filter wheel to the desired height. The filter wheel can be mounted on the posts in either orientation (optical port up or down), as required. The filter wheel can now be interfaced with other instruments (e.g. a microscope and a light source) using an appropriate adapter (Figure 10). If you need to purchase an adapter or require a custom adapter for your experimental setup, please contact the Technical Support staff at Sutter Instrument Company by phone (415 883-0128) or by E-mail (info@sutter.com).

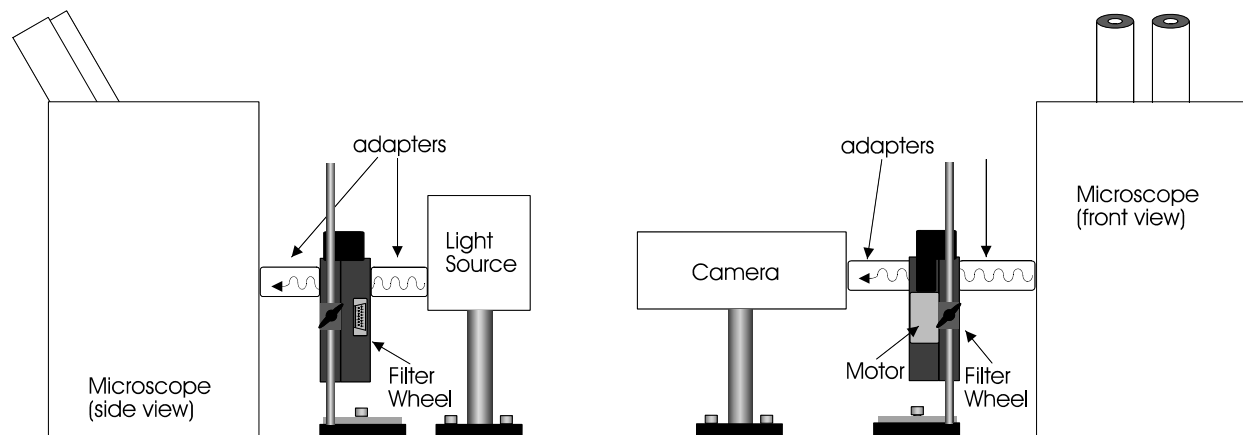


Figure 2-1. Schematic diagram of two possible experimental configurations.

The optical ports in the filter wheel housing and cover plate are threaded 1-32 (standard C-mount) allowing direct connection of like threaded devices (camera adapters, microscope adapters, etc.)

NOTE: Care should be taken that any devices threaded into the ports not project more than 0.180 inches into the port. Allowing threaded devices to penetrate further could result with damage to the filter wheel or filter cups.

Once the filter wheel has been attached to the other instrument(s) tighten the wing screws to lock the filter wheel at its final height. The filter wheel is designed to be supported on the two posts included with your system. These posts can be screwed into the base provided or into any surface with ¼”-20 holes drilled on 6” centers at an appropriate position on the tabletop or optical bench. When using the support rod base always secure it to the tabletop using the toe clamps provided with the system.

If a heavy light source is to be used (such as a vapor lamp with integral igniter) it should have its own separate support system.

2.3.1 Initializing the Lambda Vf-5 if Not Already Initialized or After Being Reset

When the Lambda VF-5 is first powered up after receiving and installing it, or if the controller has been reset, the following series of screens will be displayed:

**COPYRIGHT SUTTER
INSTRUMENT v3.16**

After the copyright screen, the unit display should be similar to the following if the controller has already been initialized with the base wavelength of each variable filter installed on the filter wheel.

**W: 25MM F0 SP3 U
S: WL-490 nm**

The start menu shown

**W: 25MM F0 SP3 L
S: WL-490 nm**

If the Lambda VF-5 controller has not been initialized for the first time or if the controller has been reset, the following screen will display for about 5 seconds,

**ENTER FILTER POS
NO. 0-9 FOR VF..**

... and then the following menu is displayed.

```
F1-BROWSE 999-*
F2-ENT 000-EXIT
```

Setting the Base Wavelengths of each Installed Variable Filter

The following menu is the first one displayed after pressing F1 (BROWSE) on the previous menu:

```
F0-F***; F1-F***
F2-F***; F3-F***
```

Note that if no base wavelength has been assigned to Filter Position 0, the wavelength is shown as “***”. The same is true for every other filter position (F2 through F9). Press F2 key to navigate to the first filter position on the screen. The 3-digit base wavelength number next the filter position or the “***” if no base wavelength defined, gets replaced with a blinking question mark (as shown on the following screen).

```
F0-F ? ; F1-F***
F2-F***; F3-F***
```

The base values (in nanometers) currently supported for the Lambda VF-5 are: 380, 440, 490, 550, 620, 700, 800. If one of these numbers is appropriate to be entered for Filter Position 0, then enter the three digits on the unit’s keypad. Pressing F2 key again, enters the wavelength value into the current position (if just previously keyed in), and selects the next valid filter position for editing. Note that in the VF-5, only five filter positions are available and positions are all even numbered (0, 2, 4, 6, and 8). None of the odd-numbered filter positions can be used. If there are more filter positions available than are shown on the screen, pressing F2 when on the last filter position for the screen will cause the controller to display the screen with the next set of filter positions, as shown in the following.

```
F4-F***; F5-F***
F6-F***; F7-F***
```

```
F8-F***; F9-F***
```

Once the desired base wavelengths have been entered for all the valid filter positions, press the 0 key three times (“000”) the base wavelength browser, whereupon an exit prompt is displayed as shown in the following:

```
ARE YOU SURE TO
EXIT? 1-YES 0-NO
```


As in the screen showing the first set of filter positions, the F2 key is used in the next two screens showing the remaining filter positions to navigate between positions (optionally changing the wavelength) and between screens. If answering “Yes” (<1>) to the “Are you sure to exit?” prompt, the main top-level screen/menu is displayed:

```
W: 25MM F0 SP3 U
S: FAST   ON *
```

If you wish to make more changes with the keypad or if simply wishing to operate the Lambda VF-5 in local mode, press <LOCAL> to change control of the unit from external USB control over to local mode.

To cause the Lambda VF-5 to switch to a specific wavelength, press the <L> (lowercase Lambda) key, whereupon the following prompt is displayed:

```
ENTER 338-800nm
WL VALUE:      nm
```

Enter the desired wavelength (in nanometers) on the keypad (1 to 3 digits), then <F2>. After the wavelength has been entered and the unit has made the switch, the main status/menu screen will appear as:

```
W: 25MM F0 SP3 L
S: WL-400 nm T3
```

Menu Navigation

Main Menu

```
W: 25MM F0 SP3 L
S: WL-400 nm T3
```

<F1>

```
1-VF#
2-TEST
```

<1> (1-VF#)

```
1-EDIT VF NO.
2-CLEAR ALL
```

<1> (1-EDIT VF NO.)

F1-BROWSE 999-*
F2-ENT 000-EXIT

<2> (2-TEST)

1-LOOP
2-DEMO

<1> (1-LOOP)

LOOP TEST:
FAILED

<2> (2-DEMO)

ENTER TILT SPEED
0-3 FOR DEMO ...

W: 25MM F0 SP3 L
S: WL-400 nm T3

<F1>

1-VF#
2-TEST

<F1>

1-VERSION
2-HOME

<F1>

VERSION: M-v3.16
SLAVE-v3.12

<F2>

1-DEVICE TYPE
2-BAUD RATE

<1> (1-DEVICE TYPE)

1- LBVF*
2- 10-B

<2> (2-BAUD RATE)

1-9600 2-19200
3-115.2K 4-128K*

2.4 Setting the Wheel Rotation Speed (<LOCAL> <SPEED> <0> through <7>)

One of eight Wheel Rotation Speeds can be selected for the Lambda VF-5. The Wheel Rotation Speed is selected while in LOCAL mode and while the main status screen is displayed. To select a Rotation Speed, press <SPEED> whereupon the following prompt is displayed. In response to the prompt, press a number key ranging from 0 through 7 for the desired rotation speed.

ENTER NEW SPEED
VALUE IN 0-7

2.5 Setting the Wheel Tilt Speed (<LOCAL> <SPEED> < λ > <0> through <3>)

One of four Tilt Speeds can be selected for the Lambda VF-5. The Tilt Speed is selected while in LOCAL mode and while the main status screen is displayed. To select a Tilt Speed, press <SPEED> followed by <Lambda> whereupon the following prompt is displayed. In response to the prompt, press a number key ranging from 0 through 3 for the desired speed.

ENTER TILT SPEED
VALUE IN 0-3

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3. OPERATIONS – GENERAL

3.1 First Time Use

3.1.1 Line Power (Mains)

The power cord provided with the Lambda VF-5 connects to the Power Entry Module located on the back of the unit (see diagram below). This Module also includes the Line Fuse and Power Switch.

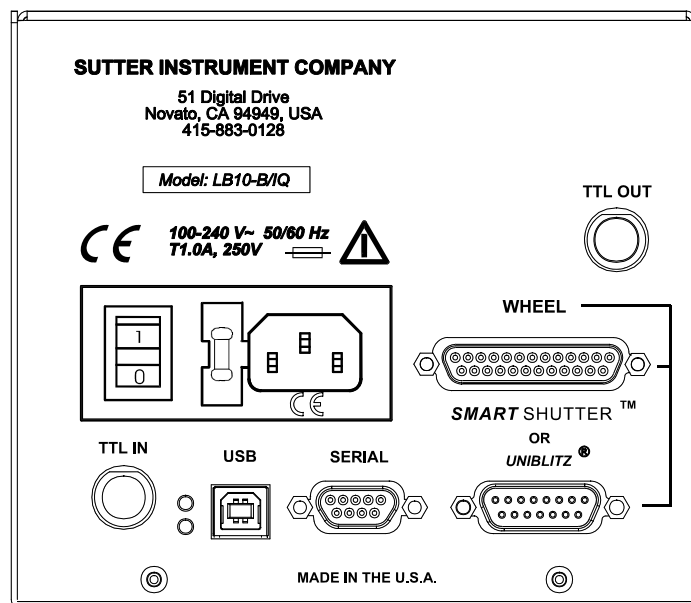


Figure 3-1. Lambda VF-5 Cabinet (rear view).

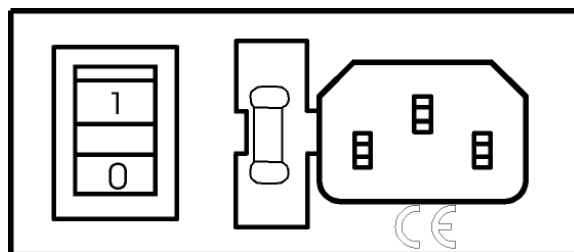


Figure 3-2. Switch, fuse, and power connection.

The Lambda VF-5 has a “universal” power supply that runs on 110 volts or 220 volts AC, 50 or 60 Hz. You do not need to change settings or fuses to suit local conditions. Make certain that the ON/OFF Switch located on the back panel of the Lambda VF-5 cabinet is turned OFF. Plug the power cord provided with the Lambda VF-5 into the Line Input socket on the Power Entry Module and then to a power source of the appropriate voltage and frequency.

You must replace the fuse with the appropriate value (see the Technical Specifications), otherwise your protection from fire and electric shock will be compromised.

3.2 Basic Operation

3.2.1 Initialization

At power on the Lambda VF-5 will rotate the filter wheel to filter position 0. If the wheel does not rotate to this position as detected by a Hall effect sensor, the display will indicate that there is an error. Once the wheel is properly initialized to filter 0, it will move to filter 9 and then back to filter 0 to complete the power on sequence. While in filter position 9 the microprocessor checks the optical sensor to determine if a full 10-position wheel is installed. If the optical switch indicates that it is not a 10-position wheel, the controller will only execute moves to filters 0 through 3.

At power on the first display will be the copyright message:

```
COPYRIGHT SUTTER
INSTRUMENT v3.14
```

After the copyright screen, the unit display should be similar to:

```
W: 25MM F0 SP3 U
S: WL-490 nm
```

Where **W** is the type of wheel detected, **F** is the filter selected, **SP** is the selected speed, **U** is the local/on-line state, and **S** is the tilt of the filter wheel..

Once the unit has initialized, it is ready for USB or serial input. To use the keypad, press the LOCAL key. You can then select filters using the numeric keys. The action associated with a key generally occurs when the key is released. Menu choices will be covered in later sections.

3.3 Filter Wheel Assembly

The following steps show how a filter wheel is set up and connected to the Lambda VF-5 controller.

NOTE: Under no circumstances should an attempt be made to connect more than one filter wheel to the Lambda VF-5.

1. Assemble the two Support Rods to the Support Base. Flats have been machined near the threaded end of these rods to facilitate tightening with a wrench. The two base-support clamps should be used to anchor the base to some convenient location for testing. These clamps are designed to allow anchoring to any of the popular hole-patterns found in optical benches.
2. Slide the filter wheel down onto the support rods and lock it at a convenient height using the wing screws on the mounting ears of the filter wheel.
 1. **IMPORTANT: Make sure that the Lambda VF-5 controller has its power turned OFF before connecting the filter wheel to the controller!** Connect the controller and filter wheel with the appropriate cable provided. It is important that the screws anchoring the

cable ends be tight to insure a good connection for the motor power leads and positioning signals.

3.4 Make It Go

1. Turn on the power using the ON/OFF switch on the back panel of the Lambda VF-5 controller cabinet. The filter wheel will automatically go to the “Home” (0) filter position. The current filter position will appear on the controller front panel display.
2. The Lambda VF-5 will default to on-line at power-on or after a reset. If the unit is connected to a USB port with properly installed software, the USB port will be selected as the default remote control interface.
3. The Lambda VF-5 will be in the on-line mode at power on, ready for serial port or USB port commands. However, it will need a valid remote-control command to pass control to the correct input.
4. To operate in local mode, press the LOCAL key. You can then press any numeric key on the keypad to manually select the corresponding filter position.
5. Press the shutter key to toggle the shutter open and closed (if installed).

Now that you have completed this FIRST TIME USE section of this manual, you should be familiar with the basic components and the MANUAL operation of the Lambda VF-5. To get set up for an experimental application you will need to:

- Install the desired filters into the FILTER WHEEL.
- Install the filter wheel into the optical pathway using the appropriate adapter.
- Establish the desired INTERFACE between the Lambda VF-5 and your computer.

Each of these steps is discussed in the following sections of the manual

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4. OPERATIONS – MANUAL CONTROL

4.1 Power up Sequence

The control electronics for the filter changer are activated by the POWER switch (MAINS) on the back panel of the unit. Remember, when using an arc lamp with this system it is best to turn the lamp power supply on BEFORE turning on the Lambda VF-5. Arc lamp power supplies produce a high voltage lamp starting pulse that may interrupt normal operation of microprocessor-controlled devices or damage electronics.

When power is applied, the Lambda VF-5 performs several initial tests in order to determine the mechanical equipment attached to the controller. As part of this process, the filter wheel will rotate at a slow rate until sensors in the mechanical units signal that the “0” filter position is lined up with the optical port. The wheel will then make an additional move away from filter 0 and then back to filter 0. The controller currently automatically recognizes three different classes of filter wheels: standard 10-position, high-speed 4-position and high-current 10 position (32 mm). At power on, the Lambda VF-5 rotates the filter wheel to filter position 0. If the wheel does not rotate to this position as detected by a Hall Effect sensor, the display will indicate that there is an error. If the microprocessor detects that it is not a 10-position wheel, the controller will only execute moves to filter positions 0 through 3.

While the unit is going through these steps, the following screen is displayed:

```
COPYRIGHT SUTTER  
INSTRUMENT v3.14
```

4.2 Main Status Screen

After the copyright screen, the unit display should be similar to one of the following, depending on your configuration:

```
W: 25MM F0 SP1 L  
S: WL-380 nm T3
```

4.3 The Lambda VF-5 Keypad



Figure 4-1. The Lambda VF-5 keypad for manual (local) control.

4.4 Placing Lambda VF-5 into Local Mode

Once the unit has initialized, it is ready for USB input, as indicated by the U at the right side of the first display line. Serial input can be activated as noted in the section on the serial port. To use the keypad, press the local key. When you press the local key, the last character on the first line will change from a U to an L.

```
W: 25MM F0 SP1 L
S: WL-380 nm T3
```

4.5 Immediate Key Control of Attached Devices (While in Local Mode)

Wavelength (<Lambda>, 380-800 nm): When pressing the <Lambda> key while in Local mode, the following prompt will be displayed.

```
ENTER 338-800nm
WL VALUE:      nm
```

In response to the wavelength prompt, enter the 3-digit wavelength (in nanometers) using the numeric keypad, and then press <F2>. If the wavelength entered is valid, the Lambda VF-5 will make the appropriate filter wheel rotational and tilt movements, whereupon the status screen will be redisplayed. If the entered wavelength is not valid, the following message is displayed for a few seconds before returning to the status screen.

```
NEW NM NUMBER IS
NOT AVAILABLE
```

Wheel Filter Position (<0>, <2>, <4>, <6>, <8>): Wheel filter positions are selected using the numeric keys. Movement to the specified filter position occurs when the key is released.

Wheel Rotational Speed (<SPEED>, <0> - <7>): The rotational speed of the filter wheel can be specified by pressing the <SPEED> key followed by the numeric keys <0> through <7>.

```
ENTER NEW SPEED
VALUE IN 0-7
```

Once the desired rotational speed has been entered, the main status screen is displayed, reflecting the new rotational speed.

**Rotational speed
indicator**

W: 25MM F0 SP1 L
S: WL-380 nm T3

NOTE: Speed values above seven (7) entered through the keypad are reserved for special options, and may not function properly on your unit.

Wheel Tilt Speed (<SPEED>, <Lambda>, <0> - <3>): The tilt speed of the filter wheel is specified by pressing <SPEED>, followed by <Lambda>, whereupon the following prompt is displayed.

**ENTER TILT SPEED
VALUE IN 0-3**

In response to the above prompt, one of four speeds can be entered (keys <0> through <3> for tilt speed. The Tilt Speed selected is then reflected in the main status screen which is displayed next.

W: 25MM F0 SP1 L
S: WL-380 nm T3

Tilt speed indicator

When you press and release a valid numeric key, the status display will return with the new speed value. If the ENTER NEW SPEED message remains, try the numeric key again.

4.6 Main Menu (F1)

In order to access the main menu in the local mode, press F1. There will be a brief display of the message:

**PRESS KEY 0 TO
EXIT ANYTIME!**

The main menu, shown below, then quickly replaces the momentary screen shown previously:

1 - VF#
2 - TEST

4.6.1 Test Mode Menu (F1 2)

Pressing **2** (“2-TEST”) at the main menu (or **F1 2**), displays the menu that lists the types of tests available for the Lambda VF-5.

1 - LOOP 2 - DEMO

4.6.1.1 Loop Test (F1 2 1)

The Loop Test is designed to perform a continuous test of all devices attached. To stop the test, press any key on the keypad.

4.6.1.2 Demo (F1 2 2)

The Demo selection places the Lambda VF-5 in demo mode, whereby the all the features of the filter wheel are cycled through, in continuous mode.

When DEMO is selected, a prompt is displayed next that asks for the Tilt Speed (0 through 3) to use with the demo. Once the Tilt Speed is entered, the controller proceeds with the demo. As the demo progresses, all the states of the controller and wheel are dynamically updated on the main status screen.

The demo can be stopped at any time by pressing the 0 key.

4.7 Selecting the Filter Position

Pressing the corresponding numeric key when the controller is in the local mode chooses a filter position on the wheel. Keys are read while depressed but the appropriate action will occur only when the key is released. If a key is pressed while a move is in progress but released after the move is over, the key will read normally. Keys pressed and released while a move is in progress are ignored. The filter position currently located in the optical port will be indicated on the display (see example above).

4.8 Selecting the Filter Switching Speed

To enter the speed selection mode, press the speed key on the keypad. Speed 0 is the fastest speed and speed 7 is the slowest. Entering the selected speed under computer control is covered in a separate section.

The switching times (in milliseconds) for each of the eight speeds is given in the Table 4-1. Note that a 5-filter position move is the longest move on the 10-position filter wheel, since the controller will always rotate the correct direction to make the fastest change of position. For a given speed, the time for a move to a non-adjacent filter will take about 1.8, 2.5, 3.3 or 4 times as long as a move to an adjacent filter, depending on the number of filters to be skipped. The highest speed that can be used will depend on the weight of the filters mounted in the wheel. In a 25mm, 10-position filter wheel equipped with two typical filters and eight blocking disks, adjacent filters can be changed in less than 40 milliseconds with a speed setting of 1. A correspondingly-equipped 32mm wheel may require a lower speed.

Table 4-1. Filter Switching Times (in milliseconds).

Speed Setting	Number of Filter Positions Moved				
	1	2	3	4	5
0*	31	51	74	95	115
1	40	65	95	120	148
2	44	75	105	136	168
3	50	88	127	165	205
4	60	108	156	205	250
5	68	123	178	235	290
6	124	235	350	460	580
7	230	440	650	860	1100

* **NOTE:** Speed 0 should be used only with 4-position filter wheels (LB10-WHS4, LB10-WHS4IQ, or LB10-WHS4E).

4.9 Error Detection and Recovery

The **LAMBDA VF-5** contains two sensor systems that are used to monitor the actual position of the filter wheel. After the controller sends the step sequence for a move to a new filter position, it compares the output of these sensors with the expected position. If there is no match, the error recovery sequence is started. First, the wheel is rotated until filter 0 is in position. Then the unit continues to rotate at a slow rate until the correct filter is in position. An **ERROR** signal is reported to the active interface.

4.10 Movement Errors: Causes and Solutions

Filter Weight vs. Speed: The **LAMBDA VF-5** is optimized for the fastest exchange of 2 filters in research applications. One element of the **LAMBDA VF-5's** overall design that contributes to its superior performance is the acceleration and deceleration profiles that are pre-programmed into the microprocessor commanding the motor. There is a separate profile for each combination of *selected speed* and *number of positions to be moved*. The motor commands produced from these profiles result in exceedingly smooth and efficient filter wheel movements. The motor, however, is driven at its rated power which limits its ability to overcome the inertial load of the filter wheel if the weight of the wheel is increased by installing more (or heavier) filters. Increases in filter wheel weight, then, can lead to movement errors unless a slower *speed setting* is selected¹. Detection of a movement error will initiate the **RECOVERY** routine described above, sending the wheel to the **HOME (0)** position.

Oscillation when Stopping: If the desired configuration of filters in your filter wheel results in a weight that is slightly excessive for the chosen speed, the filter wheel may oscillate instead of stopping quickly when the selected filter has rotated into position. Even though

¹ **WHY NOT JUST USE A LARGER MOTOR?** As the inertia increases, the force required to achieve a given acceleration and deceleration also increases. Since the step motor in the **LAMBDA 10-C** is operated at rated power, an increase in force could only be obtained by using a larger motor. This, in fact, is not a very satisfactory solution for the following reasons. First, larger motors have a higher *intrinsic inertia*. Second, if the larger motor has a larger diameter it would require that the filter wheel diameter also be expanded to move the filters radially so that the optical pathway clears the motor housing. Third, if the larger motor were longer it would increase the optical path length, which is not desirable. At best, the net result of a larger motor might be a slight increase in speed when fully loaded, but at a cost of slowing the response when relatively few filters are loaded.

this may not be detected as an error by the controller, it is advisable to use a slower speed. This will cause a slower acceleration and deceleration profile to be used and, by eliminating the oscillations, may actually allow the move to be completed more quickly.

Oscillations when Moving: Selecting a slower speed will generally eliminate errors caused by excessive total filter wheel weight, but there are other considerations. For a given weight some of the slow speeds may induce oscillations during movement. This is a result of stepping the motor near the resonance frequency (see Appendix A). Selecting a higher or lower speed will generally solve this problem.

Movement Errors after Successive Moves: With an optimal combination of speed and load-weight, it may be possible to give a new command as soon as the last move is complete. On the other hand, if the selected speed is improper for the load, as outlined above, oscillations (too small to be detected as movement errors) may be sufficient to carry-over from the end of one move to the beginning of the next. This can occur even when the delay between moves is more than 50 msec. It is possible, then, to experience movement errors after changing only the delay interval between moves. If you are making moves with a very short delay interval and errors are detected with some frequency, it is wise to consider this possibility before addressing the *selected speed*. Try using a long time interval (1 second) between moves to test whether the length of the interval is contributing to the error rate.

4.11 Helpful Tips about Movement Errors

Always determine the appropriate speed by using the same filter wheel load weight and timing intervals that will be required in your experimental protocol. There is a tendency for users to test the LAMBDA VF-5 in their system using little, if any, delay between commands even though a pause occurs during an actual experiment.

If your application requires the delay between moves to be minimal, experiment with small changes in the delay to find the best value and then keep the delay at that value. If your protocol precludes you from increasing the delay, use a slower speed to eliminate the oscillation. If you cannot use a slower speed, you must reduce the filter wheel weight to eliminate the movement errors.

If the weight is clearly excessive for the chosen speed select a slower speed. Make sure you also address the question of the delay interval before you become very serious about the speed of operation.

Remember, unless having a short delay interval is important the solution to frequent movement errors will usually require some compromise between having fast filter switching speed and having the convenience of keeping many filters loaded.

5. OPERATIONS: EXTERNAL CONTROL: GENERAL

5.1 Principles of Operation

The remote control of the Lambda VF-5 can be achieved by issuing commands on a remote computer and transmitting them to the Lambda VF-5 over a **serial** (RS-232) or **USB** (direct or via a Virtual Com Port (VCP)). These operational modes are functionally identical. Each allows the user to select:

This chapter provides a description of these commands and how they are used. Limited remote control can also be achieved with a TTL connection, a description for which is provided later in this manual.

- Setting a filter by rotating the filter wheel to the appropriate position
- Setting the filter wheel rotation speed
- Setting the tilt (angle) of the filter to achieve a specific wavelength
- Setting the tilt speed
- Assigning base wavelengths to each filter wheel position
- Acquiring device, configuration, and status data for current wavelength, wheel position, filter tilt, speeds, and overall system.

5.2 External Control Interfaces

5.2.1 Serial RS-232-C Interface Port with Control via Host Computer's Built-in Device Driver

5.2.2 USB Interface Port with Control via Direct Device Driver

5.2.3 USB Interface Port with Control via Additional Virtual Com Port (VCP) Device Driver

5.3 External Control Command Set

5.4 External Control Application Programming

The following table shows how remote commands are categorized.

Table 5-1. Remote Control Command Categories.

Category	Description
Filter commands	These are commands used exclusively for controlling filter wheels.
Special commands	These are commands for the general control of the Lambda VF-5 controller, and are not specifically related

Category	Description
	to the filter wheel.

Most of the commands described in this chapter are ones that are sent from the computer to the Lambda VF-5. Some of these commands will cause the Lambda VF-5 to return certain special codes or one or more bytes of data. Some commands must be followed by one or more bytes containing parameters. For each byte sent to the Lambda VF-5, that same byte is echoed (transmitted) back to the remote computer as confirmation that the byte was received. This echoing back of command bytes in no way indicates validation of a command or parameter, but rather is an acknowledgement on the part of the controller that it has received the byte, When the Lambda VF-5 controller has finished performing the task associated with a command (or command followed by one or more parameter bytes), the controller will transmit to the host computer an ASCII carriage return (CR, 13 decimal, or 0D hexadecimal) as an indication that function associated with the command has completed and that the controller is now ready for another command. This echoing back of bytes sent by the remote computer to the controller, and the return of an ASCII carriage return after a command's task is complete, is the same for both serial and USB interfaces.

5.5 Input Command Structure

5.5.1 Commands Description

The following table provides a complete list of all the remote commands for the Lambda VF-5.

The following table provides a list of all the remote control commands.

Table 5-2. External control commands.

Command	Value (Decimal, hexadecimal, & binary)	Description
Set Filter Wheel State (move to a position at specified speed)	(See the table "Command Code Ranges" for possible value ranges.)	Sets the filter wheel speed (0 – 7) and the filter position (0 – 9). Three items are encoded into a single byte using the following bits: Bit 7 (Wheel Select): Always 0 (zero); only one wheel is supported. Bits 6, 5, & 4 (Wheel Rotational Speed): 0 through 7. Bits 3, 2, 1, & 0 (Filter Position): 0 through 9. Only even-numbered positions (0, 2, 4, 6, & 8) are valid.
Get Status	204 CC 11001100	Returns system status in 6 bytes: 1 st . Status command echoed back 2 nd . Wheel state (speed & filter position) 3 rd . Shutter state (Always "Opened")

Command	Value (Decimal, hexadecimal, & binary)	Description
		4 th : Set Current Filter Angle command 5 th & 6 th : Angle of filter in microsteps (1 – 272)).
All Motors Power On *	206 CE 11001110	Instruct the controller to power on all motors.
All Motors Power Off *	207 CF 11001111	Instruct the controller to power off all motors.
Switch to Wavelength	218 DA 11011010	Based on the wavelength (338 – 800 nm) in the next two bytes, the specific filter and angle are set according to an internal lookup table. NOTE: The Tilt Speed is also specified with this command; it is stored in the uppermost (most significant) bits of the high order byte containing the wavelength value.
Get Current Wavelength	219 DB 11011011	Returns the current wavelength setting (in two bytes containing 338 – 800 nm), based on the current filter and angle using the internal lookup table.
Set Wheel Angle	222 DE 11011110	The wheel's angle is set according to the number of microsteps (1 – 272) coded in the next two bytes.
Batch Mode	223 DF 11011111	The Batch command is followed by the Set Filter Wheel Speed & Position and Set Current Filter Angle commands allowing the controller to execute both commands in quick succession.
Transfer to On Line	238 EE 11101110	Puts controller on-line (serial or USB)
Transfer to Local	239 EF 11101111	Puts controller in local mode
Reset	251 FB 11111011	Resets the controller
Set Filter Position Base Wavelength Assignment	252 FC 11111100	Set if command is followed by F0 – F9 (position 0 through 9) and then two bytes containing the base wavelength in nanometers.

Command	Value (Decimal, hexadecimal, & binary)	Description
or Get Base Wavelength Assignments for All Filter Positions		Error Return: If an invalid filter position is specified with this command, the controller returns two bytes indicating an error. The first byte is the “error” byte, and consists of 234 decimal (EA hexadecimal). The second byte indicates the erroneous filter position and ranges from 240 (F0 hex) through 249 (F9 hex). Get if command is followed by FA. The data returned begins with F0 (Filter Position 0) and two bytes containing the assigned base wavelength in nanometers, F1 and two bytes for Position 1, and so on, on to F9. The two bytes following each odd-numbered position will contain 0.
Get Controller Type and Configuration *	253 FD 11111011	Queries the controller as to its type and configuration.

5.6 Command Descriptions

5.6.1 Switch to Wavelength Command (218d (DAh))

Based on the wavelength (338 – 800 nm) in the next two bytes, the specific filter and angle are set according to an internal lookup table.

The Switch to Wavelength command also includes the Set Tilt Speed command, which is embedded in the high-order two bits of the 16-bit (word (two bytes)) containing the wavelength in nanometers that follows the command byte.

If the new wavelength specified is not within the range available based on the configured base wavelengths, then an error will occur and the following message will momentarily be displayed on the controller’s display, as follows:

**NEW NM NUMBER IS
NOT AVAILABLE...**

Commands sent to the controller via the serial or USB interface are structured in a one-byte (8-bit) signal. Some commands are followed by one or more bytes containing additional

parameter information for the command. The 8 bits can be used to convey three types of commands.

- **Filter Wheel Command.** This command selects the desired filter position and switching speed, both of which are encoded into a single byte.. The filter position and switching speed are each specified by the encoding of specific bits within the command byte.
 - The filter position is specified in the least significant 4 bits (nibble) of the byte (Bits 3, 2, 1, and 0), providing value range of 0 through 9. Because only 10 possible filter positions are encoded in these bits, they are effectively encoded in Binary Coded Decimal (BCD) format, leaving the values of 10 through 15 (decimal) available for use by Special commands. Note that the Lambda VF-5 supports only even-numbered filter positions (0, 2, 4, 6, & 8).
 - The filter switching speed is specified in the least significant 3 bits within the most significant nibble of the byte (Bits 6, 5, & 4), providing a value range of 0 through 7. These bits are interpreted as the filter switching speed only if the bits in the lower nibble of the byte contain a value of 0 through 9, specifying the filter position as described previously
 - The filter wheel selection is specified in the most significant bit of the byte (Bit 7). Because the Lambda VF-5 supports only one filter wheel, Bit 7 of the command byte is always set to 0.
- **Special Commands.** These commands are used to control various aspects of the controller that are not specifically related to filters. Some of these commands are also used to obtain status and configuration information of the controller.

The microprocessor in the controller is programmed to distinguish between these two types of Input Commands based on the bit pattern of the Command and will respond accordingly. These two types of Commands are discussed in more detail in the following sections.

The following table shows the command byte value ranges for filter commands and those for special commands.

5.7 Filter Wheel Commands

A byte command sent to the controller that contains a value from 0 through 121 decimal (00 through 79 hexadecimal) is interpreted as a Filter Wheel Command. Within a Filter Wheel Command byte, three parameters are encoded: Filter Wheel, Speed, and Position. The accommodation of these three parameters within a single byte is accomplished by breaking up the byte into three parts: two bit groups, and one single bit, as follows.

- **WHEEL BIT:** This bit selects the filter wheel to which the Filter and Speed commands will be directed. The model VF-5 filter wheel, however, does not support a second wheel and so this bit should always be set to 0.
- **SPEED GROUP:** These 3 bits select the speed of rotational movement used in advancing to the next filter. The speed group is treated as a three-place binary number whose equivalent decimal value, 0 through 7, corresponds to the selected speed.
- **FILTER POSITION GROUP:** This group consists of all 4 bits within the lower nibble of the byte (the least significant 4 bits of the byte). These 4 bits select the desired filter (i.e., the filter wheel position). This group is treated as a four-place binary number, with the equivalent decimal values 0 through 9 corresponding to the selected filter position. These four bits can also be thought of as containing a BCD (Binary Coded Decimal) value, since

BCD always use four bits to encode only decimal values 0 through 9. Values 10 through 15 decimal (A through F hexadecimal) in these four bits are currently undefined and should never occur. Binary codes with decimal values greater than 9 are ignored, unless the binary value (in conjunction with the SPEED GROUP bits) corresponds with the decimal equivalent of one of the Special Command Codes listed later in this chapter (see).

To send a Filter Command via the USB port the binary value must first be determined for the desired Filter Position and Switching Speed (4 bits and 3 bits, respectively). As mentioned above, the Filter Wheel (1 bit) will always be 0. Then these 8 bits must be set, in the proper order, on the controller's USB port, as shown below.

Table 5-3. Filter Command Structure.

Functional Bit Groups								
Byte Bit #	7	6	5	4	3	2	1	0
Group	Wheel	Speed			Filter Position			
Group Bit #	0	2	1	0	3	2	1	0
Decimal Group Values	0	0 - 7			0 - 9			
Binary Group Values	0	000 - 111			0000 - 1001			

NOTE: Because Lambda VF-5 supports only five filter positions, only even-numbered positions (0, 2, 4, 6, & 8) are used.

In the above table, "Decimal Group Values" are equivalent to the values of the desired Filter Wheel (always 0), Switching Speed (0 through 7) and Filter Position (0 through 9). Their hexadecimal and binary equivalents are shown as the "Hexadecimal Group Values" and "Binary Group Values", respectively. These 8 bits are the raw data, then, that serve as a Filter Command to select the Filter Position and Switching Speed via the Lambda VF-5 controller's serial and USB ports. The Wheel bit (Bit 7) is used to select the filter wheel in models of the Lambda 10 series that support more than one filter wheel; since the Lambda VF-5 supports only a single filter wheel, Bit 7 should always be set to zero. In summary, the controller will treat any byte it receives from the remote computer as a "filter command" if the byte's least significant nibble contains a value of 0 through 9. If the received byte's least significant nibble contains a decimal value of 10 through 15, then the controller treats the entire byte as a "special command".

NOTE: Because the Lambda VF-5 supports a total of five filter wheel positions, only even-numbered filter position values (out of 0 – 9) are valid (0, 2, 4, 6, & 8).

5.7.1 Filter Wheel Command Byte Encoding

The following formula may be used to encode all three filter wheel commands into a single byte. All values are in decimal):

$$(\textit{wheel} * 128) + (\textit{speed} * 16) + \textit{position} = \textit{command byte}$$

Where:

wheel = 0 (always in the Lambda VF-5 since only one filter wheel is supported)

speed = 0 through 7 (wheel rotation speed only)

position = 0, 2, 4, 6, or 8 (even-numbered positions only)

5.7.2 Set Wavelength Command Encoding

Byte 1: Set Wavelength Command (218 decimal, DA hexadecimal)

Byte 2: Low-order byte of word containing the wavelength value in nanometers.

Byte 3: High-order byte of word containing the upper part of the value in Byte 2, plus the Tilt Speed (2 bits) is encoded into Bit 15 and Bit 14.

Encode wavelength (338-800 nanometers) and Tilt Speed (0-3) as follows:

1. Load Tilt Speed value into U16(1), an unsigned 16-bit word or short.
2. Shift the contents of U16(1) left by 14 bits, so that the Tilt Speed now occupies Bit 15 and Bit 14 of the word.
3. Load the wavelength nanometers value into U16(2), a second 16-bit word or short.
4. Add to U16(1) the value stored in U16(2) so that U16(1) now contains the Tilt Speed in Bit 15 and Bit 14 and the wavelength (in nanometers) in the remaining bits.
5. Finally, extract the low-order byte out of U16(1) for “Byte 2”, and the high-order byte for “Byte 3”.

5.8 Special Commands

Special commands are those that are not specifically related to the control of filter wheels. They are used primarily for the control, and the obtaining of status, of the Lambda VF-5 controller. These commands make use of all eight bits of the command byte, and begin with the value of 204 (decimal) or CC (hexadecimal). The following table lists all of the Lambda VF-5's special commands.

Table 5-4. Special command codes.

Command	Value (Decimal, hexadecimal, & binary)	Description
Status	204 CC 11001100	Returns status of unit in two bytes
All Motors Power On	206 CE 11001110	Instruct the controller to power on all motors.
All Motors Power Off	207	Instruct the controller to power off all motors.

Command	Value (Decimal, hexadecimal, & binary)	Description
	CF 11001111	
Transfer to On Line	238 EE 11101110	Puts controller on-line
Transfer to Local	239 EF 11101111	Puts controller in local mode
Reset	251 FB 11111011	Resets the controller
Get Controller Type and Configuration	253 FD 11111011	Queries the controller as to its type and configuration.

The following paragraphs describe the special commands in more detail.

5.8.1 Status

The Status command is used to return information about the current filter position, and the angle of the wheel in microsteps. The following tables describe the type of data and information returned by the Status command.

Table 5-5. Status Command Return Codes and Data.

Order	Num. of bytes	Category	Sub Category	Value (Decimal, hexadecimal, & binary)	Description
1	1	Command echo		204 CC 11001100	The Status command byte code echoed back.
2	1	Filter wheel state	Wheel Select	0 0 0	Filter Wheel (Bit 7): Always 0.
			Speed	0 – 7 0 – 7 000 - 111	Speed (Bits 6, 5, & 4): 0 – 7.
			Filter Position	0 – 9 0 – 9 0000 - 1001	Position (Bits 3, 2, 1, & 0): Even-numbered values out of 0 – 9 (0, 2, 4, 6, or 8)

Order	Num. of bytes	Category	Sub Category	Value (Decimal, hexadecimal, & binary)	Description
			Error or no filter wheel installed	10 0A 00001010	Either no filter wheel is installed or there is an error on the 15-pin wheel port.
3	1		Undefined	170 AA 10101010	This Status byte should always contain the indicated value.
4	3	Set Wheel Angle in Microsteps command		190 BE 10111110	Command byte
			Lower byte	1 – 255 01 – FF 00000001 - 11111111	Upper and Lower bytes are combined to create a 16-bit unsigned “word” containing the number of microsteps (1 through 272).
			Upper byte	0 – 1 0 – 1 00000000 - 00000001	

*** NOTE:** Range shown for the filter wheel command/status byte is not 100% inclusive. Please refer to Table 5-3 for an explanation of how the byte is encoded, and to **Error! Reference source not found.** for a list of valid byte values.

5.8.2 All Motors Power On

This command is used to instruct the controller to switch ON electrical power to the motors of the connected filter wheel.

5.8.3 All Motors Power Off

This command is used to instruct the controller to switch OFF electrical power to the motors of the connected filter wheel.

5.8.4 Transfer to On Line

This command is the equivalent to pressing the ON LINE key on the Lambda VF-5’s keypad. If the controller is in local mode (i.e., it is off line), this command will cause the controller to go on line (the opposite of local mode), enabling it to respond to other commands from the remote computer.

5.8.5 Transfer to Local

This command is the opposite of the Transfer to On Line command. It causes the controller to go into local mode, and is the equivalent to pressing the LOCAL key on the controller’s

keypad. Once in local mode, the controller will not respond to any commands sent to it from the remote computer except the Transfer to On Line command.

5.8.6 Reset

Causes the Lambda VF-5 controller to reset, changing all settings back to their defaults. After the reset has completed, status information similar to that returned by the Status command is returned to the remote computer.

5.8.7 Get Controller Type and Configuration

This command is used to obtain information about the controller as to its model and configuration. The following table shows the type of information returned when issuing this command.

Table 5-6. “Get Controller Type and Configuration” Command Return Codes and Data.

Total num. bytes	Description				
	Category	Offset Addr.	Num. Bytes	Possible Values	
				ASCII string	Meaning
14	Command echo back	0	1	ý	253 decimal; FD hexadecimal. *
	Controller type	1	4	VF-5	Lambda VF-5
	Type of filter wheel connected	5	4	W-25	25mm
	Type of angle stepper connected	9	4	S-IQ	Always same as 25mmSmartShutter
	Command return data terminator	13	1		ASCII CR (Carriage Return); 13 decimal, 0D hexadecimal.

***NOTE:** The character shown in the “ASCII string” column for the command echo is a typical visual representation of the byte value 253 decimal (FD hexadecimal) on both Windows and Linux platforms. However, other platforms may display a different character or nothing at all. For the command return data terminator (ASCII carriage return (13 decimal, 0D hexadecimal), generally no character will be displayed, although the carriage return is acted upon in most cases in text-based console programs.

NOTE: The “Batch Transfer of Commands” and batch-related commands are not supported in the Lambda VF-5 controller.

5.9 Remote Control Command Programming

This section describes some suggested tips and techniques when writing programs on the remote control computer for communicating with the Lambda VF-5 via either the serial RS-232 port or the USB (Universal Serial Bus) port. The following paragraphs and the code examples deal with remote control command programming in a general manner, abstracted from telecommunications medium. The discussions and examples are applicable to either the serial RS-232 port or the USB port. The programming specifics for either the serial or USB ports are covered in the respective chapters, following this chapter. The discussions and examples are also relatively platform independent. The code samples written in the C programming language, for example, are written in a relatively primitive form, and thus should be easily portable to any platform for which C support exists (Windows, UNIX, Linux,

Macintosh OS, etc.). Should another programming language be desired to implement the examples, the gist of examples should be fairly easy to glean if they are viewed as pseudo code – the examples should be easy to port to C++, Java, Pascal, BASIC, and other high level languages, or even various forms of scripting languages.

5.9.1 Preparing the Command Byte

All remote control command codes for the Lambda VF-5 require no more than one byte (8 bits) of storage for each command. If using a programming language that makes the distinction between unsigned and signed bytes, always select unsigned only. “Unsigned” means that only positive numbers can be stored, whereas “signed” means that either positive or negative values can be stored. An unsigned byte can hold 256 different positive values (0 through 255). A signed byte can store only 128 different positive values (0 through 127, and 127 different negative values (-1 through -127). In the C programming language, an unsigned byte type is expressed as “unsigned char” followed by the name of the variable, such as:

```
unsigned char command_byte;
```

...where “command_byte” is the name the programmer chooses to give the variable.

5.9.1.1 Encoding Filter Commands Into a Single Byte

Filter commands are encoded into specific bit groups of the command byte. As discussed earlier in this chapter, and as shown in the table titled “Filter Command Structure”, there are actually three commands stored at the same time in the command byte. The filter wheel selector is stored in Bit 7 (the most significant bit (MSB)) of the command byte, allowing 2 values (0 and 1)¹. The filter wheel speed is stored in the next lower three bits (Bits 6, 5, and 4), allowing 8 different values (0 through 7). In addition, the filter selector is stored in the next lower four bits (least significant nibble, Bits 3, 2, 1, and 0). Of the 16 possible values that can be stored in the least significant nibble, only the first 10 (0 through 9) are used for the filter selector. Any value above 9 will invalidate the entire command byte as a “filter command”, making the value stored in the byte as whole as either a special or undefined command.

5.9.1.2 Special Commands

Special Commands make use of the remaining command byte bit patterns not being used by Filter Commands.

5.9.2 Command Transmission Protocol

The Lambda VF-5 does not use any of the standard protocols commonly used for serial line or USB communications between computers or between a computer and a peripheral device. The Lambda VF-5 controller, however, does generate a primitive form of protocol of which control software running on the remote computer can, and should, make use. This protocol consists of two main components: “confirmation command echo” and “command completion indicator”. This command transmission protocol is used in the same manner for RS-232 serial and USB port connections.

¹ Note that the Lambda VF-5 supports the connection of only one filter wheel. Therefore, the filter wheel selector stored in Bit 7 of the command byte must always be 0.

5.9.2.1 Confirmation Command Echo

When the host computer sends a command to the Lambda VF-5, each byte received is immediately echoed back to the host computer. This echoing back of each sent byte is a confirmation that the byte has been received and will be acted upon shortly. A short period after the last byte of a command has been echoed back, the Lambda VF-5 sends a confirmation byte (described next) that indicates the operation associated with the command completed.

5.9.2.2 Command Completion Indicator

When the Lambda VF-5 completes the operation associated with the command it has just received, it transmits back to the host computer a byte value of 13 decimal (0D hexadecimal, 00001101 binary). This byte value corresponds to an ASCII carriage return (often abbreviated as “CR”).

6. OPERATIONS: EXTERNAL CONTROL: SERIAL RS-232 INTERFACE

The Lambda VF-5 microprocessor sets the serial RS-232C port, by default, as the input source upon startup and anytime the ON LINE key is pressed. An appropriate command from the remote computer through the serial port will automatically set that port as the active input source and the display on the controller will reflect that change on its bottom line. The serial port will remain active until an appropriate command is sent from a remote computer through the USB port or until the LOCAL key is pressed on the controller keypad.

There are, obviously, some basic differences in the physical connections and the modes by which serial and USB data are transmitted to the controller. The command code and return code structures are, however, for the most part, the same. The connection and command structure required to control the Lambda VF-5 via the Serial port are discussed in this chapter.

6.1 Connecting to the Serial Port

The serial interface connector on the back of the Lambda VF-5 controller cabinet is a DB-9 female connector. The connections are arranged so that a standard DB-9 serial cable can be used to connect the controller to a PC serial port. The port operates on a minimal RS-232 protocol where only the signal ground and the two data lines (transmit and receive) are connected; the hardware control lines are not connected. This port is designed for connection to a standard computer serial port. It should not be connected to any other type of interface or device. The pin assignments for this connector are, as viewed from the back of the controller:

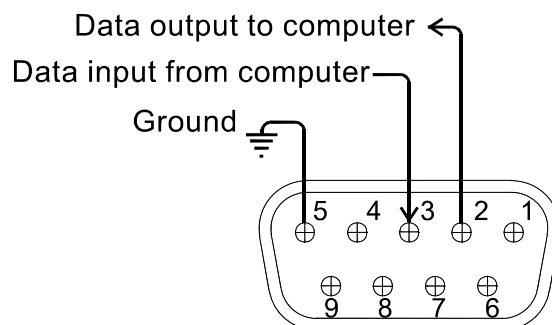


Figure 6-1. Serial port pin assignments.

Communication for the serial port requires the following settings:

- Baud rate 9600
- Data bits 8
- Parity none
- Stop bits 1
- Flow Control: none

No hardware control lines are connected. You must either set the communication mode so that these lines are ignored or provide connections that will satisfy the mode of

communication that you use. In Microsoft QuickBasic the communication channel may be opened with a statement such as:

```
OPEN "COM1:9600,N,8,1, CD0,CS0,DS0 " FOR RANDOM AS #1 LEN = 256
```

This sets COM1 to the correct mode for bi-directional communication through channel #1. The option list "CD0,CS0,DS0" causes QuickBasic to ignore the DCD, CTS and DSR control lines. Other variants of the BASIC programming language (implemented for the PC) will have a similar syntax for the above statement.

6.2 Input Command Set and Protocol

Input Commands to the controller via the serial port are structured and adhere to the same protocol as described in the REMOTE CONTROL chapter. The Filter and Special commands, as described in the REMOTE CONTROL chapter, all apply to the serial port interface. Each command consists of one byte (8-bits), and some commands are followed by one or more bytes as parameters. The command protocol is also the same as described in the REMOTE CONTROL chapter: As a command is sent to the controller, it is immediately echoed back to the computer, and when the controller has completed the task associated with the command it has just received, it sends an ASCII CR (carriage return) byte (13 decimal, 0D hexadecimal) to the computer.

Since the serial data stream format is a single byte, each command can be sent as an ASCII character. If you have used a *BASIC* language open statement to establish serial communications the subsequent 8 bit command values may be sent using a *BASIC* PRINT # command such as:

```
PRINT #1, CHR$(DATANUM);
```

...where #1 is the file number used in the open statement, and DATANUM is the value of the command to be sent. Note that the CHR\$ function allows the actual number to be sent rather than the ASCII numbers of the characters that represent the number. Sending ";" disables the automatic addition of characters such as a linefeed or a space.

7. OPERATIONS: EXTERNAL CONTROL: USB INTERFACE

The Lambda VF-5 can communicate with the computer via the Universal Serial Bus (USB) port instead of the SERIAL (RS-232) port whenever it is connected to the remote computer with a USB cable and the appropriate USB device drivers are installed. The remote computer must be equipped with the necessary USB hardware and its operating system must be properly configured to recognize and work with the USB interface. Of all the USB ports available on the remote computer, be they part of the computer itself or part of a USB hub, one port must be available for use with the Lambda VF-5.

The Lambda VF-5 microprocessor sets the SERIAL port, by default, as the input source upon startup and any time the ON LINE key is pressed. An appropriate command from the remote computer through the SERIAL port will automatically set that port as the active input source and the display on the controller will reflect that change on its bottom line. The SERIAL port remains active until an appropriate command is sent from a remote computer through the USB port or until the LOCAL key is pressed on the controller keypad.

There are some basic differences in the physical connections and the modes by which USB and serial data are transmitted to the controller. The command code structures, however, are identical. The connection and command structure required to control the Lambda VF-5 via the USB port are discussed in this chapter.

7.1 Installing the Lambda VF-5 as a USB Device on a Windows System

The Lambda VF-5 can be used as a USB device with a remote computer that is installed with the necessary USB hardware and is running one of the following versions of Microsoft Windows.

1. Windows 98¹ and Windows 98 SE (Second Edition)
2. Windows ME (Millennium Edition)
3. Windows 2000 (Professional, Server, and Advanced Server)
4. Windows XP (Professional Edition and Home Edition)²
5. Windows Advanced Server 2003
6. Windows Vista (all editions)³
7. Windows 7 (all editions)

7.1.1 Installation Steps

To install the Lambda VF-5 as a USB device on a remote computer running one of the above-listed versions of the Microsoft Windows operating system, follow these steps.

¹ **Windows 95 and USB:** With the exception of the last releases of Windows 95 prior to the release of Windows 98, Windows 95 does NOT support USB hardware. Those releases of Windows 95 that do support USB will generally have "With USB Support" as part of the operating system's title. However, the Lambda 10 series of controllers with USB interfaces have not been tested on such systems.

² **32-bit and 64-bit Versions of Windows:** The USB device driver for the Lambda SC is designed to work with 32-bit versions of the Windows operating systems listed above. This driver is not intended for use with any 64-bit version of Windows.

³ **Windows Vista:** The current USB device driver for Lambda SC has been tested under Windows Vista (32-bit version only). Because Windows Vista's security architecture has been significantly enhanced over previous versions of Windows, you will find that the installation process (described next) will frequently prompt you for permission to proceed to subsequent steps.

1. Make sure that the Lambda VF-5 is plugged into a power source and that its power switch is set to OFF.
2. Connect the “device” connector of the USB cable to the USB receptacle in the back of the Lambda VF-5. Of the two connectors on the supplied USB cable, the one that is square-shaped is the one that connects the USB device. The device connector is shown in the following figure.

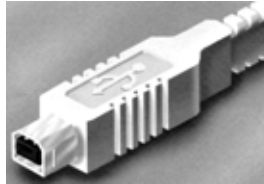


Figure 7-1 -- The USB cable device connector.

Moreover, the receptacle in the rear of the Lambda VF-5 into which the “device” connector of the USB cable connects is shown in the following figure.



Figure 7-2 -- The Lambda VF-5 USB receptacle.

Turn the power switch in the back of the Lambda VF-5 to ON.

Make sure the computer is powered up and the Windows operating system has fully finished starting up. Plug in the other end of the USB cable (the “host” connector) to any of the unused USB ports on your computer. You can also use an unused port of a USB hub connected to your computer, provided that the driver/software for the hub has already been installed and the hub is functioning properly. The “host” USB receptacle and connector are rectangular-shaped, as shown in the following figures.

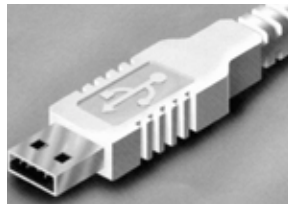


Figure 7-3 -- Host connector end of USB cable.

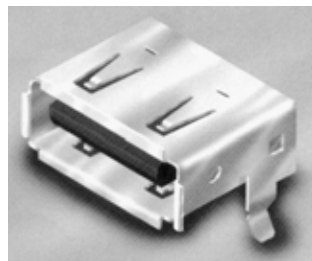


Figure 7-4 -- USB host receptacle on remote computer.

The following paragraphs describe what Windows displays after the host connector of the USB cable has been connected to the computer, and how you can interact with the computer to reach the goal of getting the appropriate USB device drivers properly installed.

7.1.2 Interactive USB Device Driver Installation

Once the USB “host” connector is inserted into the appropriate receptacle on the remote computer, the Windows operating system should immediately start the “new USB device” detection process. The following message box should appear on your screen:

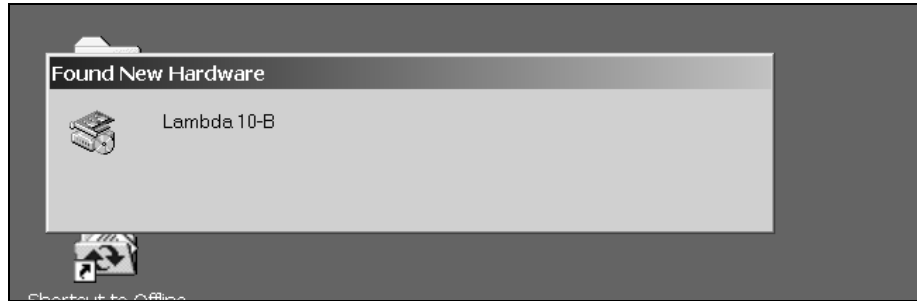


Figure 7-5 -- New USB device detected message box.

The above message box will display for a period of time, possibly up to a couple of minutes, while Windows goes through the process of determining if it already has device driver information for this new device.

If the Lambda VF-5 USB device drivers have already been installed on this computer, then Windows will usually find them and automatically reactivate them. If the drivers had been previously installed and then removed (uninstalled), it is possible that Windows is still able to locate the drivers and automatically reinstall them. Windows may also automatically install the appropriate drivers if another Sutter Instrument Company instrument with a USB interface (such as a Lambda 10-3, a Lambda SC, an MPC-200, or even another Lambda VF-5) is already connected and configured with your computer. If this is the first time the Lambda VF-5 USB device drivers are being installed, it is then quite likely that Windows will display the dialog box shown in the following figure.



Figure 7-6 -- Digital Signature dialog box.

Do not be concerned that Windows is unable to find a Microsoft digital signature for the Lambda VF-5 as shown in the previous figure. Simply press the “Yes” button to continue to the next step. The next figure shows the dialog box that Windows displays when it is ready ask you for the location of the Lambda VF-5 USB device drivers.

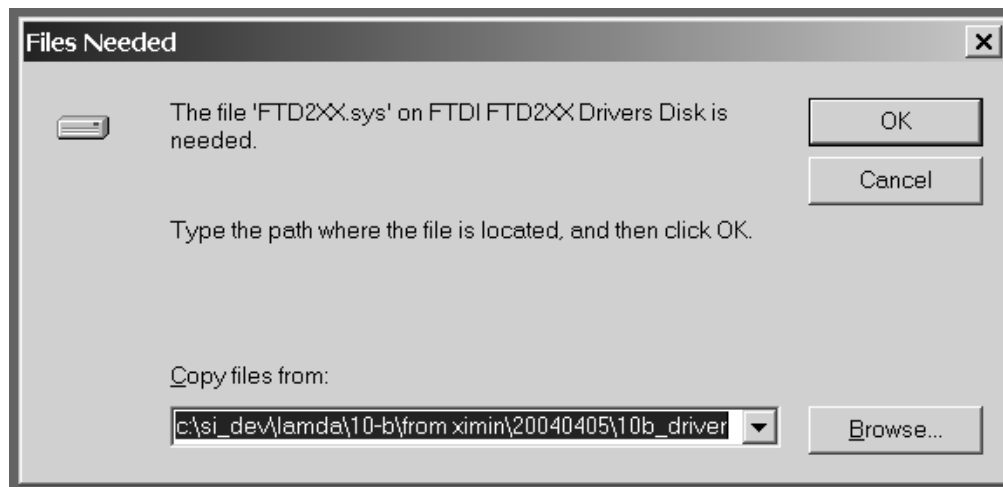


Figure 7-7 -- Specifying location of driver files.

In the previous figure, the dialog box displayed contains a combo box that contains a path to a location from which Windows remembered it had last copied a USB device driver. This may or may not be the path that currently contains the necessary files for the Lambda VF-5 USB interface installation. You have the following three choices for this dialog box:

1. Enter a path in the “Copy files from” combo box and then press OK.
2. Alternatively, select from the memory list in the “Copy files from” combo box, by pressing the inverted triangle to the right of the combo box, and then selecting and clicking on one of the items (if any) displayed in the pulldown list, and finally pressing OK.
3. Finally, clicking the Browse button displays another dialog that allows you to navigate through your system’s drives and folders for the location containing the needed Lambda VF-5 USB device driver files. Once found, and you’ve returned to the previous dialog box, the path chosen will now be shown in the “Copy files from” combo box, whereupon clicking OK will continue the process by using the path chosen. The following figure shows the dialog that is displayed after the Browse button is clicked.

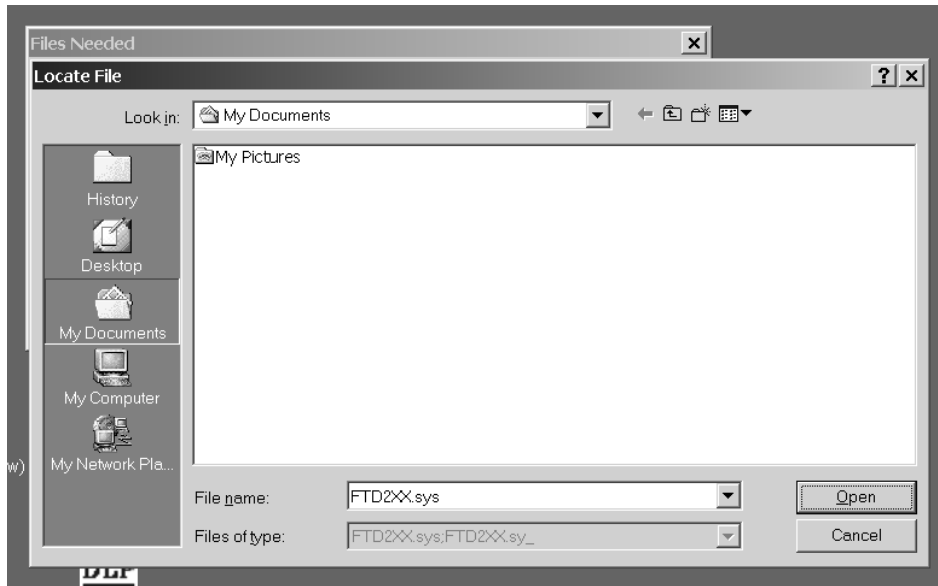


Figure 7-8 -- Browsing for the driver file needed.

Once the requested files are located, the Windows USB device installer will complete. Note that you may need to cycle through the two dialogs shown in the last two figures before the requested file is located and installed.

This completes the description for installing the Lambda VF-5 as a USB device connected to a Windows system.

7.2 Installing the USB Interface for Non-Windows Systems

The Lambda VF-5 can be connected with the USB interface to computers that are not running Windows. However, limited support and information is provided for them. For the Linux and Macintosh operating systems, please visit the following web sites for more information.

1. Linux drivers and tools:

<http://ftdi-usb-sio.sourceforge.net/>

2. Apple Macintosh drivers, tools, and information:

<http://www.ftdichip.com/FTMacDriver.htm>

7.3 Verifying USB Communication between Remote Computer and Lambda VF-5

Once the Lambda VF-5 has been connected to the remote computer with the USB cable and the remote computer has had the necessary device drivers installed, you will probably want to test and verify that the remote computer is, in fact, communicating correctly with the Lambda VF-5 over its USB connection. Probably the most expedient method for doing this testing is to install and run on the remote computer the USB Test and Demo program for the Lambda 10-series (a Windows program). This program is called “USBTest”, and once installed, can be used to determine if the remote computer is able to communicate with the Lambda VF-5 as a USB device. The USBTest program is provided on a 3.5-inch HD floppy

diskette or CD-ROM, shipped with the Lambda VF-5 or it can be downloaded from Sutter Instrument Co.'s web site (www.sutter.com). The files that make up the distribution of the USBTest program include the Setup program. Simply run this setup program to install USBTest on your system (Windows-based systems only: Windows 98, 98 SE, ME, 2000 and XP).

The USBTest program has only one screen, and appears as shown in the following figure.

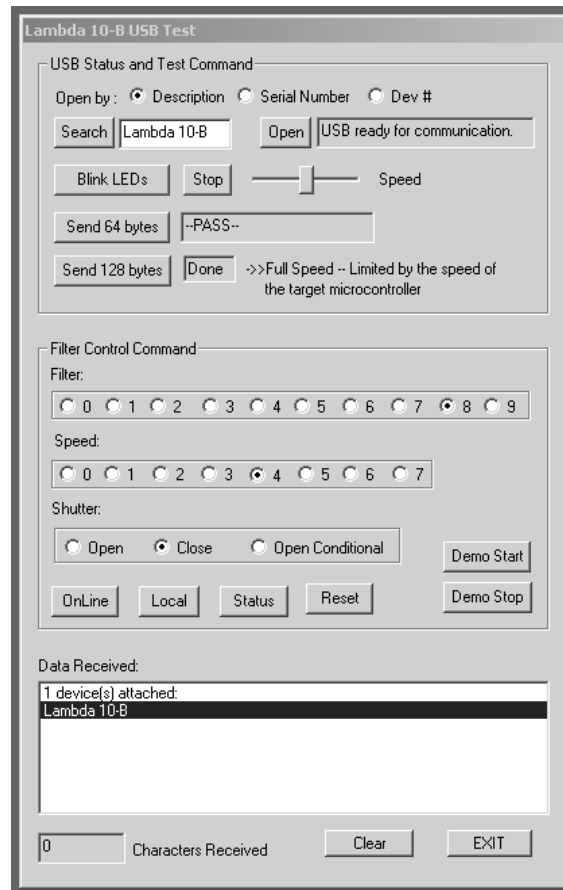


Figure 7-9 -- USBTest main screen.

Once you have the program up and running, and the screen in the previous figure is displayed, you can use the program to first identify whether or not one or more Lambda VF-5 units are installed as USB devices. This is accomplished by first clicking the Search button which causes USBTest to scan the USB for the device requested. The search criterion is dependent on which one of the three radio buttons following "Open by:" is selected: Description, Serial Number, or Dev #. The results of the search are displayed on the "Data Received:" text field: highlight the item displayed there ("Lambda VF-5", serial number, or device number) and then click on it to select it. The selected item is then automatically copied to the text field associated with the Search button. Finally, click the Open button to open the Lambda VF-5 USB device for communication. The text field associated with the Open button will be updated with a message indicating that the USB device has been successfully opened. To verify communications with the Lambda VF-5, click on different filter wheel radio buttons, at different speeds - you should be able to see and hear the filter wheel move.

The source code for the USBTest program is also available upon request. The source code consists of all source, resource, and library files, including all necessary project files for building the program with Microsoft Visual C++/Studio Version 6.0. The application is written in C and C++ for the Microsoft Windows platform, and it makes use of the Win32 and MFC (Microsoft Foundation Classes) libraries included with Microsoft Visual C++. The USBTest program also makes use of a library called FTDIXXX.DLL that is freely available from FTDI, the manufacturer of the USB chip set used in the Lambda VF-5 and which gets installed on your system when the USB device driver for the Lambda VF-5 is installed. The FTDIXXX.DLL is “bound” to the USBTest program via two files that are included with the USBTest program source code: FTDIXXX.H, a C/C++ header file that gets included at compile time, and FTDIXXX.LIB, the FTDIXXX.DLL interface library file, which gets linked to the project at link time. All three files are freely downloadable from FTDI’s web site: www.ftdichip.com.

Alternatively, a custom program can be written to verify the installation and for sending commands to the Lambda VF-5. Although providing the source code for an entire ready-to-run program is beyond the scope of this manual, the following paragraphs describe the key elements such a custom program should have in order to identify, connect with, and transmit to the Lambda VF-5 as a USB device. Accompanying these paragraphs are listings containing snippets of code written in the C programming language that may prove of further use should it be desired to create a custom program. Note that the code examples assume that the FTDIXXX.LIB and FTDIXXX.H files described previously are being used. You may download these files directly from FTDI’s web site: **Error! Hyperlink reference not valid..**

7.4 Uninstalling the USB Driver for the Lambda VF-5

Normally, the device drivers installed on your system that enable communications with the Lambda VF-5 over the USB, once installed, do not need removing from your system. If you do need to remove the USB drivers installed specifically for the Lambda VF-5 (e.g., the Lambda VF-5 will no longer be used with the system in question), the following steps can be followed for Windows 98, Windows ME, Windows 2000, Windows XP, or Vista.

1. Open the *Control Panel* (click on *Start* to bring up the main Windows menu, then click on *Settings*, and then *Control Panel* in the submenu).
2. Within the Control Panel window, double click *Add/Remove Programs*. A new window is opened in which a list of software that is installed on your system is displayed.
3. Select the line that has "FTD2XX Uninstaller" as the description, and click the “Remove” button towards the right of the description. The FTD2XX Uninstaller program starts and displays a dialog asking you to disconnect the USB cable if it is still connected.
4. Unplug the USB cable connected to the Lambda VF-5, and then click the Continue button. The uninstall process completes (one more dialog shows up indicating that registry entries and files are getting deleted). The uninstall process is now complete -- click the Finish button to finish. Alternatively, click Cancel to cancel the whole uninstall process.
5. If the uninstall process completed, the FTD2XX entry in the Add/Remove list should now be gone.

Note that although the above procedure will remove the Lambda VF-5 USB device driver from active use, not all related files on your system are actually deleted. Should you decide to reinstall the USB driver for the Lambda VF-5 after having gone through the uninstall process, Windows will most likely be able to locate the necessary USB driver file on your system during the installation process, without requiring you to supply the disk containing the driver.

In order to completely remove the USB driver and related files from the system, either manually delete the file FTD2XX.sys from the “system32” directory in your Windows directory, or navigate via My Computer or Windows Explorer to the “system32” directory in your Windows directory, locate the file FTD2XXUN.EXE, and double click on it to launch the general-purpose FTDI uninstaller program. Running this uninstall program will remove all pertinent FTDI entries in the Windows registry, a far safer approach to removing the entries manually.

7.5 Remote Commands and the USB Interface

The same set of commands described in the Remote Commands and Remote Commands: Serial port chapters are available for use when the Lambda VF-5 is connected to a computer as a USB device. The following paragraphs summarize the entire Lambda VF-5 command set for use with the USB.

8. MAINTENANCE

Routine cleaning of the Lambda VF-5 system is required to prevent excessive dust accumulations. This is done by wiping all exterior surfaces with a dry, soft, cotton cloth.

All retaining rings should be inspected occasionally to be certain that they are seated into the filter holders and cups.

The filter wheel is a precision-machined part, mounted on a stepper motor shaft. As such, it DOES NOT REQUIRE LUBRICATION. Attempting to lubricate any part of the filter wheel assembly will void the warranty and may harm the motor.

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APPENDIX A. LIMITED WARRANTY

- Sutter Instrument Company, a division of Sutter Instrument Corporation, limits the warranty on this instrument to repair and replacement of defective components for two years from date of shipment, provided the instrument has been operated in accordance with the instructions outlined in this manual.
- Abuse, misuse, or unauthorized repairs will void this warranty.
- Limited warranty work will be performed only at the factory.
- The cost of shipment both ways is to be borne by the user.
- The limited warranty is as stated above and no implied or inferred liability for direct or consequential damages is intended.
- Consumables and Uniblitz^{®1} shutters are exempt from this warranty.
- An extended warranty for up to three additional years can be purchased at the time of ordering, or until the original warranty expires. For pricing and other information, please contact Sutter Instrument.

¹ Uniblitz[®] is a registered trademark of Vincent Associates.

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APPENDIX B. ACCESSORIES

B.1. VersaChrome® Filters

CO-O573380	Tunable filter, 338-380nm with 16nm bandwidth
CO-O573440	Tunable filter, 390-440nm with 16nm bandwidth
CO-O573490	Tunable filter, 440-490nm with 15nm bandwidth
CO-O573550	Tunable filter, 490-550nm with 15nm bandwidth
CO-O573620	Tunable filter, 550-620nm with 14nm bandwidth
CO-O573700	Tunable filter, 620-700nm with 13nm bandwidth
CO-O573800	Tunable filter, 700-800nm with 12nm bandwidth

B.2. Other Accessories

O629950	Male-to-male C-mount adapter for mounting SmartShutter® to Lambda VF-5/ VF-1
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APPENDIX C. FUSE REPLACEMENT

In the event that the controller fails to power up when the power switch is turned on, check the line power fuse to see if it has blown. The fuse is located in the fuse holder on the power entry module on the back of the controller. To remove the fuse holder first unplug the power cord from the power entry module. This will reveal a slot just under the edge of the fuse holder. Use a screwdriver to pry the holder straight out of the power entry module.

The fuse holder holds two fuses. Both fuses are of the same type and rating. If either fuse is blown, it is recommended that both fuses be replaced.

The type and rating of both fuses are as follows:

**5 x 20 mm glass tube, Time Delay (IEC 60127-2, Sheet III)
T1.0A, 250V,
(Examples: Bussmann GDC-1A or S506-1R (RoHS); or
Littelfuse 218 001 or 218.001.P (RoHS))**

The fuse that is readily visible in the fuse holder when you take it out is the one that is “active” when the holder is installed. A spare fuse is also stored within the fuse holder. It is concealed in a compartment as shown in the figure below. To remove the spare fuse, press down on the end of the compartment to push it out of the other end. The old fuse can serve as a convenient tool for pushing the spare fuse compartment out. Replace the active fuse with the spare and re-install the fuse holder and power cord. If the controller fails to power up with the new fuse installed, call Sutter Instrument technical support personnel for assistance.

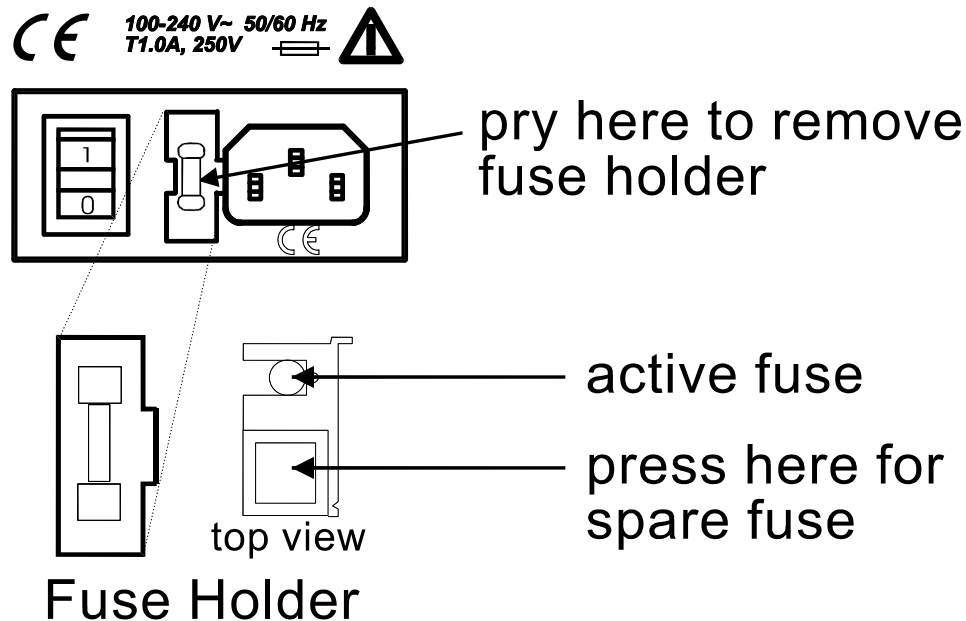


Figure 8-1. Power entry module and fuse holder.

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APPENDIX D. TECHNICAL SPECIFICATIONS

D.1. VF-5 Tunable Filterwheel

Dimensions (H x W x D):

9.4 x 6 x 5 in (23.8 x 15.2 x 12.7 cm)

Weight:

11.7 lb; 5.3 kg)

D.2. Controller

Dimensions (H x W x D):

5.38 x 5.86 x 8.25 in (13.67 x 14.88 x 20.96 cm)

Weight:

2.55 lb (2 lb., 9 oz; 1.16 kg)

Electrical:

Input voltage (Mains)

100 - 250 V, 50/60 Hz

Mains fuses (rear of cabinet)

5 x 20 mm glass tube, T1.0A, 250V,
Time Delay (IEC 60127-2, Sheet III)

(Examples:

Bussmann GDC-1A or S506-1R (RoHS); or
Littelfuse 218 001 or 218.001.P (RoHS))

Fuse holder contains two fuses. If a fuse is blown,
both fuses should be replaced.

Power cord

10A, 250V, with safety ground plug

Table 8-1. Controller Cables.

Controller Rear Panel Port Connector/Receptacle	Cable Connector Types	Connects to ...	Cable Type	Cable Max. Length
(Power entry) 3-pin male connector	←3-pin power standard (female) 3-pin male→ (Geographical region dependent)	Mains power source.	10A, 250V, with safety ground plug	3 meters (approx. 10 feet)
WHEEL – UNIBLITZ 15-Pin DSUB male connector	Not used	Not connected		
WHEEL – SMARTSHUTTER 25-Pin DSUB female receptacle	←DB-25 male DB-25 female→	Filter wheel rotational and tilt motors	Minimum of 26 awg stranded wire with 500 Volt.	
SERIAL 9-Pin DSUB female receptacle	←DB-9 male DB-9 female→ (Straight-through)	Host computer's serial (RS-232) 9-pin DSUB male connector (built-in or via plug-in board or USB-to-serial converter/adaptor)	Minimum of 26 awg stranded wire with 500 Volt. Connected to metal faceplates of connectors on both ends.	
USB USB "A" (Device) female receptacle (full-sized)	←A connector B connector→	Host computer's USB "B" receptacle (full-sized)	Dielectric separation of circuits. Foil shielding.	
TTL IN BNC female receptacle	Not used	Not connected		
S1 OUT BNC female receptacle	Not used	Not connected		
S2 IN BNC female receptacle	Not used	Not connected		
S2 OUT BNC female receptacle	Not used	Not connected		

APPENDIX F. EXTERNAL CONTROL COMMAND REFERENCE

This appendix provides a complete list of remote control commands and return values.

Table 8-2. Complete Command Reference.

Byte Value			Keyboard Entry			Filter Wheel Command			Description			
Dec.	Hex.	Binary	Alt-keypad entry	Ctrl-char.	ASCII def./-char.	W	S	F				
						h	p	i	Special Command			
						e	e	t				
						l	d	r				
0	00	00000000	Alt-0000	^@	(NUL)	A	0	0	Move to physical Position 0 at Speed 0			
1	01	00000001	Alt-0001	^A	(SOH)			1				
2	02	00000010	Alt-0002	^B	(STX)			2	Move to physical Position 1 at Speed 0			
3	03	00000011	Alt-0003	^C	(ETX)			3				
4	04	00000100	Alt-0004	^D	(EOT)			4	Move to physical Position 2 at Speed 0			
5	05	00000101	Alt-0005	^E	(ENQ)			5				
6	06	00000110	Alt-0006	^F	(ACK)			6	Move to physical Position 3 at Speed 0			
7	07	00000111	Alt-0007	^G	(BEL)			7				
8	08	00001000	Alt-0008	^H	(BS)			8	Move to physical Position 4 at Speed 0			
9	09	00001001	Alt-0009	^I	(HT)			9				
10	0A	00001010	Alt-0010	^J	(LF)							
-	-	-	-	-	-							
15	0F	00001111	Alt-0015	^O	(SI)							
16	10	00010000	Alt-0016	^P	(DLE)				A	1	0	Move to physical Position 0 at Speed 1
17	11	00010001	Alt-0017	^Q	(DC1)						1	
18	12	00010010	Alt-0018	^R	(DC2)	2	Move to physical Position 1 at Speed 1					
19	13	00010011	Alt-0019	^S	(DC3)	3						
20	14	00010100	Alt-0020	^T	(DC4)	4	Move to physical Position 2 at Speed 1					
21	15	00010101	Alt-0021	^U	(NAK)	5						
22	16	00010110	Alt-0022	^V	(SYN)	6	Move to physical Position 3 at Speed 1					
23	17	00010111	Alt-0023	^W	(ETB)	7						
24	18	00011000	Alt-0024	^X	(CAN)	8	Move to physical Position 4 at Speed 1					
25	19	00011001	Alt-0025	^Y	(EM)	9						
26	1A	00011010	Alt-0026	^Z	(SUB)							
-	-	-	-	-	-							
31	1F	00011111	Alt-0031	^_	(US)							
32	210	00100000	Alt-0032		(space)				A	2	0	Move to physical Position 0 at Speed 2
33	21	00100001	Alt-0033		!						1	
34	22	00100010	Alt-0034		“	2	Move to physical Position 1 at Speed 2					
35	23	00100011	Alt-0035		#	3						
36	24	00100100	Alt-0036		\$	4	Move to physical Position 2 at Speed 2					
37	25	00100101	Alt-0037		%	5						
38	26	00100110	Alt-0038		&	6	Move to physical Position 3 at Speed 2					
39	27	00100111	Alt-0039		‘	7						
40	28	00101000	Alt-0040		(8	Move to physical Position 4 at Speed 2					
41	29	00101001	Alt-0041)	9						
42	2A	00101010	Alt-0042		*							
-	-	-	-	-	-							
47	2F	00101111	Alt-0047		/							
46	30	00110000	Alt-0048		0	A	3	0	Move to physical Position 0 at Speed 3			

Byte Value			Keyboard Entry			Filter Wheel Command			Description
Dec.	Hex.	Binary	Alt-keypad entry	Ctrl-char.	ASCII def./-char.	W	S	F	
						h	p	i	
49	31	00110001	Alt-0049		1			1	
50	32	00110010	Alt-0050		2			2	Move to physical Position 1 at Speed 3
51	33	00110011	Alt-0051		3			3	
52	34	00110100	Alt-0052		4			4	Move to physical Position 2 at Speed 3
53	35	00110101	Alt-0053		5			5	
54	36	00110110	Alt-0054		6			6	Move to physical Position 3 at Speed 3
55	37	00110111	Alt-0055		7			7	
56	38	00111000	Alt-0056		8			8	Move to physical Position 4 at Speed 3
57	39	00111001	Alt-0057		9			9	
58	3A	00111010	Alt-0058		:				
-	-	-	-		-				
63	3F	00111111	Alt-0063		?				
64	40	01000000	Alt-0064		@			0	Move to physical Position 0 at Speed 4
65	41	01000001	Alt-0065		A			1	
66	42	01000010	Alt-0066		B			2	Move to physical Position 1 at Speed 4
67	43	01000011	Alt-0067		C			3	
68	44	01000100	Alt-0068		D			4	Move to physical Position 2 at Speed 4
69	45	01000101	Alt-0069		E	A	4	5	
70	46	01000110	Alt-0070		F			6	Move to physical Position 3 at Speed 4
71	47	01000111	Alt-0071		G			7	
72	48	01001000	Alt-0072		H			8	Move to physical Position 4 at Speed 4
73	49	01001001	Alt-0073		I			9	
74	4A	01001010	Alt-0074		J				
-	-	-	-		-				
79	4F	01001111	Alt-0079		O				
80	50	01000000	Alt-0080		P			0	Move to physical Position 0 at Speed 5
81	51	01000001	Alt-0081		Q			1	
82	52	01000010	Alt-0082		R			2	Move to physical Position 1 at Speed 5
83	53	01000011	Alt-0083		S			3	
84	54	01000100	Alt-0084		T			4	Move to physical Position 2 at Speed 5
85	55	01000101	Alt-0085		U	A	5	5	
86	56	01000110	Alt-0086		V			6	Move to physical Position 3 at Speed 5
87	57	01000111	Alt-0087		W			7	
88	58	01001000	Alt-0088		X			8	Move to physical Position 4 at Speed 5
89	59	01001001	Alt-0089		Y			9	
90	5A	01001010	Alt-0090		Z				
-	-	-	-		-				
95	5F	01011111	Alt-0095		-				
96	60	01010000	Alt-0096		`	A	6	0	Move to physical Position 0 at Speed 6
97	61	01010001	Alt-0097		a			1	
98	62	01010010	Alt-0098		b			2	Move to physical Position 1 at Speed 6
99	63	01010011	Alt-0099		c			3	
100	64	01010100	Alt-0100		d			4	Move to physical Position 2 at Speed 6
101	65	01010101	Alt-0101		e			5	
102	66	01010110	Alt-0102		f			6	Move to physical Position 3 at Speed 6
103	67	01010111	Alt-0103		g			7	
104	68	01011000	Alt-0104		h			8	Move to physical Position 4 at Speed 6

Byte Value			Keyboard Entry			Description			
Dec.	Hex.	Binary	Alt-keypad entry	Ctrl-char.	ASCII def./-char.	Filter Wheel Command			Special Command
						W h e e l	S p e e d	F i l t e r	
105	69	01011001	Alt-0105		i			9	
106	6A	01011010	Alt-0106		j				
-	-	-	-		-				
111	6F	01011111	Alt-0111		o				
112	70	01110000	Alt-0112		p	A	7	0	Move to physical Position 0 at Speed 7
113	71	01110001	Alt-0113		q			1	
114	72	01110010	Alt-0114		r			2	Move to physical Position 1 at Speed 7
115	73	01110011	Alt-0115		s			3	
116	74	01110100	Alt-0116		t			4	Move to physical Position 2 at Speed 7
117	75	01110101	Alt-0117		u			5	
118	76	01110110	Alt-0118		v			6	Move to physical Position 3 at Speed 7
119	77	01110111	Alt-0119		w			7	
120	78	01111000	Alt-0120		x			8	Move to physical Position 4 at Speed 7
121	79	01111001	Alt-0121		y			9	
122	7A	01111010	Alt-0122						
-	-	-	-						
203	CB	11001011	Alt-0203						
204	CC	11001100	Alt-0204						Status
205	CD	11001101	Alt-0205						
206	CE	11001110	Alt-0206						All motors power on *
207	CF	11001111	Alt-0207						All motors power off *
208	D0	11000000	Alt-0208						
-	-	-	-						
217	D9	11011001	Alt-0217						
218	DA	11011010	Alt-0218						Set wavelength. Followed by two bytes (lower & upper halves of a 16-bit integer) containing the wavelength value (338 – 800 nm)
219	DB	11011011	Alt-0219						Get current wavelength. Returns two bytes (lower & upper halves of a 16-bit integer) containing the wavelength value (338 – 800 nm)
208	D0	11000000	Alt-0208						
-	-	-	-						
221	DD	11001101	Alt-0221						
222	DE	11001110	Alt-0222						Set number of microsteps for the angle of the current filter. Followed by two bytes (lower & upper halves of a 16-bit integer) containing the microsteps value (1 - 272)
223	DF	11011111	Alt-0223						Batch. Followed by 4 bytes: speed & filter command and three bytes for Set Wavelength/Set Microsteps command.
223	DF	11011111	Alt-0223						
-	-	-	-						
237	ED	11011101	Alt-0237						
238	EE	11011110	Alt-0238						On Line
239	EF	11011111	Alt-0239						Local

Byte Value			Keyboard Entry			Filter Wheel Command			Description
Dec.	Hex.	Binary	Alt-keypad entry	Ctrl-char.	ASCII def./-char.	W	S	F	
						h	p	i	
						e	e	l	Special Command
						e	e	e	
						l			
240	F0	11110000	Alt-0240						
-	-	-	-						
250	FA	11111010	Alt-0250						
251	FB	11111011	Alt-0251					Reset	
252	FC	11111100	Alt-0252					Set or Get filter position to base wavelength assignment.	
253	FD	11111101	Alt-0253					Get controller type & configuration *	
254	FE	11111110	Alt-0254						
255	FF	11111111	Alt-0255						

NOTE 1: All commands indicated with “*” are not available in early versions of the Lambda VF-5 (those prior to Revision D).

NOTE 2: The Lambda VF-5 supports only one filter wheel (Wheel A). Therefore, Bit 7 should always be set to 0.

NOTE 3: The “ASCII def./char.” column for codes 128 through 255 (80 through FF hex) is left blank, since there are no ASCII character definitions for the codes in this range. However, many computers and operating systems do support characters within this range, although there is no single standard across all platforms. Furthermore, many operating systems, such as Microsoft Windows and Apple Mac OS X, have several “code pages” (character sets), many of which are country/language specific, from which the user can select. Therefore, this part of the table is left blank – if you wish, you may write in the characters defined in the character set you use on a regular basis.

Table 8-3. Filter command structure.

Functional Bit Groups								
Byte Bit #	7	6	5	4	3	2	1	0
Group	Wheel	Speed			Filter Position			
Group Bit #	0	2	1	0	3	2	1	0
Decimal Group Values	0	0 - 7			0 - 9			
Hexadecimal Group Values	0	0 - 7			0 - 9			
Binary Group Values	0	000 - 111			0000 - 1001			

Encoding filter wheel commands into a single byte (all numbers are in decimal):

$$(\text{speed} * 16) + \text{position} = \text{command byte}$$

... where *speed* = 0 through 7 and *position* = 0 through 9. The Wheel Bit is not included in the formula because in the Lambda VF-5 it is always set to 0 (Wheel A).

Table 8-4. Status Command Return Codes and Data.

Order	Num. of bytes	Category	Sub Category	Value (Decimal, hexadecimal, & binary)	Description
1	1	Command echo		204 CC 11001100	The Status command byte code echoed back.
2	1	Filter wheel state	Wheel Select	0 0 0	Filter Wheel (Bit 7): Always 0.
			Speed	0 – 7 0 – 7 000 - 111	Speed (Bits 6, 5, & 4): 0 – 7.
			Filter Position	0 – 9 0 – 9 0000 - 1001	Position (Bits 3, 2, 1, & 0): Even-numbered values out of 0 – 9 (0, 2, 4, 6, or 8)
			Error or no filter wheel installed	10 0A 00001010	Either no filter wheel is installed or there is an error on the 15-pin wheel port.
3	1		Undefined	170 AA 10101010	This Status byte should always contain the indicated value.
4	3	Set Wheel Angle in Microsteps command		190 BE 10111110	Command byte
			Lower byte	1 – 255 01 – FF 00000001 - 11111111	Upper and Lower bytes are combined to create a 16-bit unsigned “word” containing the number of microsteps (1 through 272).
			Upper byte	0 – 1 0 – 1 00000000 - 00000001	

*** NOTE:** Range shown for the filter wheel command/status byte is not 100% inclusive. Please refer to Table 5-3 for an explanation of how the byte is encoded, and to **Error! Reference source not found.** for a list of valid byte values.

Table 8-5. “Get Controller Type and Configuration” Command Return Codes and Data.

Total num. bytes	Description				
	Category	Offset Addr.	Num. Bytes	Possible Values	
				ASCII string	Meaning
14	Command echo back	0	1	ý	253 decimal; FD hexadecimal. *
	Controller type	1	4	VF-5	Lambda VF-5
	Type of filter wheel connected	5	4	W-25	25mm, 10 positions, 5 filters
	Type of angle stepper connected	9	4	S-IQ	Always same as 25mmSmartShutter
	Command return data terminator	13	1		ASCII CR (Carriage Return); 13 decimal, 0D hexadecimal.

***NOTE:** The character shown in the “ASCII string” column for the command echo is a typical visual representation of the byte value 253 decimal (FD hexadecimal) on both Windows and Linux platforms. However, other platforms may display a different character or nothing at all. For the command return data terminator (ASCII carriage return (13 decimal, 0D hexadecimal), generally no character will be displayed, although the carriage return is acted upon in most cases in text-based console programs.

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