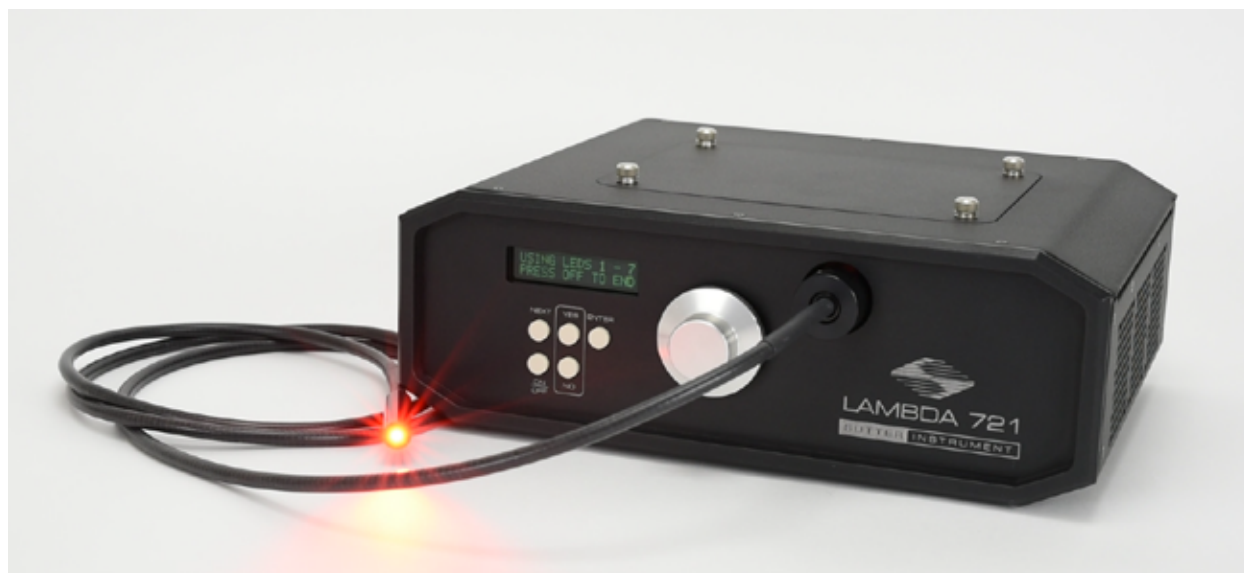# Lambda 721

Ultra-High-Speed Optical Beam Combined
7-Channel Wavelength Switching
LED Light Source System

With TTL & USB Interface for External Control

Operation Manual
Rev. 1.10c ((20210517)

CE EU Declaration of Conformity

Application of Council Directives:
2014/30/EU (EMC), 2014/35/EU (LVD), and 2015/863/EU (RoHS 3)

Manufacturer's Name:	Sutter Instrument Company
Manufacturer's Address:	One Digital Drive Novato, CA. 94949 USA Tel: +1 415 883 0128
Equipment Tested:	**Lambda 721** Optical Beam Combined 7-Channel Wavelength Switching LED Light Source System
Model(s):	**LB-721** **Optical beam-combined arrangement of low/medium-power LEDs (up to seven)** **Controller for manual and external-control, with power supply**

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
	Photobiological Safety of Lamps & Lamp Systems:	EN 62471: 2008 / IEC 62471, Ed 1.0 (2006-07)

Tested/Verified (based on LBHPX & LBHPX-L5) By:	ITC Engineering Services, Inc. 9959 Calaveras Road, PO Box 543 Sunol, CA 94586-0543 USA Tel. +1 925 862 2944 Fax: +1 925 862 9013 Email: itcemc@itcemc.com Web: www.itcemc.com Sutter Instrument
Test Report(s):	20150902-01, SI_HPX[-L5]_TF-A_(20150930), SI_EMC_LBHPX[-L5]_20160713; 20200520_REACH and RoHS Compliance Statement

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 2015/863 (2011/65/EU Annex II) for RoHS 3.

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SUTTER INSTRUMENT ®

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DISCLAIMER

The **Lambda 721** is an ultra-high-speed wavelength switching multi-LED-based beam combined illumination or light source device. The purpose of the system is to be an illuminator for microscopes. 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.

Unless otherwise indicated in this manual or by Sutter Instrument Technical Support for reconfiguration, do not open or attempt to repair the instrument.

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 721 using 110 – 240 VAC., 50-60 Hz line voltage. This instrument is designed for use in a laboratory environment that has low electrical noise and mechanical vibration. Surge suppression is recommended at all times.

- ⚠️ Fuse Replacement: Replace only with the same type and rating:

    5 x 20 mm glass tube, Time Lag (IEC 60127-2, Sheet 6)
    T3.15A 250V (Time Lag, 3.15 Amps, 250 Volts)
    (Littelfuse 02193.15MXAP (219XA Series, RoHS compliant))

    A spare fuse is located in the power input module.

Avoiding Electrical Shock and Fire-related Injury

- ⚠️ Always use the grounded power supply cord set provided to connect the system's power adapter to a grounded/earthed 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.

Electromagnetic Interference

To comply with FDA and CE/EU 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 its components (see the Technical Specifications appendix for more details).

Operational

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

- 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.

- This instrument is designed for operation in a laboratory environment (Pollution Degree I) that is free from mechanical vibrations, and electrical noise and transients.

- ⚠ DO NOT CONNECT OR DISCONNECT THE LQUID LIGHT GUIDE BETWEEN THE LAMBDA 721 AND MICROSCOPE ADAPTER (OR THE ADAPTER FROM THE MICROSCOPE) WHILE POWER IS ON.

- Operate this instrument only according to the instructions included in this manual.

- Do not operate if there is any obvious damage to any part of the instrument.

- ⚠ Do not operate this instrument near flammable materials. The use of any hazardous materials with this instrument is not recommended and, if undertaken, is done so at the users' own risk.

- ⚠ Do not operate if there is any obvious damage to any part of the instrument.

Avoiding Physical Injury while Powered up and Emitting Light

> ☀ *WARNING*
>
> *DO NOT LOOK DIRECTLY INTO THE OUTPUT OF THE LIGHT APERTURE MOUNTED ON THE CONTROLLER, THE CONNECTED LIQUID LIGHT GUIDE, OR THE ATTACHED MICROSCOPE ADAPTER! Always direct the output of the light aperture into the microscope using the appropriate adapters, directed away from anyone's eyes, and not directed toward any reflective surface.*

- ☀ INFRARED AND ULTRAVIOLET RADIATION: Possible infrared and ultraviolet radiation generated by this lamp can cause significant skin burns and eye damage.

Other

- Retain the original packaging for future transport of the instrument.
- Sutter Instrument reserves the right to change specifications without prior notice.
- This device is intended only for research purposes.

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1. INTRODUCTION

1.1 Introduction

The Lambda 721 is an illumination system designed for the rapid change of wavelength derived from up to seven light sources of different wavelengths combined into a single beam. The system comprises of two subsystems: controller with a built-in power supply and an array of seven LED cube and a liquid light guide or fiber couple. For the most part, this manual is organized around those subsystems to provide you with ready access to information, as you need it.

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 disclaimer and a series of cautionary and warning notes – it is important that these be read first. This first chapter 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 correct installation and operation. 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

Sutter Instrument Company at no charge provides unlimited technical support 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**. Furthermore, as this manual is currently under construction, if there are any areas that you feel should be covered in detail, we would like to hear from you.

1.2 General Description

Figure 1-1. Lambda 721 indicators, controls, and connectors.

The **Lambda 721** is a new concept for combining up to 7 separate LED cubes with different spectra into a single common output beam. The LED cubes contain the LED, collimating optics, and a filter. These LED cubes are easily exchanged and installed with no tools required. Each LED cube is collimated before entering the optical path through the bandpass filter. The filters for each LED cube also function as mirrors that reflect the collimated beams from the previous light sources. In the diagram below the optical paths are outlined for each position including the reflections that occur:

Traditionally, combining more than two light sources required the use of a dichroic ladder. Dichroic mirrors, which switch from transmission to reflection at one point in the spectrum, allow the combining of separate light sources, provided that those sources do not have overlapping wavelengths. The downside of this approach is that light sources cannot be easily changed. Dichroic ladders also demand careful attention to the order in which the light sources are introduced into the optical path to avoid having the light blocked by the next dichroic in line. Typically, additional bandpass filters must be added in front of each light source before the dichroic, to select the desired range of wavelengths for each source. Each filter and dichroic used in the ladder decreases the total light output of the system.
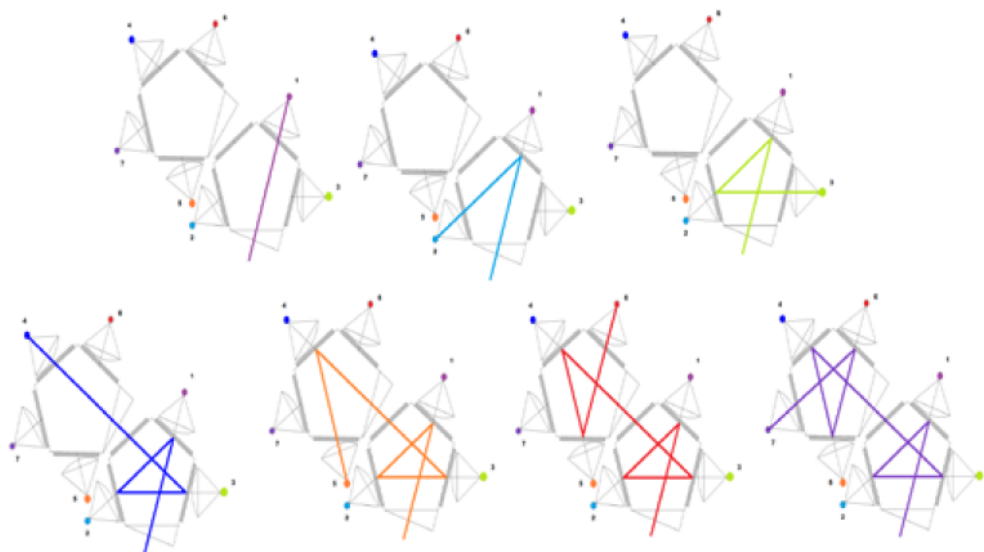
e 1-2. Stages of pass-through and reflection from each LED cube light source.

Dichroic ladders also demand careful attention to the order in which the light sources are introduced into the optical path to avoid having the light blocked by the next dichroic in line. Typically, additional bandpass filters must be added in front of each light source before the dichroic, to select the desired range of wavelengths for each source.

1.2.1 Features

- Easy to change the spectral output of the light source.
- Any LED cube can be placed in any of 7 positions without concern for the order.
- Wavelength selection and beam reflection using Semrock® STR Filters.

1.2.2 Common Applications

- Fluorescent microscopy
- Calcium imaging
- FURA
- Optogenetics
- High speed wavelength selection

The **Lambda 721** is designed to keep the size of the beam combiner small and the optical path short and efficient. Thin-film bandpass filters, such as Semrock's STR, reflect greater than 90% of out-of-band light. If the band pass of each light source does not overlap, it is possible to use the filters for both attenuation and reflection of the light from the other sources. By arranging the filters and sources into a double pentagon, we were able to combine seven light sources in a compact design with lower losses than previously achievable. As an added benefit, the last position in the optical train does not require any filter since no other input reflects

from that position. This position can be used with LED's that have broad spectral output, such as the 561nm LED, and may allow the excitation of more than single channel of fluorescence from a single LED. (raw spectra available upon request)

- The light from position #1 goes directly to the device output without being reflected. This position might be preferred for the source with the greatest desired output.
- The filter for the seventh light source is not used as a reflective surface and could be used with LED cubes with broader outputs.
- In configurations with fewer than 7 light sources, sources should be filled from lowest to highest number of reflections to ensure the greatest light output.
- This filter is installed at 18° angle-of-incidence to the collimated beam of the LED cube. This will cause a small shift in the band pass toward shorter wavelengths. While it would be ideal to have a coating optimized for this application, we have found that stock -STR filters can be used if you correct for the shift in the band pass when selecting the filters.
- The Lambda optical beam combiner is designed for flexibility and expandability. Should your illumination need change over time a simple configuration change and possibly additional filters can produce an entirely different output.

Figure 1-3. Lambda 721 LED Spectra Options.

2. INSTALLATION

2.1 Unpacking

The Lambda 721 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.

- Lambda 721 cabinet containing factory-installed power supply, control electronics, seven light source drivers, front-panel controls, and rear-panel external-control connectors.
- Seven LED cube modules with optics and filter for the following wavelength (nanometers): 340, 365, 385, 410, 440, 460, 480, 480 Narrow Band, 506, 506 Narrow Band, 530, 561, 590, 617, 630, 660, 740, 850, or 940. Each cube's optics (mirror & filter) are especially installed and aligned according to the LED's wavelength chosen.
- Power Cord
- 3mm Liquid Light Guide with dovetail C-mount extension or SMA fiber optic cable and adapter
- Small Zeiss female dovetail
- USB Interface Cable
- Manual
- One or more additional LED cube assemblies containing different wavelength LEDs (if ordered)
- Microscope adapters (if ordered)

2.2 Getting Started

1. Turn the power switch to the OFF ("0") position.
2. Plug power cable into the mains outlet.
3. Connect the optical output directly to the microscope via the appropriate adapter or to a liquid light guide, as appropriate.
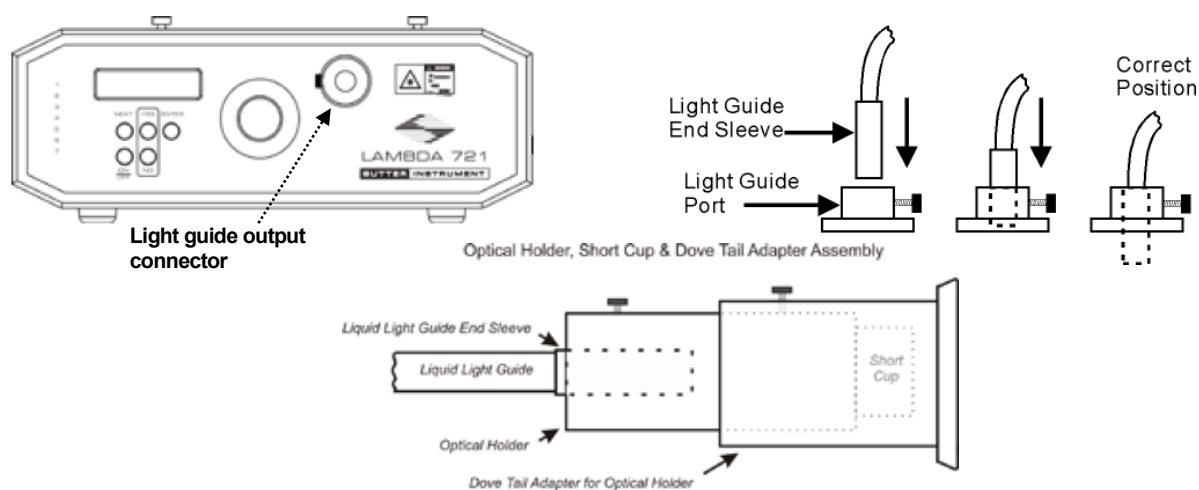
Figure 2-1. Light guide installation.

4. Power up the Lambda 721 rocking the power switch (rear panel) upwards in "1" position.

Power input module: Receptacle, fuse, & switch
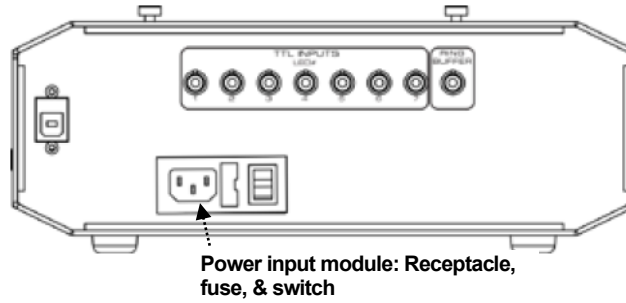
Figure 2-2. Rear panel showing power entry module receptacle and switch.

 WARNING: DO NOT LOOK DIRECTLY INTO THE LIGHT GUIDE! The output of the light or the light guide should be directed into the microscope using the appropriate adapters, directed away from anyone's eyes, and not directed toward any reflective surface.

5. Refer to the Operations chapter for instructions on turning on the Lambda 721, operating the controls on the front panel, and making connections to the rear panel.

2.3 Configuration

The Lambda 721 is shipped with the LED cube configuration set as ordered. The unit can be operated manually and many of its features can be demonstrated without having to make any TTL input, Ring Buffer strobe, or USB connections. After first exploring the manual operation of the Lambda 721, you may wish to configure the unit by connecting the TTL inputs for all seven LED channels, the Ring Buffer strobe input, and USB communications interface for external computer control. The following figures show the locations of these connectors on the rear panel of the unit, followed by the location of the configuration switches and their definitions. It is recommended that operating the unit with the factory-default settings for the configuration switches, as shown in the table.
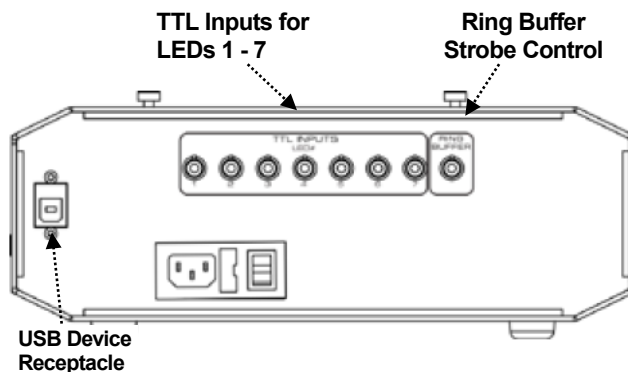
Figure 2-1. Rear panel showing connectors for TTL input for all 7 LED channels, Ring Buffer strobe input, and USB for external control.
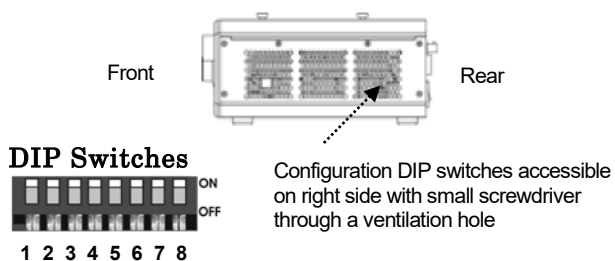
Figure 2-2. Left-side panel and DIP switches.

Table 2-1. Configuration Switches 1 – 8 definitions.

Sw #	Definition	State	Setting	Position
1	TTL level state on power-up	**Low***	**Off***	**Up***
		High	On	Down
2	I/O interface return of data from Lambda 10-3 "Get Controller Type & Config." and "Get Status" commands (Ver. 1.26+)	**Enabled***	**Off***	**Up***
		Disabled	On	Down
3	Camera Mode while running the Ring Buffer	**Disabled: Stays ON until next strobe***	**Off***	**Up***
		Enabled: Turns OFF before next strobe	On	Down
4	I/O interface return of current Ring Buffer entry LED number(s) while Ring Buffer is running	**Enabled***	**Off***	**Up***
		Disabled	On	Down
5	Select data ("Baud") rate for I/O interface	**9600 bps***	**Off***	**Up***
		57600 bps	On	Down
6	Reserved		**Off***	**Up***
7	Reserved		**Off***	**Up***
8	Allow setting of maximum current for each LED on power up	**Disabled***	**Off****	**Up***
		Enabled	On	Down

Factory default setting.

3. OPERATIONS

This chapter describes the operation of the Lambda 721. The locations of the individual indicators, controls, and connectors are indicated in the following figure.
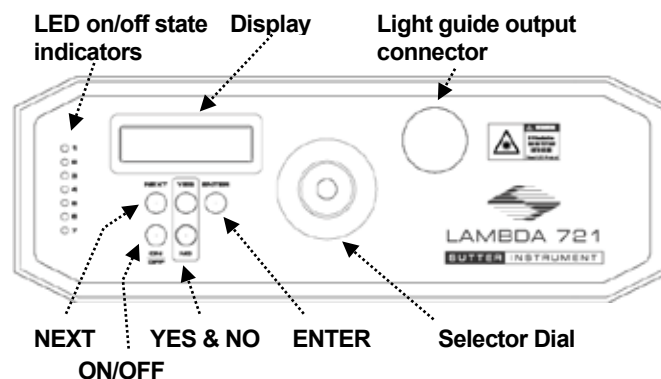
Figure 3-1. Locations of individual indicators, controls, and connectors on the Lambda 721 controller front panel.
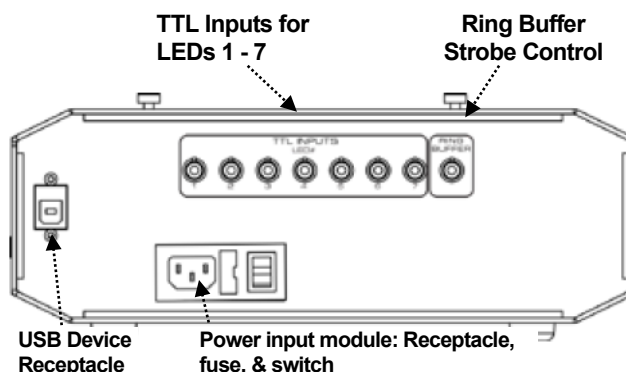
Figure 3-2. Locations of power switch and individual connectors on the Lambda 721 controller rear panel.

3.1 Controls

3.1.1 Power Switch

Main power switch turns unit off/on.

3.2 Indicators

3.2.1 LED On/Off State Indicators

The LED on/off state indicators are located vertically, LED 1 through 7 top to down, on the left side of the front panel.

3.3 Connectors

3.3.1 Light Beam Combiner Output

Provides the interface between the combined light source output to a microscope or liquid light/fiber guide.

3.3.1 TTL Inputs (LED # 1 – 7) BNC Connectors

LED 1 through 7 TTL input controls.

3.3.1 Ring Buffer BNC Connector

Used as a strobe to step through the ring buffer.

3.3.2 USB Device Interface Connector

Provides the interface for controlling the Lambda 721 by computer via USB connection.

3.4 Operation

The arrangement of the LED cubes in the Lambda 721 allows for up to seven light sources with differing spectral output to be combined and delivered on a common output light path. While LED cube arrangement has many possible uses, the Lambda 721 provides a means by which one can rapidly select any one of up to seven different LEDs as the output.

On power up, the following two screens are displayed momentarily.

```
  Sutter
Instrument
```

Figure 3-3. Startup screen.

```
   721
Rev. 1.2
```
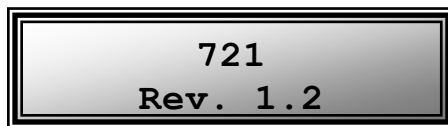
Figure 3-4. Product and firmware revision screen.

The next item displayed is a prompt for the last-used mode: Lambda 10, TTL, or Ring Buffer mode. When starting the Lambda 721 for the first time, the prompt for Lambda 10 mode is displayed as shown in the following figure.

```
LAMBDA 10 MODE?
PRESS YES OR NO
```

Figure 3-5. Lambda 10 Mode prompt.

Described next is the Lambda 10 mode, followed by the TTL Mode, Ring Buffer Mode, Setup Mode, and Demo Mode

3.1 Lambda 10 Mode

The Lambda 10 Mode is a mode in which the Lambda 721 responds to the Sutter Instrument Lambda 10-x Series (Lambda 10-2, Lambda 10-3, Lambda 10-B, etc.) filter wheel external commands to the control the ON/OFF state of each of the Lambda 721's seven LEDs.

```
LAMBDA 10 MODE?
PRESS YES OR NO
```

Figure 3-6. Lambda 10 Mode prompt.

Pressing YES places the Lambda 721 into Lambda 10 Mode, as shown in the following figure. Pressing NO, causes the next mode prompt (TTL Mode) to display, described next.

```
USING LEDS 1 - 7
PRESS OFF TO END
```

Figure 3-7. Lambda 10 Mode screen

3.1.1 Control Operations

The Lambda 10 Series commands that can be sent while in the Lambda 10 Mode, are described in the External Control chapter.

NOTE: It is recommended that the compatible Lambda 10 series filter wheel movement commands are sent to the Lambda 721 only while in Lambda 10 Mode.

3.1.2 Mode Exit

To exit Lambda 10 Mode, press the OFF button. Upon exiting Lambda 10 Mode, the display is updated with the TTL Mode prompt, described next.

3.1 TTL Mode

The TTL Mode is a mode in which the ON/OFF state of each of the seven LED channels can be controlled by TTL signaling via the connections to one or more of the seven TTL Input connectors on the rear panel.

```
USE TTL MODE?
PRESS YES OR NO
```
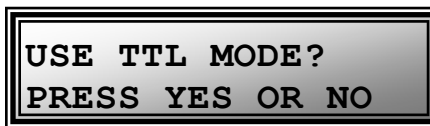
Figure 3-8. Use TTL Mode prompt.

Pressing YES places the Lambda 721 into TTL Mode, as shown in the following figure. Pressing NO, causes the next mode prompt (Ring Buffer Mode) to display, described next.

```
PRESS ENTER TO
START TTL MODE
```

Figure 3-9. TTL Mode start screen.

Pressing ENTER places the Lambda 721 into TTL Mode, as shown in the following figure.

```
TTL MODE RUNNING
OFF TO STOP
```

Figure 3-10. TTL Mode running screen.

3.1.1 Control Operations

The state of an LED is ON when its corresponding TTL input receives a TTL "high" signal and is OFF with a TTL "low". This is the factory-default operation. The signaling can reconfigured to be the opposite (ON with a TTL low, and OFF with a TTL high) via a switch setting (see the Configuration section in Installation chapter).

3.1.1 Mode Exit

Pressing OFF returns to the TTL Mode prompt. Pressing NO while at the TTL Mode prompt, results in displaying the Ring Buffer Mode prompt, described next.

3.2 Ring Buffer Mode

The Ring Buffer Mode is a mode in which the ON/OFF state of each of the seven LED channels can be controlled by a series of programmable settings that are sequenced by TTL signaling (strobing) to the RING BUFFER input on the rear panel when the Ring Buffer is run.

```
USE RING BUFFER?
PRESS YES OR NO
```

Figure 3-11. Use Ring Buffer prompt.

Pressing YES places the Lambda 721 into Ring Buffer Mode, asking if the current Ring Buffer should be run, as shown in the following figure. Pressing NO, causes the next mode prompt (Setup Mode) to display, described next.

```
RUN EXISTING
RING BUFFER? Y/N
```

Figure 3-12. Run existing Ring Buffer prompt.

Pressing YES runs the existing Ring Buffer. Pressing NO, displays the edit Ring Buffer prompt, described next.

```
RB MODE RUNNING
OFF TO STOP
```

Figure 3-13. Ring buffer running screen.

3.2.1 Running the Ring Buffer Control Operations

The state of an LED is ON when its corresponding TTL input receives a TTL "high" signal and is OFF with a TTL "low". This is the factory-default operation. The signaling can reconfigured to be the opposite (ON with a TTL low, and OFF with a TTL high) via a switch setting (see the Configuration section in Installation chapter).

3.2.2 Stopping the Ring Buffer Run

Pressing OFF stops the ring buffer from running and returns the displaying the Use Ring Buffer prompt.

3.2.1 Editing the Ring Buffer

If pressing NO in response to the Run Existing Ring Buffer prompt, the Edit Ring Buffer prompt is displayed.

```
EDIT RING BUFFER
PRESS YES OR NO
```

Figure 3-14. Edit ring buffer query screen.

Pressing NO, causes the unit to enter Setup Mode. Pressing YES, displays the Ring Buffer edit screen, showing Ring Buffer Entry 1,

```
RB 1 LED 2
NEXT/ENTER/OFF
```
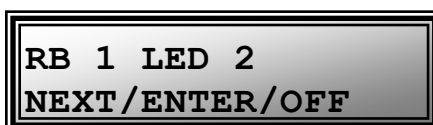
Figure 3-15. Ring buffer entry #1 screen.

The selector knob adjusts the current entry for All Off, LED 1 through 7, and End RB.

If RB entry is empty (undefined), then it is declared as "End RB".

Selecting "End RB" for an entry sets the end of the Ring Buffer.

Pressing NEXT advances to the next entry without saving any changes to the current entry.

Pressing ENTER saves any change to the entry, and advances to the next entry.

Up to 100 entries are supported in the Ring Buffer. The 100th entry must contain "End RB".

Pressing OFF, exits Ring Buffer Edit mode and enters Setup mode.

3.1 Setup Mode

```
SETUP MODE?
PRESS YES OR NO
```

Figure 3-16. Setup Mode prompt screen.

```
LED#1   PWM =100%
OFF     Amp =  1.0
```

Figure 3-17. Edit ring buffer query screen.

Knob (turn slowly) adjusts PWM down from 100% to 0%.

ON turns on LED ("ON" on screen); OFF turns it off ("OFF" on screen).

NEXT advances to the next LED without saving any adjustments to the power level.

ENTER saves any adjustment to the LED's power level, and advances to the next LED. Pressing ENTER on LED 7, exits Setup Mode and the Use Ring Buffer prompt is then displayed.

3.1 Demo Mode

```
USE DEMO MODE?
PRESS YES OR NO
```

Figure 3-18. Demo Mode prompt screen.

Pressing YES displays the following screen. Pressing NO causes the display to loop back to the Lambda 10 Mode prompt.

```
PRESS ENTER TO
START DEMO MODE
```

Figure 3-19. Enter Demo Mode prompt screen.

Pressing ENTER starts running the demo.

```
DEMO RUNNING
OFF TO STOP
```

Figure 3-20. Demo Mode running screen.

Pressing OFF stops the Demo Mode from running, returning the display to the Lambda 10 Mode prompt.

4. EXTERNAL CONTROL OPERATIONS

Controlling the Lambda 721 externally via computer is accomplished by sending commands over the USB interface between the computer and the relevant connector on the rear panel of the Lambda 721 controller.

4.1 USB Interface

The USB device driver for Windows is downloadable from Sutter Instrument's web site (www.sutter.com). The Lambda 721 requires USB CDM (Combined Driver Model) Version 2.10.00 or higher. The CDM device driver for the Lambda 721 consists of two device drivers: 1) USB device driver, and 2) VCP (Virtual COM Port) device driver. Install the USB device driver first, followed by the VCP device driver. The VCP device driver provides a serial RS-232 I/O interface between a Windows application and the Lambda 721. Although the VCP device driver is optional, its installation is recommended even if it is not going to be used. Once installed, the VCP can be enabled or disabled.

The CDM device driver package provides two I/O methodologies over which communications with the Lambda 721 can be conducted: 1). USB Direct, or 2). Serial RS-232 asynchronous via the VCP device driver. The first method requires that the VCP device driver be disabled (or not installed). The second method requires that the VCP be installed and enabled.

4.1.1 Virtual COM Port (VCP) Serial Port Settings

The following table lists the required RS-232 serial settings for the COM port (COM3, COM5, etc.) generated by the installation of the VCP device driver.

Table 4-1. USB-VCP interface serial port settings.

Property	Setting
Data ("Baud") Rate (bits per second (bps)) (Configurable with rear-panel DIP Switch 5.)	**9600***, 57600
Data Bits	8
Stop Bits	1
Parity	None
Flow Control	None

* Factory default setting.

The settings shown in the above table can be set in the device driver's properties (via the Device Manager if in Windows) and/or programmatically in your application.

4.2 Handshaking

Command sequences do not have terminators. If a command sequence just sent to the controller is determined to be valid, the entire sequence is immediately echoed back to the computer. All commands return an ASCII CR (Carriage Return; 13 decimal, 0D hexadecimal) to indicate that the task associated with the command has completed. When the Lambda 721 completes the task associated with a command, it sends an ASCII CR back to the host computer indicating that it is ready to receive a new command. If a command returns data, the last byte returned is the task-completed indicator.

4.3 Commands

Each command sequence consists of at least one byte, the first of which is the "command byte". Those commands that have parameters or arguments require a sequence of bytes that follow the command byte. No delimiters are used between command sequence arguments. Every command and command sequence ends with a terminator byte containing an ASCII CR (13 decimal, 0D hexadecimal). Although most command bytes can be expressed as ASCII displayable/printable characters, the rest of a command sequence must always be expressed as a sequence of unsigned byte values (0-255 decimal; 00 – FF hexadecimal, or 00000000 – 11111111 binary). Each byte in a command sequence being transmitted to the controller must contain an unsigned binary value. Attempting to code command sequences as "strings" is not advisable. Any command data being returned from the controller must also be received and initially treated as a sequence of unsigned byte values. Groups of contiguous bytes can later be combined to form larger values, as appropriate (e.g., 2 bytes into 16-bit "word" or "short", or 4 bytes into a 32-bit "long" or "double word"). For the Lambda 721, all Ring Buffer entry values are stored as "unsigned short" (16-bit) values. A 16-bit value is transmitted and received to and from the controller as two contiguous bytes.

"Unsigned" means the value can only be positive; negative values are not permitted. A U16 consists of two contiguous bytes, with a byte/bit-ordering format of Little Endian ("Intel") (most significant byte (MSB) in the first byte and least significant (LSB) in the last byte). If the platform on which your application is running is Little Endian, then no byte order reversal of Ring Buffer entry values is necessary. Examples of platforms using Little Endian formatting include any system using an Intel processor (including Microsoft Windows and Apple Mac OS X), and most Linux distributions running on Intel/AMD processor-based systems.

If the platform on which your application is running is "Big Endian" ("Motorola"), then these U16 position values must have their bytes reverse-ordered <u>after</u> receiving from, or <u>before</u> sending to, the Lambda 721. Examples of Big-Endian platforms include most all non-Intel-based systems, LabVIEW (regardless of system & operating system), and Java (programming language/environment).

4.3.1 Lambda 10-x Mode ('L' or 'l') Command

This command is the external-control equivalent to answering YES in response to the "LAMBDA 10 MODE?" prompt on the display.

Table 4-2. Lambda 10-x Mode ('L' or 'l') Command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	1	0	76 or 108	4C or 63	0100 1100 or 0110 1100	0076 or 0108		'L' or 'l'	Places Lambda 721 into Lambda 10-x compatibility mode.
Rx	All	1	12	13	0D	0000 1101			<CR>	Completion indicator

4.3.1.1 <u>Lambda 10 Series Compatible LED Selection Commands</u>

While in Lambda 10-x Mode, the Lambda 721 will respond to the Lambda 10-x Series filter wheel commands for Wheel A, Speed 0, Filter Positions 0 through 7, where Position 0 turns all LEDs off, and Positions 1 through 7 correspond to LEDs 1 through 7. The LED ON/OFF

state is mutually exclusive, meaning that for any LED that is turned on, all other LEDs are turned off.

NOTE: It is recommended that the compatible Lambda 10 series filter wheel movement commands are sent to the Lambda 721 only while in Lambda 10 Mode.

Table 4-3. Lambda 10 Series compatible LED selection commands.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-keypad #	Ctrl-code	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	1	0	0	00	00000000	0000	^@	`<NUL>`	**Turn all LEDs off.**
Rx	All	2	0	0	00	00000000		^@	`<NUL>`	Command echo
			1	13	0D	0000 1101		^M	`<CR>`	Completion indicator
Tx	All	1	0	1	01	00000001	0001	^A	`<SOH>`	**Turn LED 1 on**
Rx	All	2	0	1	01	00000001		^A	`<SOH>`	Command echo
			1	13	0D	0000 1101		^M	`<CR>`	Completion indicator
Tx	All	1	0	2	02	00000010	0002	^B	`<STX>`	**Turn LED 2 on**
Rx	All	2	0	2	02	00000010		^B	`<STX>`	Command echo
			1	13	0D	0000 1101		^M	`<CR>`	Completion indicator
Tx	All	1	0	3	03	00000011	0003	^C	`<ETX>`	**Turn LED 3 on**
Rx	All	2	0	3	03	00000011		^C	`<ETX>`	Command echo
			1	13	0D	0000 1101		^M	`<CR>`	Completion indicator
Tx	All	1	0	4	04	00000100	0004	^D	`<EOT>`	**Turn LED 4 on**
Rx	All	2	0	4	04	00000100		^D	`<EOT>`	Command echo
			1	13	0D	0000 1101		^M	`<CR>`	Completion indicator
Tx	All	1	0	5	05	00000101	0005	^E	`<ENQ>`	**Turn LED 5 on**
Rx	All	2	0	5	05	00000101		^E	`<ENQ>`	Command echo
			1	13	0D	0000 1101		^M	`<CR>`	Completion indicator
Tx	All	1	0	6	06	00000110	0006	^F	`<ACK>`	**Turn LED 6 on**
Rx	All	2	0	6	06	00000110		^F	`<ACK>`	Command echo
			1	13	0D	0000 1101		^M	`<CR>`	Completion indicator
Tx	All	1	0	7	07	00000111	0007	^G	`<BEL>`	**Turn LED 7 on**
Rx	All	2	0	7	07	00000111		^G	`<BEL>`	Command echo
			1	13	0D	0000 1101		^M	`<CR>`	Completion indicator

NOTE: All Lambda 10 Mode commands for the Lambda 721 correspond to the Lambda 10 series filter wheel movement for Wheel A, Speed 0, Positions 1 – 7. Any other wheel-select, speed settings, and positions 8 – 9 are not supported. Values 1 through 7 correspond to LEDs 1 – 7. Value 0, used to turn all LEDs off, can be used as the equivalent of closing Shutter A.

While in Lambda 10-x Mode, the Lambda 721 will also respond ASCII <u>digits</u> 0 through 7, as equivalents to <u>values</u> 0 through 7 (see the next table). (These are equivalent to the Lambda 10-x Series commands for Wheel A, Speed 3, Filter Positions 0 through 7.)

Table 4-4. LED selection commands using ASCII digits.

Tx/- Delay/- Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt- key- pad #	Ctrl- code	ASCII def./- char.	Description
				Dec.	Hex.	Binary				
Tx	All	1	0	48	30	00110000	0048		**0**	**Turn all LEDs off.**
Rx	All	2	0	48	30	00110000	0048		0	Command echo
			1	13	0D	0000 1101		^M	<CR>	Completion indicator
Tx	All	1	0	49	31	00110001	0049		**1**	**Turn LED 1 on**
Rx	All	2	0	49	31	00110001	0049		1	Command echo
			1	13	0D	0000 1101		^M	<CR>	Completion indicator
Tx	All	1	0	50	32	00110010	0050		**2**	**Turn LED 2 on**
Rx	All	2	0	50	32	00110010	0050		2	Command echo
			1	13	0D	0000 1101		^M	<CR>	Completion indicator
Tx	All	1	0	51	33	00110011	0051		**3**	**Turn LED 3 on**
Rx	All	2	0	51	33	00110011	0051		3	Command echo
			1	13	0D	0000 1101		^M	<CR>	Completion indicator
Tx	All	1	0	52	34	00110100	0052		**4**	**Turn LED 4 on**
Rx	All	2	0	52	34	00110100	0052		4	Command echo
			1	13	0D	0000 1101		^M	<CR>	Completion indicator
Tx	All	1	0	53	35	00110101	0053		**5**	**Turn LED 5 on**
Rx	All	2	0	53	35	00110101	0053		5	Command echo
			1	13	0D	0000 1101		^M	<CR>	Completion indicator
Tx	All	1	0	54	36	00110110	0054		**6**	**Turn LED 6 on**
Rx	All	2	0	54	36	00110110	0054		6	Command echo
			1	13	0D	0000 1101		^M	<CR>	Completion indicator
Tx	All	1	0	55	37	00110111	0055		**7**	**Turn LED 7 on**
Rx	All	2	0	55	37	00110111	0055		7	Command echo
			1	13	0D	0000 1101		^M	<CR>	Completion indicator

4.3.1 TTL Mode ('T' or 't') Command

This command is the external-control equivalent to answering YES in response to the "TTL MODE?" prompt on the display.

Table 4-5. TTL Mode ('T' or 't') Command.

Tx/- Delay/- Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt- key- pad #	Ctrl- char	ASCII def./- char.	Description
				Dec.	Hex.	Binary				
Tx	All	1	0	84 or 116	54 or 74	0101 0100 or 0111 0100	0084 or 0116		'T' or 't'	Places Lambda 721 into TTL mode.
Rx	All	1	12	13	0D	0000 1101			<CR>	Completion indicator

4.3.1 Start Ring Buffer Run ('R' or 'r') Command

This command is the external-control equivalent to answering YES in response to the "USE RING BUFFER?" → "RUN EXISTING RING BUFFER?" prompts on the display.

Table 4-6. Start Ring Buffer Run ('R' or 'r') Command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value Dec.	Value Hex.	Value Binary	Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
Tx	All	1	0	82 or 114	52 or 72	0101 0010 or 0111 0010	0082 or 0114		'R' or 'r'	Start running the ring buffer.
Rx	All	1	0	13	0D	0000 1101			<CR>	Completion indicator

Each TTL pulse on the RING BUFFER STROBE input (BNC connector on the rear panel of the unit) will cause the next ring buffer entry to "play" until the last entry that is defined (containing "RB END"), and then loop back to the beginning of the ring buffer. The ring buffer can consist of up to 100 entries.

4.3.1.1 Return Values while Running the Ring Buffer

Table 4-7. Return values while running the Ring Buffer.

LED On/Off State	Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value Dec.	Value Hex.	Value Binary	ASCII def./-char.
LED 1 On	**Rx**	All	1	0	49	31	0011 0001	'1'
LED 2 On	**Rx**	All	1	0	50	32	0011 0010	'2'
LED 3 On	**Rx**	All	1	0	51	33	0011 0011	'3'
LED 4 On	**Rx**	All	1	0	52	34	0011 0100	'4'
LED 5 On	**Rx**	All	1	0	53	35	0011 0101	'5'
LED 6 On	**Rx**	All	1	0	54	36	0011 0110	'6'
LED 7 On	**Rx**	All	1	0	55	37	0011 0111	'7'

NOTE: The return of the values shown in the table while running the ring buffer is contingent DIP Switch 4 being set to the ON (down) position.

4.3.1 Stop TTL Mode or Ring Buffer Run ('O' or 'o') Command

This command stops TTL Mode or if the Ring Buffer is running. It is the external-control equivalent to pressing the OFF button when the unit is in TTL Mode or when the Ring Buffer is running.

Table 4-8. Stop TTL Mode or Ring Buffer Run ('O' or 'o') Command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value Dec.	Value Hex.	Value Binary	Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
Tx	All	1	0	79 or 111	4F or 6F	0100 1111 or 0110 1111	0079 or 0111		'O' or 'o'	Stop TTL Mode or Buffer Ring run.
Rx	All	1	0	13	0D	0000 1101			<CR>	Completion indicator

If the RING BUFFER STROBE input is disconnected before or after starting the Ring Buffer Run (manually or via 'R'/'r' command), the stopping the ring buffer with the 'O'/'o' command will fail until the strobe is reconnected.

4.3.1 Load Ring Buffer ('B' or 'b') Command

This command begins the ring buffer loading sequence. Once sent, the Lambda 721 waits to receive up to 100 two-byte entry values until the Stop Loading Ring Buffer value is received.

Table 4-9. Load Ring Buffer ('B' or 'b') Command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	1	0	66 or 98	42 or 62	0100 0010 or 0110 0010	0066 or 0098		'B' or 'b'	Begin loading the ring buffer.
		2 – 200	1 – 199	Each two-byte ("word") value that follows is the entry for the position, and what follows after is for the next entry (see the *Ring Buffer Entry Values* table), until F0F0 hexadecimal is sent, which stops the loading of the ring buffer. Up to 100 entries are supported.						
Rx	All	1	0	13	0D	0000 1101			<CR>	Completion indicator is returned after the Stop Loading Ring Buffer entry (see next) is sent, effectively ending the command sequence.

4.3.1.1 'B' or 'b' Command Stop Loading Ring Buffer Entry Value

This ring buffer entry value stops the ring buffer loading sequence and marks the end of the ring buffer. Once sent, the 'B' or 'b' command sequence ends and a completion indicator is returned.

Table 4-10. 'B' or 'b' Command Stop Loading the Ring Buffer entry value.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	2	0	240	F0	1111 0000	0240			Stop loading the ring buffer.
			1	240	F0	1111 0000	0240			
Rx	All	1	0	13	0D	0000 1101			<CR>	Completion indicator

4.3.1.1 'B' or 'b' Command Ring Buffer Entry Values

This ring buffer entry value stops the ring buffer loading sequence and marks the end of the ring buffer. Once sent, the 'B' or 'b' command sequence ends, and a completion indicator is returned.

Table 4-11. 'B' or 'b' Command Ring Buffer entry values.

LED On/Off State	Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	16-bit "Word" value (Little Endian)		
					Dec.	Hex.	Binary				Dec.	Hex.	Binary
All Off	**Tx**	All	2	0	0	00	0000 0000	0000	^@	<NUL>	8	0008	00000000 00001000
				1	8	08	0000 1000	0008	^H	<BS>			

LED On/Off State	Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-keypad #	Ctrl-char	ASCII def./-char.	16-bit "Word" value (Little Endian)		
					Dec.	Hex.	Binary				Dec.	Hex.	Binary
LED 1 On	Tx	All	2	0	1	01	0000 0001	0001	^A	<SOH>	272	0110	00000001 00010000
				1	16	10	0001 0000	0016	^P	<DLE>			
LED 2 On	Tx	All	2	0	2	02	0000 0010	0002	^B	<STX>	536	0218	00000010 00011000
				1	24	18	0001 1000	0024	^X	<CAN>			
LED 3 On	Tx	All	2	0	4	04	0000 0100	0004	^D	<EOT>	1056	0420	00000100 00100000
				1	32	20	0010 0000	0032		space			
LED 4 On	Tx	All	2	0	8	08	0000 1000	0008	^H	<BS>	2088	0828	00001000 00101000
				1	40	28	0010 1000	0040		(			
LED 5 On	Tx	All	2	0	16	10	0001 0000	0016	^P	<DLE>	4144	1030	00010000 00110000
				1	48	30	0011 0000	0048		0			
LED 6 On	Tx	All	2	0	32	20	0010 0000	0032		space	8248	2038	00100000 00111000
				1	56	38	0011 1000	0056		8			
LED 7 On	Tx	All	2	0	64	40	0100 0000	0064		@	16448	4040	01000000 01000000
				1	64	40	0100 0000	0064		@			
End of Ring Buffer	Tx	All	2	0	240	F0	1111 0000	0240		≡	61680	F0F0	11110000 11110000
				1	240	F0	1111 0000	0240		≡			
	Rx	All	1	1	13	0D	0000 1101		^M	<CR>	Completion indicator		

NOTE: The 'B' or 'b' command and each 2-byte Ring Buffer entry, once transmitted, does not return anything, except for End of Ring Buffer which returns an ASCII CR (carriage return) completion indicator (13 decimal, 0D hexadecimal, 0000 1101 binary).

4.3.1 Turn on a discrete LED or a group of LEDs ('M' or 'm') Command

Command followed by 1 byte containing the bit-encoded ON/OFF states of all LEDs (1 – 7).

Table 4-12. Change the on/off state of one or more LEDs ('M' or 'm') Command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-keypad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	2	0	77 or 109	4D or 6D	01001101 or 01101101	0077 or 0109		'M' or 'm'	Command followed by 1 byte containing the bit-encoded ON/OFF states of all LEDs (1 – 7).
			1	0 – 127	00 – 7F	00000000 – 01111111	0000 – 0127	^@ –	<NUL> – <DEL>	See *'M' Command 1st argument (2nd byte) values for individual LED ON/OFF state bit encoding* for a discrete LED value or *'M' Command 1st argument (2nd byte) values for ON/OFF state bit encoding for all LEDs and groups* for an LED group value.
Rx	All	1	1	13	0D	0000 1101		^M	<CR>	Completion indicator

4.3.1 Set LED Power Level ('P' or 'p') Command

Command followed by one byte containing the LED number (1 – 7) and a second byte containing the power level (0 through 100 percent).

Table 4-13. Set LED Power Level ('P' or 'p') Command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	3	0	80 or 112	50 or 70	0101 0000 or 0111 0000	0080 or 0112		'P' or 'p'	Sets the power level (0 – 100%) for a specified LED.
			1	1 – 7	01 – 07	0000 0001 – 0000 0111	0001 – 0007	^A – ^G	<SOH> – <BEL>	LED number (1 – 7)
			2	1 – 100	01 – 64	0000 0001 – 0110 0100	0001 – 0100	^A –	<SOH> – 'd'	Power level (1 – 100%)
Rx	All	3	1	1 – 7	01 – 07	0000 0001 – 0000 0111	0001 – 0007		<SOH> – <BEL>	Echoed LED number (1 – 7)
			2	1 – 100	01 – 64	0000 0001 – 0110 0100	0001 – 0100		<SOH> – 'd'	Echoed power level (1 – 100%)
			0	13	0D	0000 1101			<CR>	Completion indicator

4.3.1 Get LED ON/OFF Status ('S' or 's') Command

Command returns an ASCII digit for every LED that is currently on (in 1 – 7 order).

Table 4-14. Get LED ON/OFF Status ('S' or 's') Command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	All	1	0	83 or 115	53 or 73	0101 0011 or 0111 0011	0083 or 0115		'S' or 's'	Returns a value of 0 (all LEDs off), or one or more ASCII digits ('1' – '7') for each LED that is ON.
Rx	All	2 – 8	0	0 or 49 – 55	00 or 31 – 37	0000 0000 or 0011 0001 – 0011 0111			<NUL> or '1' – '7'	Value 0 for all LEDs OFF, or ASCII digit '1' – '7' for each LED that is ON, in that order (1 to 7 bytes).
			1 – 8	13	0D	0000 1101			<CR>	Completion indicator

4.3.1 Get Lambda 10-3 Compatible Controller Type and Configuration Command

Returns a Lambda 10-3 compatible data block containing controller type identifier, and filter wheel /shutter configuration information.

NOTE: *The "**Get Lambda 10-3 Compatible Controller Type and Configuration**" command is provided to allow external-control software originally written for the Lambda 10-3 to control a Lambda 721 while identifying itself as a Lambda 10-3. All data returned is static (i.e., data*

remains unchanged regardless of all Lambda 721 states). This command is functional only if DIP Switch 2 is OFF (up).

Table 4-15. Get Lambda 10-3 Compatible Controller Type and Configuration Command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	1.26+	1	0	253	FD	1111 1101	0253			Returns a Lambda 10-3 compatible data block containing controller type identifier, and filter wheel /shutter configuration information. (See note.)
Rx	1.26+	31	0	253	FD	1111 1101				Command echo
			1 (4)	49	31	0011 0001			1	"10-3" (controller type is Lambda 10-3)
				48	30	0011 0000			0	
				45	2D	0010 1101			–	
				51	33	0011 0011			3	
			5 (5)	87	57	0101 0111			W	"WA-25" (Filter Wheel A is a 10-position wheel with 25mm filters)
				65	41	0100 0001			A	
				45	2D	0010 1101			–	
				50	32	0011 0010			2	
				53	35	0011 0101			5	
			10 (5)	87	57	0101 0111			W	"WB-NC" (Filter Wheel B is not connected)
				66	42	0100 0010			B	
				45	2D	0010 1101			–	
				78	4E	0100 1110			N	
				67	43	0100 0011			C	
			15 (5)	87	57	0101 0111			W	"WC-NC" (Filter Wheel C is not connected)
				67	43	0100 0011			C	
				45	2D	0010 1101			–	
				78	4E	0100 1110			N	
				67	43	0100 0011			C	
			20 (5)	83	53	0101 0011			S	"SA-VS" (Shutter A is not connected or is a standard shutter (not a SmartShutter))
				65	41	0100 0001			A	
				45	2D	0010 1101			–	
				86	56	0101 0110			V	
				83	53	0101 0011			S	
			25 (5)	83	53	0101 0011			S	"SB-VS" (Shutter B is not connected or is a standard shutter (not a SmartShutter))
				66	42	0100 0010			B	
				45	2D	0010 1101			–	
				86	56	0101 0110			V	
				83	53	0101 0011			S	
			30	13	0D	0000 1101			<CR>	Completion indicator

4.3.1 Get Lambda 10-3 Compatible Status Command

Returns a Lambda 10-3 compatible data block containing filter wheel and shutter status information.

*NOTE: The "**Get Lambda 10-3 Compatible Status**" command is provided to allow external-control software originally written for the Lambda 10-3 to control a Lambda 721 while identifying itself as a Lambda 10-3. All data returned is static (i.e., data remains unchanged*

regardless of all Lambda 721 states). This command is functional only if DIP Switch 2 is OFF (up).

Table 4-16. Get Lambda 10-3 Compatible Controller Type and Configuration Command.

Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
				Dec.	Hex.	Binary				
Tx	1.26+	1	0	204	CC	1100 1100	0204			Returns a Lambda 10-3 compatible data block containing filter wheel and shutter status information.
Rx	1.26+	13	0	204	CC	1100 1100				Command echo
			1	16	10	0001 0000				Wheel A, Speed 1, Pos. 0
			2	138	8A	1000 1010				Wheel B, Speed 0, Pos. 10
			3 (2)	252	FC	1111 1100				Wheel C prefix byte
				10	0A	0000 1010				Wheel C, Speed 0, Pos. 10
			5	172	AC	1010 1100				Shutter A closed
			6	188	BC	1011 1100				Shutter B closed
			7 (2)	219	DB	1101 1011				Shutter A mode: N/A
				1	01	0000 0001				Shutter A designator
			9 (2)	219	DB	1101 1011				Shutter B mode: N/A
				2	02	0000 0010				Shutter B designator
			11	13	0D	0000 1101			<CR>	Completion indicator
			12	13	0D	0000 1101			<CR>	Completion indicator

5. MAINTENANCE AND RECONFIGURATION

5.1 Routine Maintenance

Routine cleaning of the Lambda 721 system is required to prevent excessive dust accumulations. Wipe all exterior surfaces with a dry, soft, cotton cloth.

Periodically inspect all cables ensuring that all connections are made well, and connectors are evenly seated.

5.2 Reconfiguration

5.2.1 Replacing and Installing New LED Cubes

The following figure shows the placement of each LED cube according to its channel: 1 through 7.

LED Cubes Placement
(Top view, with LED cube hatch cover removed.)
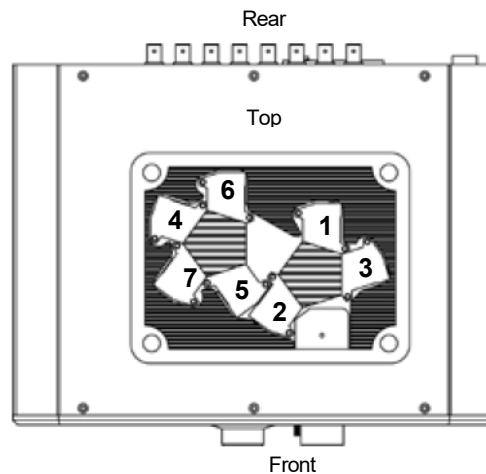
Figure 5-1. LED cube placement.

⚠ CAUTION

When replacing any LED cube, it is very important that the maximum current in Amps allowed for any new or replacement LED cube be configured in the Lambda 721 . The maximum current for any given LED channel must not exceed the Amp rating of the cube installed for that channel. Failure to adjust the maximum current for a given LED cube will cause the LED to immediately or eventually fail (burn out). See the next section on changing the maximum current level for all the LED channels.

5.2.2 Setting up the Maximum Current Level for each LED

To change the maximum current (in Amps) for the LEDs in the system, power off the unit, change the position of DIP Switch 8 to the ON (Down) position, and then power up the unit. Upon doing so, the unit starts up with the following on the display.
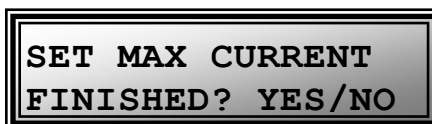
```
┌─────────────────────────┐
│ SET MAX CURRENT         │
│ LED#1 Amps = 2.0        │
└─────────────────────────┘
```

Figure 5-2. Setting the maximum current for an LED.

Press NEXT to cycle through all seven LEDs.

The Selector knob (turning slowly) adjusts the current level (Amps) between 0.5, 1.0, 1.5, 2.0, 3.0, 4.0, and 5.0 the present LED. Pressing NEXT advances to the next LED, while ENTER saves the new current value before advancing to the next LED (or exit if LED 7).

Press ENTER to set new current level for current LED, and advance to next LED. On LED 7, ENTER displays a prompt asking if finished setting the current level.

```
┌─────────────────────────┐
│ SET MAX CURRENT         │
│ FINISHED? YES/NO        │
└─────────────────────────┘
```

Figure 5-3. Prompt for finishing setting LED current levels.

Pressing NO, returns to the "Set Max. Current" display.
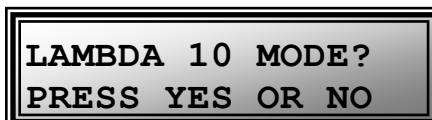
Pressing YES, displays a message to turn off the Lambda 721 and reset DIP Switch 8 to the OFF (UP) position.

```
┌─────────────────────────┐
│ TURN OFF UNIT           │
│ RESET DIP-SWITCH        │
└─────────────────────────┘
```

Figure 5-4. Message to turn off unit and reset DIP Switch 8 position before turning unit back on.

When finished setting the maximum current levels for all the LEDs, power off the unit and reset DIP Switch 8 to the OFF (up) position. On the next power up, the unit will revert to normal operation.

```
┌─────────────────────────┐
│ LAMBDA 10 MODE?         │
│ PRESS YES OR NO         │
└─────────────────────────┘
```

Figure 5-5. Lambda 10 Mode prompt.

APPENDIX A. LIMITED WARRANTY

- Sutter Instrument Company 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.

- Warranty work will be performed only at the factory.

- The cost of shipment both ways is paid for by Sutter Instrument during the first three months this warranty is in effect, after which the cost is the responsibility of the customer.

- The limited warranty is as stated above and no implied or inferred liability for direct or consequential damages is intended.

- 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.

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APPENDIX B. ACCESSORIES

B.1. Liquid Light Guides, SMA Fiber, and Other Accessories

LLG   Liquid light guide (2 meters, 3mm diameter), C-mount, lens, and lens tube

SMA-LB   SMA fiber adapter with SMA fiber.

B.2. Microscope Mounting Adapters

Mounting adapters for Nikon, Zeiss, Leica and Olympus microscopes are available. Please refer to the Microscope Adapters section of Sutter Instrument's web site (http://www.sutter.com) for further information.

B.3. LED Cubes

721CUBE-340	LED cube with optics and filter, 340 nm
721CUBE-365	LED cube with optics and filter, 365 nm
721CUBE-385	LED cube with optics and filter, 385 nm
721CUBE-410	LED cube with optics and filter, 410 nm
721CUBE-440	LED cube with optics and filter, 440 nm
721CUBE-460	LED cube with optics and filter, 460 nm
721CUBE-480	LED cube with optics and filter, 480 nm
721CUBE-480NB	LED cube with optics and NARROW BAND filter, 480 nm
721CUBE-506	LED cube with optics and filter, 506 nm
721CUBE-506NB	LED cube with optics and NARROW BAND filter, 506nm
721CUBE-530	LED cube with optics and filter, 530 nm
721CUBE-561	LED cube with optics and filter, 561 nm
721CUBE-590	LED cube with optics and filter, 590 nm
721CUBE-617	LED cube with optics and filter, 617 nm
721CUBE-630	LED cube with optics and filter, 630 nm
721CUBE-660	LED cube with optics and filter, 660 nm
721CUBE-740	LED cube with optics and filter, 740 nm
721CUBE-850	LED cube with optics and filter, 850 nm

721CUBE-940   LED cube with optics and filter, 940nm

NOTE: For a full list of available accessories for the Lambda 721, refer to the Products section of Sutter Instrument's web site (http://www.sutter.com).

APPENDIX C. FUSE REPLACEMENT

In the event that the lamp fails to power up when the power switch is turned on, please check to see if the line power fuse has blown. The fuse is located in a pry-out holder on the power entry module on the back of the unit. 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.
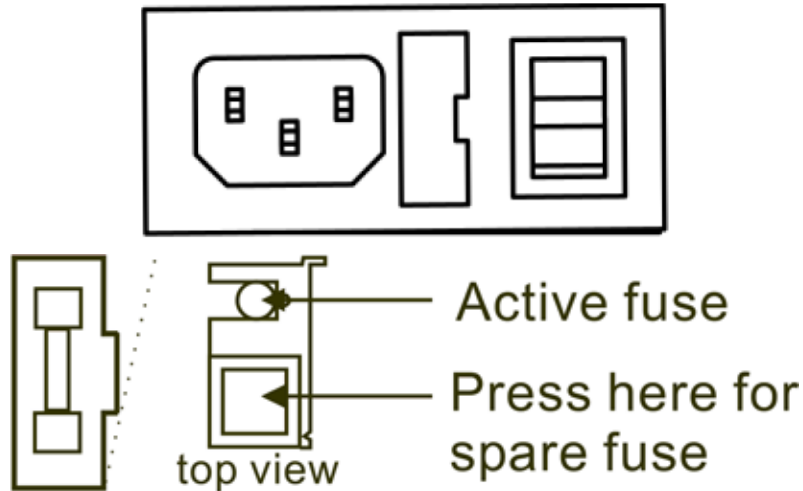
Figure C-1. Power entry module and fuse detail.

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 Lag (IEC 60127-2, Sheet 6)
T3.15A 250V (Time Lag, 3.15 Amps, 250 Volts)
(Littelfuse 02193.15MXAP (219XA Series, RoHS compliant))

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APPENDIX D. TECHNICAL SPECIFICATIONS

Lamp:

Output Range	330 to 960 nm, depending on LED configuration)
Shuttering	Turn ON/OFF time: $<25\mu$s.
Noise/Short Term Stability:	0.01%
LED Life	>50,000 hours

Dimensions (W x D x H):	19 x 10.5 x 7 in (48.26 x 26.67 x 17.78 cm)
Weight:	23 lbs. (10.44 kg)

Light Guide:

Core Type	Liquid
Length	2 m (6.5 ft)
Diameter	3 mm (0.11 in)

Electrical:

Mains voltage	110 – 240 V, 50 – 60 Hz
Power consumption	148.8 W
Power cord	10A, 250V, 60°C, PVC, with IEC-320 C13 connector
Mains fuse (rear of cabinet)	5 x 20 mm glass tube, T3.15A, 250V, Time Lag (IEC 60127-2, Sheet 6) (Littelfuse 02193.15MXAP (219XA Series, RoHS compliant))
	Fuse holder contains two fuses. If a fuse is blown, both fuses should be replaced.

Cables

Table 5-1. Cable specifications.

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)
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.	

APPENDIX E. QUICK REFERENCE

E.1. Manual Operation

Selector dial:
    SETUP Mode: Adjusts current LED's power level.
    Ring Buffer Edit: Adjusts entry ("ALL OFF", 1 - 7, "END RB").

NEXT button:
    SETUP Mode: Navigate to next LED. On last, goes to 1st.
    Ring Buffer Edit: Navigate to next Ring Buffer entry (0 - 99).

YES & NO buttons: Use for all "Y/N" or "YES" or "NO" prompts.

ENTER button:
    Enters current mode (TTL, DEMO) when prompted.
    SETUP Mode: Navigate to next LED. On last, exit.

ON/OFF button:
    Stops/exits Lambda 10, TTL, or Ring Buffer Run/Edit modes.
    SETUP Mode: Toggles state of current LED.

Figure E-1. Lambda 721 front panel and controls.
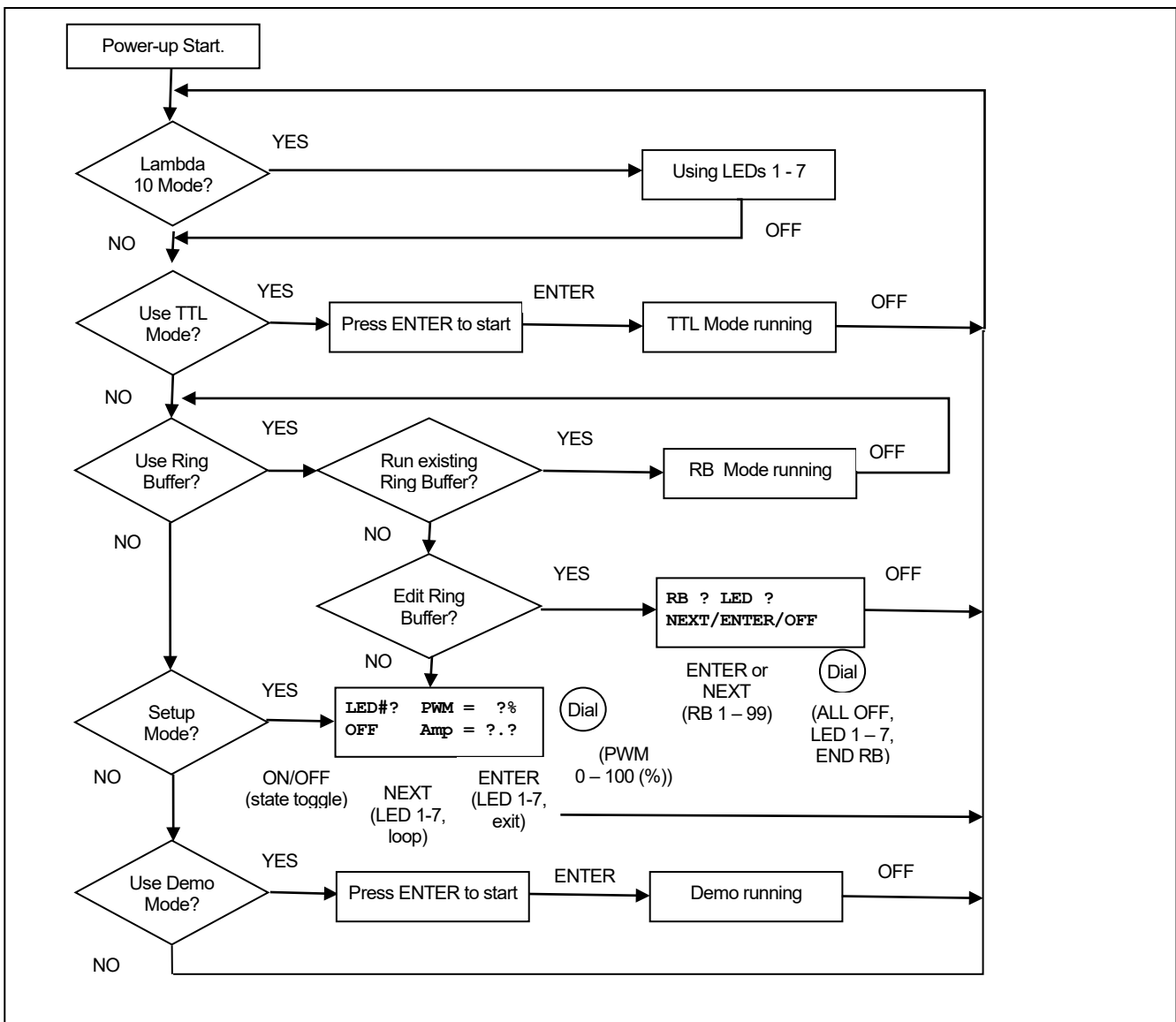
Figure E-2. Lambda 721 menu navigation diagram.

E.2. Configuration

Rear-Panel
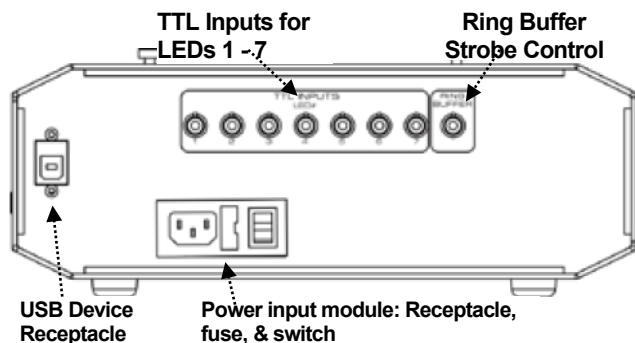
Figure E-3. Lambda 721 rear panel, connectors, and controls.
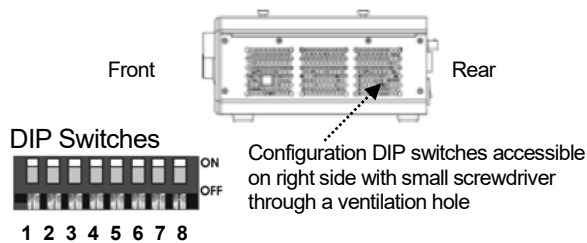
Figure E-4. Lambda 721 left-side panel and DIP switches.

Table E-1. Configuration Switches 1 – 8.

Sw #	Definition	State	Setting	Position
1	TTL level state on power-up	Low*	Off*	Up*
		High	On	Down
2	I/O interface return of data from Lambda 10-3 "Get Controller Type & Config." and "Get Status" commands (Ver. 1.26+)	Enabled*	Off*	Up*
		Disabled	On	Down
3	Camera Mode while running the Ring Buffer	Disabled: Stays ON until next strobe*	Off*	Up*
		Enabled: Turns OFF before next strobe	On	Down
4	I/O interface return of current Ring Buffer entry LED number(s) while Ring Buffer is running	Enabled*	Off*	Up*
		Disabled	On	Down
5	Select data ("Baud") rate for I/O interface	9600 bps*	Off*	Up*
		57600 bps	On	Down
6	Reserved		Off*	Up*
7	Reserved		Off*	Up*
8	Allow setting of maximum current for each LED on power up	Disabled*	Off**	Up*
		Enabled	On	Down

Factory default setting.

LED Cubes Placement

(Top view with LED cube hatch cover removed)
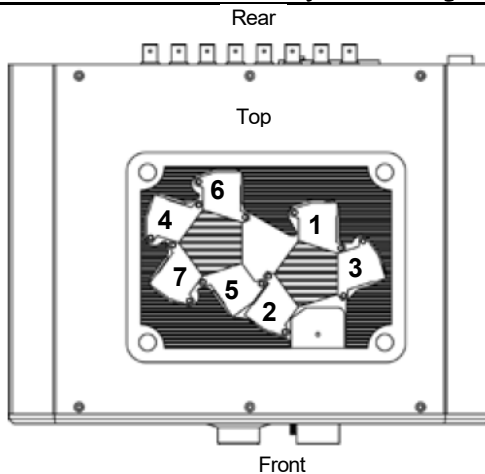
Figure E-5. LED cube placement.

E.3. External Control

Controlling the Lambda 721 externally via computer is accomplished by sending commands over the USB interface between the computer and the relevant connector on the rear panel of the Lambda 721 controller.

USB Interface: The USB device driver for Windows is downloadable from Sutter Instrument's web site (www.sutter.com). The Lambda 721 requires USB CDM (Combined Driver Model) Version 2.10.00 or higher. The CDM device driver for the Lambda 721 consists of two device drivers: 1) USB device driver, and 2) VCP (Virtual COM Port) device driver. Install the USB device driver first, followed by the VCP device driver. The VCP device driver provides a serial RS-232 I/O interface between a Windows application and the Lambda 721. Although the VCP device driver is optional, its installation is recommended even if it is not

going to be used. Once installed, the VCP can be enabled or disabled.

The CDM device driver package provides two I/O methodologies over which communications with the Lambda 721 can be conducted: 1). USB Direct, or 2). Serial RS-232 asynchronous via the VCP device driver. The first method requires that the VCP device driver be disabled (or not installed). The second method requires that the VCP be installed and enabled.

Virtual COM Port (VCP) Serial Port Settings:
The following table lists the required RS-232 serial settings for the COM port (COM3, COM5, etc.) generated by the installation of the VCP device driver.

Table E-2. Serial port settings.

Property	Setting
Data ("Baud") Rate (bits per second (bps)) (Configurable with DIP Switch 5.)	**9600***, 57600
Data Bits	8
Stop Bits	1
Parity	None
Flow Control	None

* Factory default setting.

The settings shown in the above table can be set in the device driver's properties (via the Device Manager if in Windows) and/or programmatically in your application.

Handshaking: Command sequences do not have terminators. If a command sequence just sent to the controller is determined to be valid, the entire sequence is immediately echoed back to the computer. All commands return an ASCII CR (Carriage Return; 13 decimal, 0D hexadecimal) to indicate that the task associated with the command has completed. When the Lambda 721 completes the task associated with a command, it sends an ASCII CR back to the host computer indicating that it is ready to receive a new command. If a command returns data, the last byte returned is the task-completed indicator.

Commands: Each command sequence consists of at least one byte, the first of which is the "command byte". Those commands that have parameters or arguments require a sequence of bytes that follow the command byte. No delimiters are used between command

sequence arguments. Every command and command sequence ends with a terminator byte containing an ASCII CR (13 decimal, 0D hexadecimal). Although most command bytes can be expressed as ASCII displayable/printable characters, the rest of a command sequence must always be expressed as a sequence of unsigned byte values (0-255 decimal; 00 – FF hexadecimal, or 00000000 – 11111111 binary). Each byte in a command sequence being transmitted to the controller must contain an unsigned binary value. Attempting to code command sequences as "strings" is not advisable. Any command data being returned from the controller must also be received and initially treated as a sequence of unsigned byte values. Groups of contiguous bytes can later be combined to form larger values, as appropriate (e.g., 2 bytes into 16-bit "word" or "short", or 4 bytes into a 32-bit "long" or "double word"). For the Lambda 721, all Ring Buffer entry values are stored as "unsigned short" (16-bit) values. A 16-bit value is transmitted and received to and from the controller as two contiguous bytes.

"Unsigned" means the value can only be positive; negative values are not permitted. A U16 consists of two contiguous bytes, with a byte/bit-ordering format of Little Endian ("Intel") (most significant byte (MSB) in the first byte and least significant (LSB) in the last byte). If the platform on which your application is running is Little Endian, then no byte order reversal of Ring Buffer entry values is necessary. Examples of platforms using Little Endian formatting include any system using an Intel processor (including Microsoft Windows and Apple Mac OS X), and most Linux distributions running on Intel/AMD processor-based systems.

If the platform on which your application is running is "Big Endian" ("Motorola"), then these U16 position values must have their bytes reverse-ordered <u>after</u> receiving from, or <u>before</u> sending to, the Lambda 721. Examples of Big-Endian platforms include most all non-Intel-based systems, LabVIEW (regardless of system & operating system), and Java (programming language/environment).

Command Reference: The following tables lists all the external-control commands for the Lambda 721.

Table E-3. Lambda 721 external control commands.

Command	Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value Dec.	Value Hex.	Value Binary	Alt-keypad #	Ctrl-char	ASCII def./-char.	Description
Lambda 10-x Mode ('L' or 'l')	Tx	All	1	0	76 or 108	4C or 63	0100 1100 or 0110 1100	0076 or 0108		'L' or 'l'	Places Lambda 721 into Lambda 10-x compatibility mode.
	Rx	All	1	12	13	0D	0000 1101			<CR>	Completion indicator
TTL Mode ('T' or 't')	Tx	All	1	0	84 or 116	54 or 74	0101 0100 or 0111 0100	0084 or 0116		'T' or 't'	Places Lambda 721 into TTL mode.
	Rx	All	1	12	13	0D	0000 1101			<CR>	Completion indicator
Start Ring Buffer Run ('R' or 'r')	Tx	All	1	0	82 or 114	52 or 72	0101 0010 or 0111 0010	0082 or 0114		'R' or 'r'	Start running the ring buffer.
	Rx	All	1	0	13	0D	0000 1101			<CR>	Completion indicator
Stop TTL or Ring Buffer Run ('O' or 'o')	Tx	All	1	0	79 or 111	4F or 6F	0100 1111 or 0110 1111	0079 or 0111		'O' or 'o'	Stop TTL Mode or Buffer Ring run.
	Rx	All	1	0	13	0D	0000 1101			<CR>	Completion indicator
Load Ring Buffer ('B' or 'b')	Tx	All	1	0	66 or 98	42 or 62	0100 0010 or 0110 0010	0066 or 0098		'B' or 'b'	Begin loading the ring buffer.
			2 – 200	1 – 199	Each two-byte ("word") value that follows is the entry for the position, and what follows after is for the next entry (see the *Ring Buffer Entry Values* table), until F0F0 hexadecimal is sent, which stops the loading of the ring buffer. Up to 100 entries are supported.						
	Rx	All	1	0	13	0D	0000 1101			<CR>	Completion indicator is returned after the Stop Loading Ring Buffer entry (see next) is sent, effectively ending the command sequence.
Turn on a discrete LED or a group of LEDs ('M' or 'm')	Tx	All	2	0	77 or 109	4D or 6D	01001101 or 01101101	0077 or 0109		'M' or 'm'	Command followed by 1 byte containing the bit-encoded ON/OFF states of all LEDs (1 – 7).
				1	0 – 127	00 – 7F	00000000 – 01111111	0000 – 0127	^@ –	<NUL> – <DEL>	See *'M' Command 1st argument (2nd byte) values for individual LED ON/OFF state bit encoding* for a discrete LED value or *'M' Command 1st argument (2nd byte) values for ON/OFF state bit encoding for all LEDs and groups* for an LED group value.
	Rx	All	1	1	13	0D	0000 1101		^M	<CR>	Completion indicator

Command	Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Dec.	Hex.	Binary	Alt-key-pad #	Ctrl-char	ASCII def./-char.	Description
Set LED Power Level ('P' or 'p')	Tx	All	3	0	80 or 112	50 or 70	0101 0000 or 0111 0000	0080 or 0112		'P' or 'p'	Sets the power level (0 – 100%) for a specified LED.
				1	1 – 7	01 – 07	0000 0001 – 0000 0111	0001 – 0007	^A – ^G	<SOH> – <BEL>	LED number (1 – 7)
				2	1 – 100	01 – 64	0000 0001 – 0110 0100	0001 – 0100	^A –	<SOH> – 'd'	Power level (1 – 100%)
	Rx	All	3	1	1 – 7	01 – 07	0000 0001 – 0000 0111	0001 – 0007		<SOH> – <BEL>	Echoed LED number (1 – 7)
				2	1 – 100	01 – 64	0000 0001 – 0110 0100	0001 – 0100		<SOH> – 'd'	Echoed power level (1 – 100%)
				0	13	0D	0000 1101			<CR>	Completion indicator
Get LED ON/OFF Status ('S' or 's')	Tx	All	1	0	83 or 115	53 or 73	0101 0011 or 0111 0011	0083 or 0115		'S' or 's'	Returns a value of 0 (all LEDs off), or one or more ASCII digits ('1' – '7') for each LED that is ON.
	Rx	All	2 – 8	0	0 or 49 – 55	00 or 31 – 37	0000 0000 or 0011 0001 – 0011 0111			<NUL> or '1' – '7'	Value 0 for all LEDs OFF, or ASCII digit '1' – '7' for each LED that is ON, in that order (1 to 7 bytes).
				1 – 8	13	0D	0000 1101			<CR>	Completion indicator
Get Lambda 10-3 Compatible Controller Type and Configuration (see note)	Tx	1.26+	1	0	253	FD	1111 1101	0253			Returns a Lambda 10-3 compatible data block containing controller type identifier, and filter wheel /shutter configuration information. (See note.)
	Rx	1.26+	31	0	253	FD	1111 1101				Command echo
				1 (4)	49	31	0011 0001			1	"10-3" (controller type is Lambda 10-3)
					48	30	0011 0000			0	
					45	2D	0010 1101			-	
					51	33	0011 0011			3	
				5 (5)	87	57	0101 0111			W	"WA-25" (Filter Wheel A is a 10-position wheel with 25mm filters)
					65	41	0100 0001			A	
					45	2D	0010 1101			-	
					50	32	0011 0010			2	
					53	35	0011 0101			5	
				10 (5)	87	57	0101 0111			W	"WB-NC" (Filter Wheel B is not connected)
					66	42	0100 0010			B	
					45	2D	0010 1101			-	
					78	4E	0100 1110			N	
					67	43	0100 0011			C	
				15 (5)	87	57	0101 0111			W	"WC-NC" (Filter Wheel C is not connected)
					67	43	0100 0011			C	
					45	2D	0010 1101			-	
					78	4E	0100 1110			N	
					67	43	0100 0011			C	

Command	Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Dec.	Hex.	Binary	Alt-keypad #	Ctrl-char	ASCII def./char.	Description
				20 (5)	83	53	0101 0011			S	"SA-VS" (Shutter A is not connected or is a standard shutter (not a SmartShutter))
					65	41	0100 0001			A	
					45	2D	0010 1101			–	
					86	56	0101 0110			V	
					83	53	0101 0011			S	
				25 (5)	83	53	0101 0011			S	"SB-VS" (Shutter B is not connected or is a standard shutter (not a SmartShutter))
					66	42	0100 0010			B	
					45	2D	0010 1101			–	
					86	56	0101 0110			V	
					83	53	0101 0011			S	
				30	13	0D	0000 1101			<CR>	Completion indicator
Get Lambda 10-3 Compatible Status (see note)	Tx	1.26+	1	0	204	CC	1100 1100	0204			Returns a Lambda 10-3 compatible data block containing filter wheel and shutter status information. (See note.)
	Rx	1.26+	13	0	204	CC	1100 1100				Command echo
				1	16	10	0001 0000				Wheel A, Speed 1, Pos. 0
				2	138	8A	1000 1010				Wheel B, Speed 0, Pos. 10
				3 (2)	252	FC	1111 1100				Wheel C prefix byte
					10	0A	0000 1010				Wheel C, Speed 0, Pos. 10
				5	172	AC	1010 1100				Shutter A closed
				6	188	BC	1011 1100				Shutter B closed
				7 (2)	219	DB	1101 1011				Shutter A mode: N/A
					1	01	0000 0001				Shutter A designator
				9 (2)	219	DB	1101 1011				Shutter B mode: N/A
					2	02	0000 0010				Shutter B designator
				11	13	0D	0000 1101			<CR>	Completion indicator
				12	13	0D	0000 1101			<CR>	Completion indicator

NOTE: The "Get Lambda 10-3 Compatible Controller Type and Configuration" and "Get Lambda 10-3 Compatible Status" commands are provided to allow external-control software originally written for the Lambda 10-3 to control a Lambda 721 while identifying itself as a Lambda 10-3. All data returned is static (i.e., data remains unchanged regardless of all Lambda 721 states). These two commands are functional only if DIP Switch 2 is OFF (up).

Table E-4. Lambda 10 Series compatible LED selection commands.

Command	Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-code	ASCII def./-char.	Description
					Dec.	Hex.	Binary				
All LEDs Off	Tx	All	1	0	0	00	00000000	0000	^@	<NUL>	Turn all LEDs off.
	Rx	All	2	0	0	00	00000000		^@	<NUL>	Command echo
				1	13	0D	0000 1101		^M	<CR>	Completion indicator
LED 1 On	Tx	All	1	0	1	01	00000001	0001	^A	<SOH>	Turn LED 1 on
	Rx	All	2	0	1	01	00000001		^A	<SOH>	Command echo
				1	13	0D	0000 1101		^M	<CR>	Completion indicator
LED 2 On	Tx	All	1	0	2	02	00000010	0002	^B	<STX>	Turn LED 2 on
	Rx	All	2	0	2	02	00000010		^B	<STX>	Command echo
				1	13	0D	0000 1101		^M	<CR>	Completion indicator
LED 3 On	Tx	All	1	0	3	03	00000011	0003	^C	<ETX>	Turn LED 3 on
	Rx	All	2	0	3	03	00000011		^C	<ETX>	Command echo
				1	13	0D	0000 1101		^M	<CR>	Completion indicator
LED 4 On	Tx	All	1	0	4	04	00000100	0004	^D	<EOT>	Turn LED 4 on
	Rx	All	2	0	4	04	00000100		^D	<EOT>	Command echo
				1	13	0D	0000 1101		^M	<CR>	Completion indicator
LED 5 On	Tx	All	1	0	5	05	00000101	0005	^E	<ENQ>	Turn LED 5 on
	Rx	All	2	0	5	05	00000101		^E	<ENQ>	Command echo
				1	13	0D	0000 1101		^M	<CR>	Completion indicator
LED 6 On	Tx	All	1	0	6	06	00000110	0006	^F	<ACK>	Turn LED 6 on
	Rx	All	2	0	6	06	00000110		^F	<ACK>	Command echo
				1	13	0D	0000 1101		^M	<CR>	Completion indicator
LED 7 On	Tx	All	1	0	7	07	00000111	0007	^G	<BEL>	Turn LED 7 on
	Rx	All	2	0	7	07	00000111		^G	<BEL>	Command echo
				1	13	0D	0000 1101		^M	<CR>	Completion indicator

NOTE: *All Lambda 10 Mode commands for the Lambda 721 correspond to the Lambda 10 series filter wheel movement for Wheel A, Speed 0, Positions 1 – 7. Any other wheel-select, speed settings, and positions 8 – 9 are not supported. Values 1 through 7 correspond to LEDs 1 – 7. Value 0, used to turn all LEDs off, can be used as the equivalent of closing Shutter A.*

Table E-5. LED selection commands using ASCII digits.

Command	Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value Dec.	Value Hex.	Value Binary	Alt-key-pad #	Ctrl-code	ASCII def./-char.	Description
All LEDs Off ('0')	Tx	All	1	0	48	30	00110000	0048		0	Turn all LEDs off.
	Rx	All	2	0	48	30	00110000	0048		0	Command echo
				1	13	0D	0000 1101		^M	<CR>	Completion indicator
LED 1 On ('1')	Tx	All	1	0	49	31	00110001	0049		1	Turn LED 1 on
	Rx	All	2	0	49	31	00110001	0049		1	Command echo
				1	13	0D	0000 1101		^M	<CR>	Completion indicator
LED 2 On ('2')	Tx	All	1	0	50	32	00110010	0050		2	Turn LED 2 on
	Rx	All	2	0	50	32	00110010	0050		2	Command echo
				1	13	0D	0000 1101		^M	<CR>	Completion indicator
LED 3 On ('3')	Tx	All	1	0	51	33	00110011	0051		3	Turn LED 3 on
	Rx	All	2	0	51	33	00110011	0051		3	Command echo
				1	13	0D	0000 1101		^M	<CR>	Completion indicator
LED 4 On ('4')	Tx	All	1	0	52	34	00110100	0052		4	Turn LED 4 on
	Rx	All	2	0	52	34	00110100	0052		4	Command echo
				1	13	0D	0000 1101		^M	<CR>	Completion indicator
LED 5 On ('5')	Tx	All	1	0	53	35	00110101	0053		5	Turn LED 5 on
	Rx	All	2	0	53	35	00110101	0053		5	Command echo
				1	13	0D	0000 1101		^M	<CR>	Completion indicator
LED 6 On ('6')	Tx	All	1	0	54	36	00110110	0054		6	Turn LED 6 on
	Rx	All	2	0	54	36	00110110	0054		6	Command echo
				1	13	0D	0000 1101		^M	<CR>	Completion indicator
LED 7 On ('7')	Tx	All	1	0	55	37	00110111	0055		7	Turn LED 7 on
	Rx	All	2	0	55	37	00110111	0055		7	Command echo
				1	13	0D	0000 1101		^M	<CR>	Completion indicator

Table E-6. Ring Buffer entry values.

LED On/Off State	Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			Alt-key-pad #	Ctrl-char	ASCII def./-char.	16-bit "Word" value (Little Endian)		
					Dec.	Hex.	Binary				Dec.	Hex.	Binary
All Off	**Tx**	All	2	0	0	00	0000 0000	0000	^@	<NUL>	8	0008	00000000 00001000
				1	8	08	0000 1000	0008	^H	<BS>			
LED 1 On	**Tx**	All	2	0	1	01	0000 0001	0001	^A	<SOH>	272	0110	00000001 00010000
				1	16	10	0001 0000	0016	^P	<DLE>			
LED 2 On	**Tx**	All	2	0	2	02	0000 0010	0002	^B	<STX>	536	0218	00000010 00011000
				1	24	18	0001 1000	0024	^X	<CAN>			
LED 3 On	**Tx**	All	2	0	4	04	0000 0100	0004	^D	<EOT>	1056	0420	00000100 00100000
				1	32	20	0010 0000	0032		space			
LED 4 On	**Tx**	All	2	0	8	08	0000 1000	0008	^H	<BS>	2088	0828	00001000 00101000
				1	40	28	0010 1000	0040		(			
LED 5 On	**Tx**	All	2	0	16	10	0001 0000	0016	^P	<DLE>	4144	1030	00010000 00110000
				1	48	30	0011 0000	0048		0			
LED 6 On	**Tx**	All	2	0	32	20	0010 0000	0032		space	8248	2038	00100000 00111000
				1	56	38	0011 1000	0056		8			
LED 7 On	**Tx**	All	2	0	64	40	0100 0000	0064		@	16448	4040	01000000 01000000
				1	64	40	0100 0000	0064		@			
End of Ring Buffer	**Tx**	All	2	0	240	F0	1111 0000	0240		≡	61680	F0F0	11110000 11110000
				1	240	F0	1111 0000	0240		≡			
	Rx	All	1	1	13	0D	0000 1101		^M	<CR>	Completion indicator		

NOTE: *The 'B' or 'b' command and each 2-byte Ring Buffer entry, once transmitted, does not return anything, except for End of Ring Buffer which returns an ASCII CR (carriage return) completion indicator (13 decimal, 0D hexadecimal, 0000 1101 binary).*

Table E-7. Return values while running the Ring Buffer.

LED On/Off State	Tx/-Delay/-Rx	Ver.	Total Bytes	Byte Offset (Len.)	Value			ASCII def./-char.
					Dec.	Hex.	Binary	
LED 1 On	**Rx**	All	1	0	49	31	0011 0001	'1'
LED 2 On	**Rx**	All	1	0	50	32	0011 0010	'2'
LED 3 On	**Rx**	All	1	0	51	33	0011 0011	'3'
LED 4 On	**Rx**	All	1	0	52	34	0011 0100	'4'
LED 5 On	**Rx**	All	1	0	53	35	0011 0101	'5'
LED 6 On	**Rx**	All	1	0	54	36	0011 0110	'6'
LED 7 On	**Rx**	All	1	0	55	37	0011 0111	'7'

NOTE: *The return of the values shown in the table while running the ring buffer is contingent on DIP Switch 4 being set to the ON (down) position.*

Table E-8. 'M' Command 1st argument (2nd byte) values for individual LED ON/OFF state bit encoding.

n/a (7)	7 (6)	6 (5)	5 (4)	4 (3)	3 (2)	2 (1)	1 (0)	Command 'M' or 'm' Byte Argument	Dec.	Hex.	Binary	Alt-keypad #	Ctrl-code	ASCII def./char.
								All LEDs Off	0	00	000000000	0000	^@	<NUL>
							ON	LED 1 On	1	01	00000001	0001	^A	<SOH>
						ON		LED 2 On	2	02	00000010	0002	^B	<STX>
					ON			LED 3 On	4	04	00000100	0004	^D	<EOT>
				ON				LED 4 On	8	08	00001000	0008	^H	<BS>
			ON					LED 5 On	16	10	00010000	0016	^P	<DLE>
		ON						LED 6 On	32	20	00100000	0032		<DEL>
	ON							LED 7 On	64	40	01000000	0064		@

Table E-9. 'M' Command 1st argument (2nd byte) values for ON/OFF state bit encoding for all LEDs and groups.

n/a (7)	7 (6)	6 (5)	5 (4)	4 (3)	3 (2)	2 (1)	1 (0)	Command 'M' or 'm' Byte Argument	Dec.	Hex.	Binary	Alt-keypad #	Ctrl-code	ASCII def./char.
								All LEDs Off	0	00	000000000	0000	^@	<NUL>
							ON	LED 1 On	1	01	00000001	0001	^A	<SOH>
						ON		LED 2 On	2	02	00000010	0002	^B	<STX>
						ON	ON	LED 1 2 On	3	03	00000011	0003	^C	<ETX>
					ON			LED 3 On	4	04	00000100	0004	^D	<EOT>
					ON		ON	LED 3 1 On	5	05	00000101	0005	^E	<ENQ>
					ON	ON		LED 3 2 On	6	06	00000110	0006	^F	<ACK>
					ON	ON	ON	LED 3 2 1 On	7	07	00000111	0007	^G	<BEL>
				ON				LED 4 On	8	08	00001000	0008	^H	<BS>
				ON			ON	LED 4 1 On	9	09	00001001	0009	^I	<HT>
				ON		ON		LED 4 2 On	10	0A	00001010	0010	^J	<LF>
				ON		ON	ON	LED 4 2 1 On	11	0B	00001011	0011	^K	<VT>
				ON	ON			LED 4 3 On	12	0C	00001100	0012	^L	<FF>
				ON	ON		ON	LED 4 3 1 On	13	0D	00001101	0013	^M	<CR>
				ON	ON	ON		LED 4 3 2 On	14	0E	00001110	0014	^N	<SO>
				ON	ON	ON	ON	LED 4 3 2 1 On	15	0F	00001111	0015	^O	<SI>
			ON					LED 5 On	16	10	00010000	0016	^P	<DLE>
			ON				ON	LED 5 1 On	17	11	00010001	0017	^Q	<DC1>
			ON			ON		LED 5 2 On	18	12	00010010	0018	^R	<DC2>
			ON			ON	ON	LED 5 2 1 On	19	13	00010011	0019	^S	<DC3>
			ON		ON			LED 5 3 On	20	14	00010100	0020	^T	<DC4>
			ON		ON		ON	LED 5 3 1 On	21	15	00010101	0021	^U	<NAK>
			ON		ON	ON		LED 5 3 2 On	22	16	00010110	0022	^V	<SYN>
			ON		ON	ON	ON	LED 5 3 2 1 On	23	17	00010111	0023	^W	<ETB>
			ON	ON				LED 5 4 On	24	18	00011000	0024	^X	<CAN>
			ON	ON			ON	LED 5 4 1 On	25	19	00011001	0025	^Y	<EM>
			ON	ON		ON		LED 5 4 2 On	26	1A	00011010	0026	^Z	<SUB>
			ON	ON		ON	ON	LED 5 4 2 1 On	27	1B	00011011	0027	^[	<ESC>
			ON	ON	ON			LED 5 4 3 On	28	1C	00011100	0028	^\	<FS>
			ON	ON	ON		ON	LED 5 4 3 1 On	29	1D	00011101	0029	^]	<GS>
			ON	ON	ON	ON		LED 5 4 3 2 On	30	1E	00011110	0030	^^	<RS>
			ON	ON	ON	ON	ON	LED 5 4 3 2 1 On	31	1F	00011111	0031	^_	<US>

LED # On/Off State (Bit #)								Command 'M' or 'm' Byte Argument	Value			Alt-key-pad #	Ctrl-code	ASCII def./-char.
n/a (7)	7 (6)	6 (5)	5 (4)	4 (3)	3 (2)	2 (1)	1 (0)		Dec.	Hex.	Binary			
		ON						LED 6 On	32	20	00100000	0032		\<DEL\>
		ON					ON	LED 6 1 On	33	21	00100001	0033		!
		ON				ON		LED 6 2 On	34	22	00100010	0034		"
		ON				ON	ON	LED 6 1 2 On	35	23	00100011	0035		#
		ON			ON			LED 6 3 On	36	24	00100100	0036		$
		ON			ON		ON	LED 6 3 1 On	37	25	00100101	0037		%
		ON			ON	ON		LED 6 3 2 On	38	26	00100110	0038		&
		ON			ON	ON	ON	LED 6 3 2 1 On	39	27	00100111	0039		'
		ON		ON				LED 6 4 On	40	28	00101000	0040		(
		ON		ON			ON	LED 6 4 1 On	41	29	00101001	0041		)
		ON		ON		ON		LED 6 4 2 On	42	2A	00101010	0042		*
		ON		ON		ON	ON	LED 6 4 2 1 On	43	2B	00101011	0043		+
		ON		ON	ON			LED 6 4 3 On	44	2C	00101100	0044		,
		ON		ON	ON		ON	LED 6 4 3 1 On	45	2D	00101101	0045		–
		ON		ON	ON	ON		LED 6 4 3 2 On	46	2E	00101110	0046		.
		ON		ON	ON	ON	ON	LED 6 4 3 2 1 On	47	2F	00101111	0047		/
		ON	ON					LED 6 5 On	48	30	00110000	0048		0
		ON	ON				ON	LED 6 5 1 On	49	31	00110001	0049		1
		ON	ON			ON		LED 6 5 2 On	50	32	00110010	0050		2
		ON	ON			ON	ON	LED 6 5 2 1 On	51	33	00110011	0051		3
		ON	ON		ON			LED 6 5 3 On	52	34	00110100	0052		4
		ON	ON		ON		ON	LED 6 5 3 1 On	53	35	00110101	0053		5
		ON	ON		ON	ON		LED 6 5 3 2 On	54	36	00110110	0054		6
		ON	ON		ON	ON	ON	LED 6 5 3 2 1 On	55	37	00110111	0055		7
		ON	ON	ON				LED 6 5 4 On	56	38	00111000	0056		8
		ON	ON	ON			ON	LED 6 5 4 1 On	57	39	00111001	0057		9
		ON	ON	ON		ON		LED 6 5 4 2 On	58	3A	00111010	0058		:
		ON	ON	ON		ON	ON	LED 6 5 4 2 1 On	59	3B	00111011	0059		;
		ON	ON	ON	ON			LED 6 5 4 3 On	60	3C	00111100	0060		<
		ON	ON	ON	ON		ON	LED 6 5 4 3 1 On	61	3D	00111101	0061		=
		ON	ON	ON	ON	ON		LED 6 5 4 3 2 On	62	3E	00111110	0062		>
		ON	ON	ON	ON	ON	ON	LED 6 5 4 3 2 1 On	63	3F	00111111	0063		?
	ON							LED 7 On	64	40	01000000	0064		@
	ON						ON	LED 7 1 On	65	41	01000001	0065		A
	ON					ON		LED 7 2 On	66	42	01000010	0066		B
	ON					ON	ON	LED 7 1 2 On	67	43	01000011	0067		C
	ON				ON			LED 7 3 On	68	44	01000100	0068		D
	ON				ON		ON	LED 7 3 1 On	69	45	01000101	0069		E
	ON				ON	ON		LED 7 3 2 On	70	46	01000110	0070		F
	ON				ON	ON	ON	LED 7 3 2 1 On	71	47	01000111	0071		G
	ON			ON				LED 7 4 On	72	48	01001000	0072		H
	ON			ON			ON	LED 7 4 1 On	73	49	01001001	0073		I
	ON			ON		ON		LED 7 4 2 On	74	4A	01001010	0074		J
	ON			ON		ON	ON	LED 7 4 2 1 On	75	4B	01001011	0075		K
	ON			ON	ON			LED 7 4 3 On	76	4C	01001100	0076		L
	ON			ON	ON		ON	LED 7 4 3 1 On	77	4D	01001101	0077		M

n/a (7)	7 (6)	6 (5)	5 (4)	4 (3)	3 (2)	2 (1)	1 (0)	Command 'M' or 'm' Byte Argument	Dec.	Hex.	Binary	Alt-key-pad #	Ctrl-code	ASCII def./-char.
	ON			ON	ON	ON		LED 7 4 3 2 On	78	4E	01001110	0078		N
	ON			ON	ON	ON	ON	LED 7 4 3 2 1 On	79	4F	01001111	0079		O
	ON		ON					LED 7 5 On	80	50	01010000	0080		P
	ON		ON				ON	LED 7 5 1 On	81	51	01010001	0081		Q
	ON		ON			ON		LED 7 5 2 On	82	52	01010010	0082		R
	ON		ON			ON	ON	LED 7 5 2 1 On	83	53	01010011	0083		S
	ON		ON		ON			LED 7 5 3 On	84	54	01010100	0084		T
	ON		ON		ON		ON	LED 7 5 3 1 On	85	55	01010101	0085		U
	ON		ON		ON	ON		LED 7 5 3 2 On	86	56	01010110	0086		V
	ON		ON		ON	ON	ON	LED 7 5 3 2 1 On	87	57	01010111	0087		W
	ON		ON	ON				LED 7 5 4 On	88	58	01011000	0088		X
	ON		ON	ON			ON	LED 7 5 4 1 On	89	59	01011001	0089		Y
	ON		ON	ON		ON		LED 7 5 4 2 On	90	5A	01011010	0090		Z
	ON		ON	ON		ON	ON	LED 7 5 4 2 1 On	91	5B	01011011	0091		[
	ON		ON	ON	ON			LED 7 5 4 3 On	92	5C	01011100	0092		\
	ON		ON	ON	ON		ON	LED 7 5 4 3 1 On	93	5D	01011101	0093		]
	ON		ON	ON	ON	ON		LED 7 5 4 3 2 On	94	5E	01011110	0094		^
	ON		ON	ON	ON	ON	ON	LED 7 5 4 3 2 1 On	95	5F	01011111	0095		_
	ON	ON						LED 7 6 On	96	60	01100000	0096		`
	ON	ON					ON	LED 7 6 1 On	97	61	01100001	0097		a
	ON	ON				ON		LED 7 6 2 On	98	62	01100010	0098		b
	ON	ON				ON	ON	LED 7 6 1 2 On	99	63	01100011	0099		c
	ON	ON			ON			LED 7 6 3 On	100	64	01100100	0100		d
	ON	ON			ON		ON	LED 7 6 3 1 On	101	65	01100101	0101		e
	ON	ON			ON	ON		LED 7 6 3 2 On	102	66	01100110	0102		f
	ON	ON			ON	ON	ON	LED 7 6 3 2 1 On	103	67	01100111	0103		g
	ON	ON		ON				LED 7 6 4 On	104	68	01101000	0104		h
	ON	ON		ON			ON	LED 7 6 4 1 On	105	69	01101001	0105		i
	ON	ON		ON		ON		LED 7 6 4 2 On	106	6A	01101010	0106		j
	ON	ON		ON		ON	ON	LED 7 6 4 2 1 On	107	6B	01101011	0107		k
	ON	ON		ON	ON			LED 7 6 4 3 On	108	6C	01101100	0108		l
	ON	ON		ON	ON		ON	LED 7 6 4 3 1 On	109	6D	01101101	0109		m
	ON	ON		ON	ON	ON		LED 7 6 4 3 2 On	110	6E	01101110	0110		n
	ON	ON		ON	ON	ON	ON	LED 7 6 4 3 2 1 On	111	6F	01101111	0111		o
	ON	ON	ON					LED 7 6 5 On	112	70	01110000	0112		p
	ON	ON	ON				ON	LED 7 6 5 1 On	113	71	01110001	0113		q
	ON	ON	ON			ON		LED 7 6 5 2 On	114	72	01110010	0114		r
	ON	ON	ON			ON	ON	LED 7 6 5 2 1 On	115	73	01110011	0115		s
	ON	ON	ON		ON			LED 7 6 5 3 On	116	74	01110100	0116		t
	ON	ON	ON		ON		ON	LED 7 6 5 3 1 On	117	75	01110101	0117		u
	ON	ON	ON		ON	ON		LED 7 6 5 3 2 On	118	76	01110110	0118		v
	ON	ON	ON		ON	ON	ON	LED 7 6 5 3 2 1 On	119	77	01110111	0119		w
	ON	ON	ON	ON				LED 7 6 5 4 On	120	78	01111000	0120		x
	ON	ON	ON	ON			ON	LED 7 6 5 4 1 On	121	79	01111001	0121		y
	ON	ON	ON	ON		ON		LED 7 6 5 4 2 On	122	7A	01111010	0122		z
	ON	ON	ON	ON		ON	ON	LED 7 6 5 4 2 1 On	123	7B	01111011	0123		{

LED # On/Off State (Bit #)								Command 'M' or 'm' Byte Argument	Value			Alt-key-pad #	Ctrl-code	ASCII def./-char.
n/a (7)	7 (6)	6 (5)	5 (4)	4 (3)	3 (2)	2 (1)	1 (0)		Dec.	Hex.	Binary			
	ON	ON	ON	ON	ON			LED 7 6 5 4 3 On	124	7C	01111100	0124		|
	ON	ON	ON	ON	ON		ON	LED 7 6 5 4 3 1 On	125	7D	01111101	0125		}
	ON	ON	ON	ON	ON	ON		LED 7 6 5 4 3 2 On	126	7E	01111110	0126		~
	ON	ON	ON	ON	ON	ON	ON	LED 7 6 5 4 3 2 1 On	127	7F	01111111	0127		

NOTES:

1. **Task-Complete Indicator:** All commands will send back to the computer the "Task-Complete Indicator" to signal the command and its associated function in the controller is complete. The indicator consists of one (1) byte containing a value of 13 decimal (0D hexadecimal), and which represents the ASCII CR (Carriage Return).

2. **Intercommand Delay:** A short delay (usually around 2 ms) is recommended between commands (after sending a command sequence and before sending the next command).

3. **Clearing Send/Receive Buffers:** Clearing (purging) the transmit and receive buffers of the I/O port immediately before sending any command is recommended.

4. **16-Bit Value Bit Ordering:** All multibyte values transmitted to, and received from, the controller must be bit/byte-ordered in "Little Endian" format. This means that the least significant bit/byte is last (last to send and last to receive). Byte-order reversal may be required on some platforms. Microsoft Windows, Intel-based Apple Macintosh systems running Mac OS X, and most Intel/AMD processor-based Linux distributions handle byte storage in Little-Endian byte order, so byte reordering is not necessary before converting to/from 16-bit "short" or "word" values. LabVIEW always handles "byte strings" in "Big Endian" byte order irrespective of operating system and CPU, requiring that the two bytes containing a 16-bit value be reverse ordered before/after conversion to/from a multibyte type value (I16, U16, etc.). MATLAB automatically adjusts the endianess of multibyte storage entities to that of the system on which it is running, so explicit byte reordering is generally unnecessary unless the underlying platform is Big Endian. If your development platform does not have built-in Little/Big Endian conversion functions, bit reordering can be accomplished by first swapping positions of the two bytes in each 16-bit value. This method efficiently and quickly changes the bit ordering of any multibyte value between the two Endian formats (if Big Endian, it becomes Little Endian, and if Little Endian, it becomes then Big Endian).

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