

Operation and Service Manual

Laser Diode Controllers

LDC500 Series



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LDC500 Series Laser Diode Controllers

Contents

General Information	v
Safety and Preparation for Use	v
Symbols	vi
Notation	vii
Specifications	viii
1 Overview	1 - 1
1.1 How to use this Manual	1 - 2
1.2 Introduction to the Instrument	1 - 2
1.2.1 Instrument architecture	1 - 2
1.2.2 Grounding	1 - 5
1.3 Features and controls	1 - 6
1.4 Power	1 - 6
1.4.1 Power entry module	1 - 6
1.4.2 Grounding terminal	1 - 6
1.4.3 Turning on power	1 - 6
1.4.4 Hardware reset	1 - 8
1.5 Cable Interfaces	1 - 8
1.5.1 Modulate	1 - 8
1.5.2 Sync	1 - 8
1.5.3 Laser diode	1 - 8
1.5.4 TEC	1 - 9
1.5.5 Remote interface connections	1 - 10
1.6 User Interface	1 - 10
1.6.1 Hard controls	1 - 10
1.6.2 Dedicated displays	1 - 11
1.6.3 Alphanumeric display	1 - 11
1.6.4 Local/Remote	1 - 13
2 Getting Started	2 - 1
2.1 Preparation for Use	2 - 2
2.1.1 Power and ground	2 - 2
2.1.2 Laser diode connections	2 - 2
2.1.3 TEC module connections	2 - 2
2.1.4 Checking wiring	2 - 3
2.1.5 Turning on power	2 - 5

2.2	Operating the TEC controller	2-6
2.2.1	Sensor configuration	2-6
2.2.2	TEC settings	2-7
2.2.3	Verify TEC wiring polarity	2-8
2.2.4	Auto-tuning	2-9
2.2.5	TEC operation in CT mode	2-10
2.2.6	Thermal runaway	2-10
2.2.7	TEC operation in CC mode	2-11
2.2.8	TEC limit values	2-11
2.2.9	Monitoring the TEC	2-12
2.2.10	Configuring TEC trip-offs	2-12
2.3	Operating the Laser Diode Driver	2-14
2.3.1	Laser driver configuration	2-14
2.3.2	Laser settings	2-15
2.3.3	Operating the laser in CC mode	2-15
2.3.4	Operating the laser in CP mode	2-16
2.3.5	Modulation	2-17
2.3.6	Monitoring the LD	2-17
2.3.7	Optical power calibration	2-18
2.3.8	Configuring LD trip-offs	2-18
2.4	Factory Default Settings	2-19
3	Menus	3 - 1
3.1	Menu Navigation	3-2
3.2	Laser Menus	3-2
3.2.1	LD settings	3-2
3.2.2	LD monitor	3-4
3.2.3	LD configuration	3-5
3.3	TEC Menus	3-7
3.3.1	TEC settings	3-7
3.3.2	TEC monitor	3-8
3.3.3	TEC configuration	3-9
3.4	Other Menus	3-12
3.4.1	Utility	3-13
3.4.2	Other messages	3-14
4	Remote Operation	4 - 1
4.1	Index of Common Commands	4-2
4.2	Alphabetic List of Commands	4-6
4.3	Introduction	4-10
4.3.1	Interface configuration	4-10
4.3.2	Buffers	4-10

4.4	Ethernet	4-10
4.4.1	Connection example	4-11
4.5	Commands	4-16
4.5.1	Command syntax	4-16
4.5.2	Notation	4-17
4.5.3	Examples	4-17
4.5.4	Laser limit commands	4-18
4.5.5	Laser setting commands	4-20
4.5.6	Laser monitor commands	4-22
4.5.7	Laser configuration commands	4-24
4.5.8	Laser trip-off commands	4-29
4.5.9	TEC limit commands	4-31
4.5.10	TEC setting commands	4-33
4.5.11	TEC monitor commands	4-35
4.5.12	TEC configuration commands	4-36
4.5.13	TEC sensor commands	4-40
4.5.14	TEC trip-off commands	4-45
4.5.15	Interface commands	4-46
4.5.16	Status commands	4-52
4.6	Status Model	4-57
4.6.1	Status byte (SB)	4-58
4.6.2	Service request enable (SRE)	4-59
4.6.3	Standard event status (ESR)	4-59
4.6.4	Laser diode condition (LDCR)	4-60
4.6.5	TEC controller condition (TECR)	4-61
5	Error Messages	5-1
5.1	Laser Diode Driver Messages	5-2
5.1.1	Interlock	5-2
5.1.2	Transitions with high photodiode current . . .	5-2
5.1.3	Transitions with limited laser current	5-2
5.1.4	Transitions locked out	5-2
5.1.5	Responsivity	5-3
5.1.6	Photodiode current overflow	5-3
5.1.7	Responsivity underflow	5-3
5.1.8	Responsivity overflow	5-4
5.1.9	Trip-off from TEC	5-4
5.1.10	Trip-off from temperature	5-4
5.2	TEC Messages	5-4
5.2.1	Autotune	5-4
5.2.2	No loop control	5-5
5.2.3	Transitions locked out	5-5

5.2.4	Temperature faults	5-6
5.2.5	Thermal runaway	5-6
5.2.6	Polarity change locked out	5-6
5.3	Other messages	5-6
5.3.1	Restart	5-6
6	Accessories	6-1
6.1	Cables	6-2
6.1.1	Laser diode cables	6-2
6.1.2	TEC cables	6-4

General Information

Safety and Preparation for Use

 **WARNING**

Dangerous voltages, capable of causing injury or death, are present in this instrument. Do not remove the product covers or panels. Do not apply power or operate the product without all covers and panels in place.

AC line voltage

The LDC500 Series Laser Diode Controllers operate from a 100 V, 120 V, 220 V, or 240 V nominal AC power source having a line frequency of 50 Hz or 60 Hz. Before connecting the power cord to a power source, verify that the LINE VOLTAGE SELECTOR, located in the rear panel power-entry module, is set so that the correct AC line voltage value is visible.

 **CAUTION**

The LDC500 Series Laser Diode Controllers will be damaged if operated with the LINE VOLTAGE SELECTOR set for the wrong AC line voltage, or if the wrong fuses are installed. Verify that the correct line fuses are installed before connecting the line cord. Fuse size is 5MF "fast blow" ($\phi 5 \times 20$ mm). For 100 V/120 V, use 4 A fuses; for 220 V/240 V, use 2 A fuses.

Line cord

The LDC500 Series Laser Diode Controllers have a detachable, three-wire power cord for connection to the power source and to a protective ground. The exposed metal parts of the instrument are connected to the outlet ground to protect against electrical shock. Always use an outlet which has a properly connected protective ground.

Service

The LDC500 Series Laser Diode Controllers do not have any user serviceable parts inside. Refer service to a qualified technician.

Do not install substitute parts or perform any unauthorized modifications to this instrument. Contact the factory for instructions on how to return the instrument for authorized service and adjustment.

Symbols you may Find on SRS Products

Symbol	Description
	Alternating current
	Caution - risk of electric shock
	Frame or chassis terminal
	Caution - refer to accompanying documents
	Earth (ground) terminal
	Battery
	Fuse
	On (supply)
○	Off (supply)

Notation

The following notation will be used throughout this manual.

Unless otherwise specified in the text, LDC500 refers generally to either the LDC500, LDC501, or LDC502 Laser Diode Controller.

WARNING

A warning means that injury or death is possible if the instructions are not obeyed.

CAUTION

A caution means that damage to the instrument or other equipment is possible.

Typesetting conventions used in this manual are:

- Front-panel buttons are set as [Button].
- Front-panel indicators are set as *Overload*.
- Remote command names are set as *IDN?.
- Literal text other than command names is set as OFF.

Remote command examples will all be set in monospaced font. In these examples, data sent by the host computer to the LDC500 are set as *straight teletype font*, while responses received by the host computer from the LDC500 are set as *slanted teletype font*.

Specifications

All performance specifications after 1 hour warm-up at 25 °C ambient.

Laser diode current source

		LDC500	LDC501	LDC502	Units
Output current	Range, high	0–100	0–500	0–2000	mA
	low	0–50	0–250	0–1000	
Setpoint resolution	1	10	100	1000	µA
Accuracy	±10	±50	±200	±2000	µA
DC output impedance		1			MΩ min
Thermal drift		±10			ppm/°C max
Short-term stability (1 hr)		±5			ppm FS
Long-term stability (24 hr)		±15			ppm FS
Noise density [1]					nA/√Hz typ.
	high range	0.7	3.5	12.5	
	low range	0.4	1.8	6.3	
Wide band noise [2]					µA rms max
	high range, high BW	0.9	4.5	25	
	high range, low BW	0.6	1.5	5.0	
	low range, high BW	0.5	2.3	10	
	low range, low BW	0.3	1	3.5	
Power fail transient [3]	1	1	5	5	mA max
Compliance voltage	Range	0.1–10			V
	Resolution	10			mV
	Accuracy	+0.2			V
Output current limit	Range, high	0–100	0–500	0–2000	mA
	low	0–50	0–250	0–1000	
	Resolution	10	10	100	µA
	Accuracy	±100	±100	±400	µA

		LDC500	LDC501	LDC502	Units
Analog modulation	Input range	−10 to +10		V	
	Input impedance	2		kΩ typ.	
	Transfer function				
	high range, CC mode	10	50	200	
	low range, CC mode	5	25	100	mA/V
	CP mode	500	500	1000	μA/V
	Modulation bandwidth (−3 dB)[4]				
	high BW, CC mode	DC−1.0		0.8	MHz
	low BW, CC mode	DC−10			kHz
	high BW, CP mode	DC−5			kHz
	low BW, CP mode	DC−100			Hz
Photodiode feedback	Bias voltage	0−5		V	
	Photodiode current	0−5000	0−10,000		μA
	Setpoint resolution [5]	0.1		μA	
	Accuracy [5]	±3	±6		μA
Trigger output	TTL pulse width (negative)	10		μs	
	Delay [6]	0.004−1000		s	
Measurement & display	LD current resolution	1	10	100	μA
	accuracy	±200		ppm FS	
	PD current resolution	0.1		μA	
	accuracy	±200		ppm FS	
	LD voltage resolution	1		mV	
	accuracy	±300		ppm FS	

Conditions:

- [1] Measured electrically at 1 kHz through a 50 Ω load (LDC500), 10 Ω load (LDC501), 4 Ω load (LDC502).
- [2] Measured electrically with an RMS meter from 10 Hz to 1 MHz, through a 50 Ω load (LDC500), 10 Ω load (LDC501), 4 Ω load (LDC502).
- [3] Output current change, measured with an oscilloscope, upon removing AC power cord.
- [4] Bandwidth can be affected by cable and load parameters.
- [5] In CP control mode.
- [6] Delay programmed by the remote SYND command.

TEC controller

		Min	Typ	Max	Units
Temperature control	Control ranges				
	IC sensors	-55		+150	
	Resistance sensors	-150		+250	°C
		0.010		500	kΩ
	Setpoint resolution				
	Temperature		0.001		°C
	Resistance		0.1		Ω
	Setpoint Accuracy [1]				
	Temperature		±0.01		°C
	Resistance		±0.1		%
	Stability				
	Thermal drift [2]			±0.0005	°C/°C
	Short term (1 hr)			±0.001	
	Long term (24 hr)			±0.002	°C
	Control algorithm			digital PID	
	Autotuning method			open-loop step response	
TEC current control	Output range	-4.5		+4.5	A
	Output power			36	W
	Setpoint resolution		1		mA
	Setpoint accuracy			±5	mA
	Compliance voltage	8			V
	Polarity			software reversible	
	Noise and ripple [3]				
	1 A output			0.1	
	4 A output			0.2	mA rms
	Limit range	0		4.5	A
	Limit resolution		1		mA
	Limit accuracy			±5	mA

Temperature sensors	Excitation range	10, 100, 1000	μA
	Thermistors	0.010	500 $\text{k}\Omega$
	RTD	Pt-100, Pt-1000, and equiv	
	IC voltage sensors (1 mA bias)	LM335 and equiv.	
IC current sensors (> 5 V bias)		AD590 and equiv.	
Measurement & display	Temperature resolution	0.001	$^{\circ}\text{C}$
	Thermistor resolution	0.1	Ω
	Accuracy [4]		$\pm 0.2 \% + 0.05 \Omega$
	TEC current resolution	1	mA
	Accuracy	± 5	
	TEC voltage resolution	1	mV
	Accuracy	± 5	

Conditions:

- [1] Accuracy figures represent the uncertainty added by the measurement circuitry inside the instrument. Sensor uncertainty is not included, which can add up to 2°C .
- [2] Measured by a monitor thermistor on the TEC stage. The LDC500 is operated in an environmental chamber between 0°C and 40°C . The TEC and heatsink are at room temperature.
- [3] Measured output current noise from 10 Hz to 1 MHz.
- [4] With 1 mA excitation current

General characteristics

Interface	GPIB (IEEE-488.2), RS-232, Ethernet/TCP-IP
Connectors	DB9-F (laser diode), DB15-F (TEC), BNC (modulate in, trigger out)
Power	100 W, 100 V, 120 V, 220 V, 240 V 50 Hz or 60 Hz
Fuse	Type 5MF, $\phi 5 \times 20$ mm, "fast blow" 4 A (100 V – 120 V); 2 A (220 V – 240 V)
Weight	15 lbs
Dimensions	8.5" W \times 5" H \times 15" D

1 Overview

This chapter provides a basic overview of the LDC500 Series Laser Diode Controllers.

In This Chapter

1.1	How to use this Manual	1-2
1.2	Introduction to the Instrument	1-2
1.2.1	Instrument architecture	1-2
1.2.2	Grounding	1-5
1.3	Features and controls	1-6
1.4	Power	1-6
1.4.1	Power entry module	1-6
1.4.2	Grounding terminal	1-6
1.4.3	Turning on power	1-6
1.4.4	Hardware reset	1-8
1.5	Cable Interfaces	1-8
1.5.1	Modulate	1-8
1.5.2	Sync	1-8
1.5.3	Laser diode	1-8
1.5.4	TEC	1-9
1.5.5	Remote interface connections	1-10
1.6	User Interface	1-10
1.6.1	Hard controls	1-10
1.6.2	Dedicated displays	1-11
1.6.3	Alphanumeric display	1-11
1.6.4	Local/Remote	1-13

1.1 How to use this Manual

All users new to the LDC500 should begin with section 1.2 of this chapter, to familiarize themselves with the basic architecture and grounding scheme for the product. Section 1.6 provides an introduction to the user interface, and will also benefit new users.

Chapter 2 provides step-by-step examples for a new user getting started with the LDC500, and is a good starting point for users already familiar with the basics of the user interface.

Chapter 3 provides a comprehensive treatment of the user interface menu structure, with complete lists of all the parameter items.

Chapter 4 discusses remote operation of the LDC500, over RS-232, GPIB, and ethernet. Many of the menu items discussed in chapter 3 refer to more detailed information here.

1.2 Introduction to the Instrument

The LDC500 Series Laser Diode Controllers are combination precision current source and temperature controllers. The current source, intended to provide power to a laser diode (LD), provides a low noise, high stability output with programmable current and voltage limits. The temperature controller operates with most commonly used temperature sensors and thermoelectric coolers (TEC) to maintain precision thermal control of the laser. Multiple remote interfaces—GPIB, RS-232, and ethernet—give you complete control of the instrument from your computer.

1.2.1 Instrument architecture

The LDC500 is logically divided into two functional sections, the LD Driver and the TEC Controller, with a common control and interface section for front-panel and remote operation. All three of these sections are electrically isolated from each other, with only the control/interface section electrically grounded to chassis ground.

A block diagram of the LDC500, showing the arrangement of independently-isolated power sources, is given in Figure 1.1.

1.2.1.1 Laser diode driver

The primary function of the LD driver is providing stable, low-noise electrical current to bias a laser into emission. This excitation is delivered by a low-noise current source circuit. The current source has two range settings, with a maximum current commandable between 50 mA and 100 mA (LDC500), 250 mA and 500 mA (LDC501),

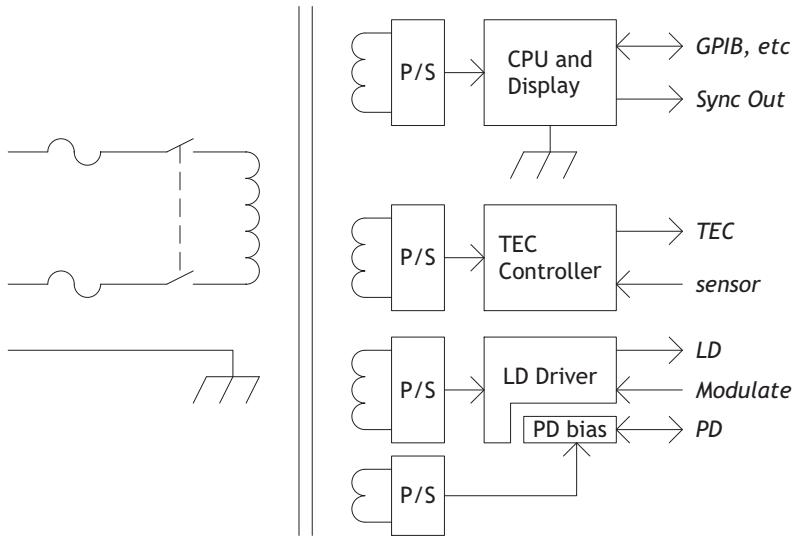


Figure 1.1: The LDC500 power supply block diagram.

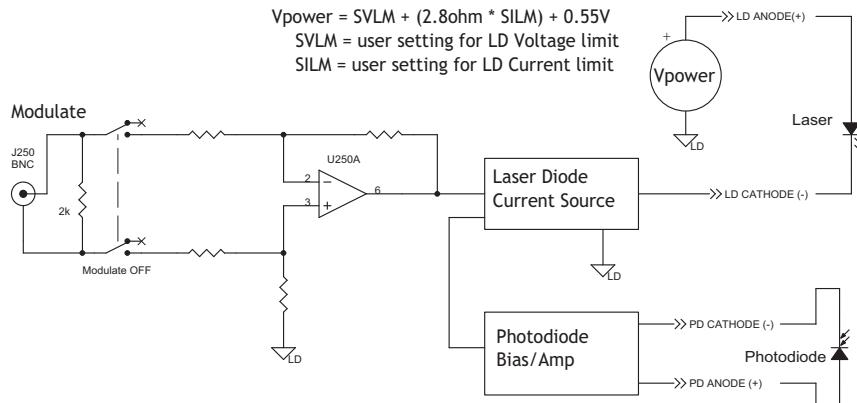


Figure 1.2: The laser diode drive circuitry (simplified).

or 1000 mA and 2000 mA (LDC502). For both ranges, there are two control modes for the magnitude of the current source output: constant current (CC), and constant optical power (CP). A simplified circuit diagram is in Figure 1.2.

Operating in CC mode, the LDC500 programs the desired current magnitude, in milliamps. To operate in CP mode, a monitor photodiode must be used to measure the output intensity of the laser diode. In CP mode, the LDC500 measures this photodiode current, and continuously adjusts (servos) the LD current source to maintain a constant photodiode current. Since the photodiode current is proportional to optical power, this operating mode stabilizes the laser's

output power optically. The CP setpoint can be given either in raw microamps of photodiode current, or in optical power as milliwatts (given a photodiode responsivity value).

For both ranges and operating modes of the LD driver, a DC-coupled analog modulation input is available on the front panel. Modulation can be used on all ranges and operating modes, and can be configured for low or high bandwidth. When unused, the modulation input relay should be opened by setting “Modulate enable” to “N” in the Laser Configure menu. Commanding the modulation input off in this way, when not in use, will result in slightly lower current noise.

1.2.1.2 TEC controller

The TEC controller section of the LDC500 delivers high performance temperature control for thermally stabilizing the laser diode. Most commonly-used thermal sensors are supported, including thermistors, RTDs, LM335-class voltage-output IC sensors, and AD590-class current-output IC sensors. A 36 W, ± 4.5 A bipolar current source drives the thermoelectric cooler (TEC) module of the laser. A block diagram of the TEC circuitry is in Figure 1.3.

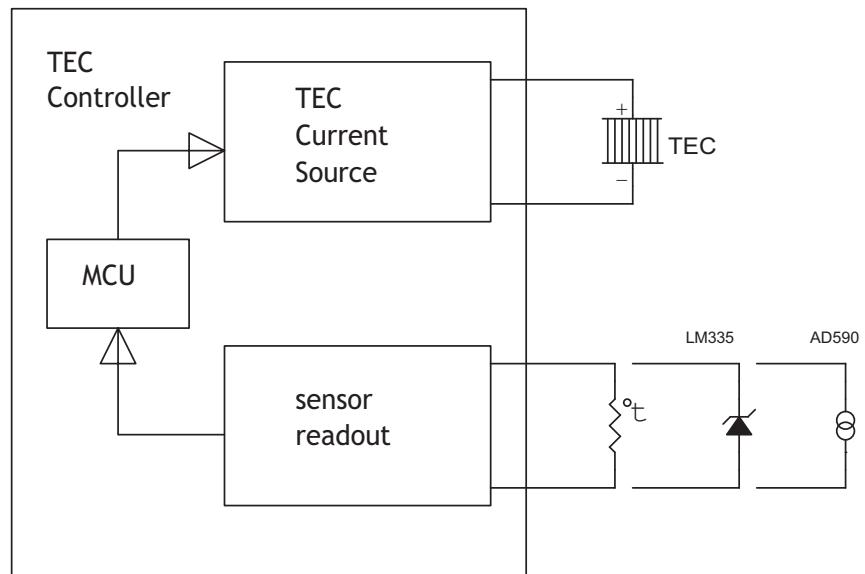


Figure 1.3: The TEC controller (simplified).

Two operating modes are available for the TEC controller. In constant temperature (CT) mode, a digital proportional-integral-differential (PID) control algorithm adjusts the TEC output current to maintain the temperature sensor at a desired temperature. For characterizing TEC modules, a second operating mode—constant current (CC)—

allows the user to set the TEC current at a constant value. Four wire connections to the TEC module allow accurate voltage sensing independent of resistive losses in the current leads, allowing for more accurate device characterization.

For best temperature control, the autotuning feature of the LDC500 should be used. This will optimize the P , I , and D feedback parameters for the temperature control loop; the user can then inspect and modify the loop parameters for best operation if necessary.

1.2.2 Grounding

For maximum user flexibility, many sections of the LDC500 are electrically isolated from chassis ground, and from each other. In particular, the LD current source and the TEC controller are separately floated. SRS recommends operating the laser diode, and the TEC module, floating without connection to ground. Note that many laser packages ground one terminal of the laser (either anode or cathode) to the package case. We still recommend configurations where the package case does not connect to ground. In situations where the laser case must be connected to ground, be careful to understand *all* potential ground paths in your system to avoid inadvertant ground loops or short circuits.

The monitor photodiode, if any, will perform best if also left floating, or one terminal can be tied to one of the laser diode terminals. However, do *not* separately ground one of the photodiode terminals, as this will interfere with the proper function of the laser diode driving circuitry.

1.2.2.1 Grounding and modulation

It is important that the user understand the internal grounding arrangement of the LDC500 when using analog modulation with a ground-referenced laser diode. As can be seen in Figure 1.2, the center and outer conductors of the Modulate BNC input are received differentially by an input amplifier which then modulates the LD current source. The “ground” symbol in the figure, labeled “LD”, is *not* chassis ground or any other externally-referenced potential; it is simply an *internal* reference potential for the LD current source. If the user’s laser is isolated from ground, then an earth-referenced signal connected to the Modulate BNC will cause the “LD ground” to come to earth.

If either the LD cathode, or the LD anode, is tied to earth, however, then the internal node “LD ground” will be biased at a definite, negative potential relative to earth. The differential input circuit (formed

by resistors R269 and R255) will still allow correct modulation control with an earth-referenced modulation signal, but it now becomes more important that the modulation source has a balanced output impedance. If the modulation source has a 50Ω output impedance (on the center conductor of the BNC), with the outer shield at earth (low impedance), then a “common-mode” DC error, of the order of up to 1 mA, may be induced. The user has 4 strategies to avoid this effect:

1. Keep the laser diode fully floating,
2. Use a floating source for the modulation input,
3. Ensure the modulation source has a low output impedance, or
4. Balance the modulation source impedance.

1.3 Features and controls

The remaining sections in this chapter explains each part of the front and rear panel of the LDC500. Circled numbers in the left margin refer to Figure 1.4.

1.4 Power

1.4.1 Power entry module

- (14) A rear-panel power entry module contains a standard IEC-C13 power connector. The power cord shipped with your LDC500 mates with the power entry module, and should match the standard wall sockets for your locale. The fuse and voltage selector is also in the power entry block, and must show the correct voltage setting for your location. See page v for details on fuse and voltage selection.

1.4.2 Grounding terminal

- (13) A dedicated chassis ground terminal is adjacent to the power entry module.

1.4.3 Turning on power

- (1) Power to the LDC500 is controlled by the front-panel keyswitch. In order to turn on the instrument, the key must be inserted and rotated clockwise to the “1” position. The key cannot be removed when in this position.

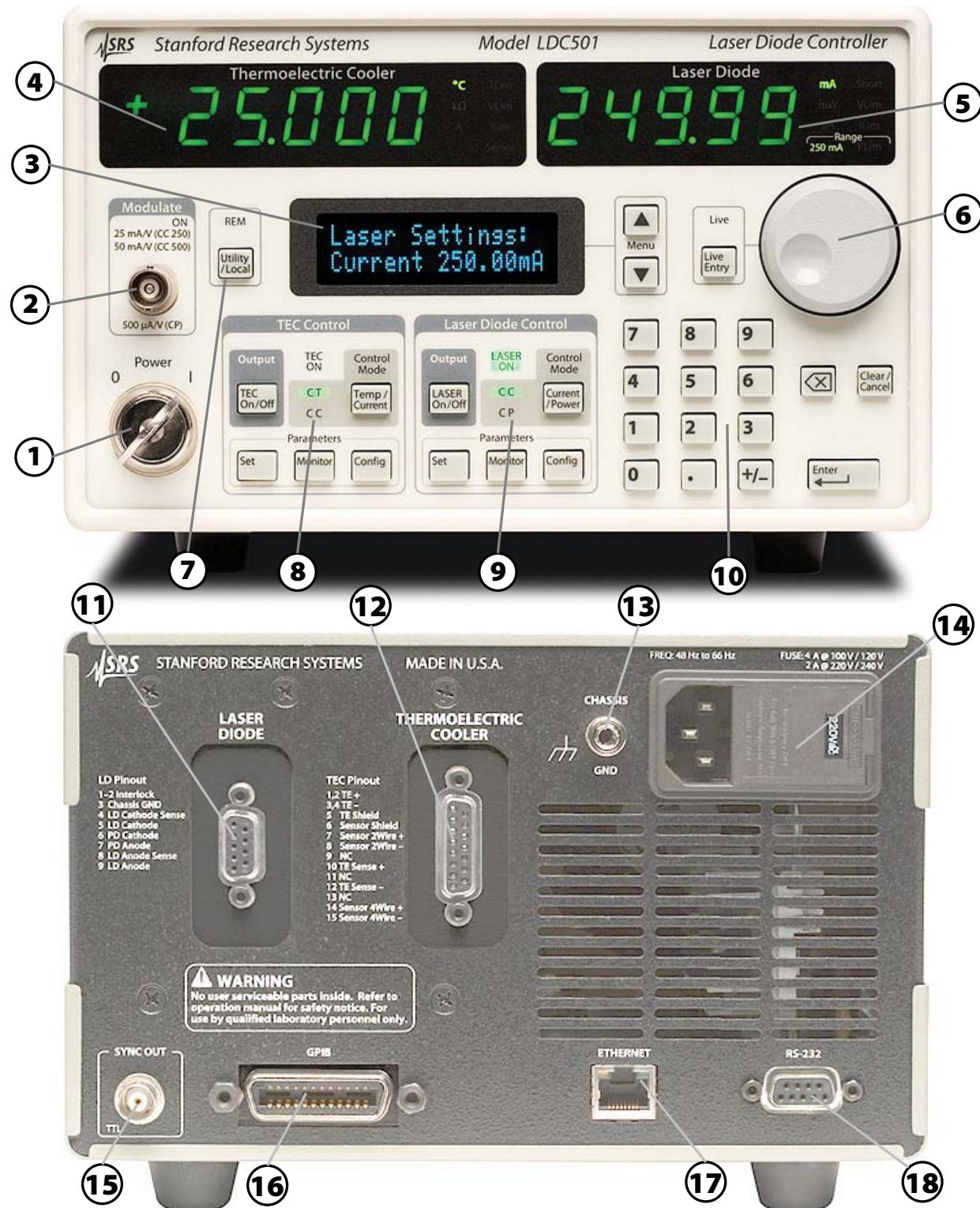


Figure 1.4: The LDC500 front and rear panels.

1.4.4 Hardware reset

- (10) (1) To restore the LDC500 to its factory default state, press and hold the [Clear/Cancel] button while turning on the power keyswitch. Note that this performs a full low-level reset of the instrument, and will erase all saved user configurations, limits, sensor calibrations, and network parameters. After this, all parameters are set to their default settings. See section 2.4 for more details.

1.5 Cable Interfaces

Two separate rear-panel subminiature-D connectors provide the interface from the LDC500 to the laser diode assembly. Additionally, a front-panel input allows for analog modulation, and a rear-panel output provides synchronization for multi-step scans.

1.5.1 Modulate

- (2) The front-panel BNC input “Modulate” accepts ± 10 V inputs to modulate the laser diode operating point. In CC mode, the scale factor is either 25 mA/V (when on the 250 mA current range), or 50 mA/V (on the 500 mA current range). When operating in CP mode, the scale factor is 500 μ A/V, independent of the instrument current range.

Analog modulation is DC-coupled, with a total bandwidth set by the SIBW command (see section 3.2.3.3).

The modulation input can be enabled or disabled through an internal relay by using the MODU command (see section 3.2.3.2). When unused, the modulation input should be disabled for best noise performance.

1.5.2 Sync

- (15) The rear-panel BNC output “SYNC OUT” provides low-going timing pulses for synchronizing external instrumentation after each step in a multi-step scan. See the SCAN command (4 – 21) for more details.

1.5.3 Laser diode

- (11) The DB-9 female connector marked “LASER DIODE” provides the electrical connection to the laser diode itself.

pin	description
1	Interlock
2	Interlock
3	Chassis ground
4	Laser Cathode Voltage Sense
5	Laser Cathode
6	Photodiode Cathode
7	Photodiode Anode
8	Laser Anode Voltage Sense
9	Laser Anode



CAUTION

Pin 4 and pin 8 are used for 4-wire measurement of the laser diode bias voltage. If these are left disconnected, the voltage sensing is performed (through resistors) from pin 5 and pin 9. Be careful that the connection from the LDC500 to your device preserves the wiring polarity, with pin 5 connecting to the laser diode *cathode*, and pin 9 connecting to the laser diode *anode*.

The interlock function requires a low-resistance electrical connection between pins 1 and 2 for the laser to operate. Neither of these pins may be allowed to contact ground or any other signal.

See Figure 2.2 in section 2.1.2 for further examples.

1.5.4 TEC

(12)

The DB-15 female connector marked “THERMOELECTRIC COOLER” provides the electrical connection to the TEC and thermometer in the laser assembly. For best performance, the TEC cable should be an independent, separately-shielded cable assembly from the laser diode cable.

pin	description
1, 2	TEC + current terminal (*)
3, 4	TEC – current terminal (*)
5	shield for TEC current
6	shield for sensor connection
7	Sensor 2-wire +
8	Sensor 2-wire –
9	no connection
10	TEC + sense
11	no connection
12	TEC – sense
13	no connection
14	Sensor 4-wire +
15	Sensor 4-wire –

(*): terminals can be switched with TPOL command

The power current to the TEC module is through pins 1 and 2, re-

turning through pins 3 and 4. This connection may carry as much as 4.5 A at full current. Be careful to wire the TEC sense connection (pins 10 and 12) independently to the TEC module, so that any ohmic drop across the current leads does not introduce errors in the voltage sensing.

Note the polarity convention for the TEC module: when *positive* current flows from the TEC + terminal, through the TEC element, and returning through the TEC – terminal, then the TEC element will be actively *cooling* the load.

The sensor connection is ideally suited to 4-wire (Kelvin-lead) connection; however, satisfactory results may be obtained in some cases by leaving the sense connections, pins 14 and 15, disconnected. If possible, pin 14 should be tied to pin 7, and pin 15 to pin 8, either near the temperature sensor, or else at the cable connector.

See Figure 2.3 in section 2.1.3 for examples.

1.5.5 Remote interface connections

- (16) An IEEE-488 (GPIB) interface is standard on all LDC500s. The GPIB address can be configured from the Utility menu (see section 3.4.1.4). The default GPIB address is 2.
- (17) An RJ-45 10/100 base-T Ethernet connection is also standard. TCP/IP settings for IP address, netmask, and default gateway can all be set from the Utility menu (section 3.4.1.3)
- (18) Finally, a 9-pin female subminiature-D connector provides an RS-232 interface (wired for DCE). The interface operates at 8-bits data, 1 stop bit, no parity, and no flow control. The baud rate can be configured from the Utility menu (section 3.4.1.6). The default baud rate is 9600.

1.6 User Interface

1.6.1 Hard controls

Four principal functions of the LDC500 are controlled by dedicated front-panel keys, and are always accessible independent of menu navigation.

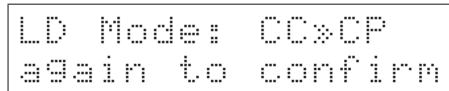
1.6.1.1 Laser on/off

- (9) The [LASER On/Off] button, under the “Laser Diode Control” block, toggles the laser diode current source on and off. When turning the laser on, a 3 s safety delay is imposed before the circuitry is engaged.

During this delay, the *LASER ON* indicator will blink back-and-forth. To abort energizing the laser during this time, simply press the [Laser On/Off] button a second time.

1.6.1.2 Laser control mode

The principal control mode of the laser, either CC or CP, is controlled by the [Current/Power] button under the “Laser Diode Control” block. When the laser is off, pressing this button toggles between CC and CP modes (as shown by the *CC* and *CP* indicators). When on, the user may still switch between control modes by pressing the [Current/Power] button; however, in this case, a confirmation message



LD Mode: CC>CP
again to confirm

appears on the display. If the button is not depressed a second time within 3 s, the request is abandoned.

1.6.1.3 TEC on/off

- (8) The [TEC On/Off] button, under the “TEC Control” block, toggles the TEC current source on and off. There is no delay imposed on this action, and the state of the TEC is indicated by the *TEC ON* lamp.

1.6.1.4 TEC control mode

The principal control mode of the TEC, either CT or CC, is controlled by the [Temp/Current] button under the “TEC Control” block. When the TEC is off, pressing this button toggles between CT and CC modes (as shown by the *CT* and *CC* indicators). When the TEC is on, the user must confirm the change with a second button press within 3 s.

1.6.2 Dedicated displays

- (4) (5) The two primary sections of the LDC500, the LD and the TEC, each have a large numeric display dedicated to that subsystem’s “primary” measurement value. For the LD, this is either the laser operating current or the photodiode current (or power), when in CC or CP mode, respectively. For the TEC, this is temperature or resistance, or TEC current. Units and warning indicators are also in the dedicated display blocks.

1.6.3 Alphanumeric display

- (3) All user inputs, and non-primary monitor functions, are handled by the central alphanumeric display. Control of this display is through

a collection of 7 menus, each of which is selected with a dedicated front-panel button.

- (9) The LD subsystem has three dedicated menu trees: Settings, Monitor, and Configuration. These can be selected by pressing one of the “Parameters” buttons under the “Laser Diode Control” section of the panel. The TEC has a similar collection of menus, which are selected by pressing the “Parameters” buttons under the “TEC Control” section of the panel.
- (8) A seventh menu tree, Utility, can be selected by pressing the [Utility/Local] button.

1.6.3.1 Menu navigation

- (3) Once a menu tree is selected, individual menu items are navigated by pressing the [**▲**] or [**▼**] buttons in the “Menu” block, just to the right of the alphanumeric display. Note that some menu items are only visible when the instrument is appropriately configured. To jump between major menus, press the button associated with the new menu. For instance, to jump from the LD voltage monitor menu

LD Monitor:
V1d= 1.302V

to the TEC temperature setpoint menu

TEC Settings:
T: 22.000 °C

simply press the [Set] button under the “TEC Control” block.

Pressing the [Monitor] button back in the “Laser Diode Control” block will return to the menu selection previously being visited (in this case, the LD voltage monitor).

1.6.3.2 Floating-point entry

- (10) Setting and Configuration menu items that have continuously-adjustable parameters can be set using the numeric keypad. Values are not entered until the [Enter] button is pressed. A lamp will blink above the [Enter] button whenever there is a pending user value that has not been entered to the instrument. Pressing the [Clear/Cancel] button, or any menu navigation button, will abandon a non-entered pending user value.

1.6.3.3 Token entry

Configuration menu items that have a discrete list of selections can be set using either the numeric keypad or the wheel. List selections typically include a numeric index followed by a right parenthesis,

such as “**30**”, to help guide the user to keypad entry values. Menus with “Y/N” selections do not display the numeric labels; keypad “0” corresponds to “No”, while “1” corresponds to “Yes”. Modified values will remain pending, with the indicator blinking above the [Enter] button, until [Enter] is pressed or the pending value is cancelled.

1.6.3.4 Wheel entry

- (6) Any numeric value can also be edited by turning the wheel on the front panel. Typically, this will begin incrementing (clockwise) or decrementing (counterclockwise) the value being displayed, and the pending lamp above the [Enter] button will begin flashing. In this mode, the wheel behaves similarly to the numeric keypad, and pending values await acceptance by [Enter], or cancellation by [Clear/Cancel].

Several parameters also have a real-time entry feature. For these parameters (see list, below), the wheel can be used to dynamically modify the operating point of the instrument. To turn on this real-time entry, press the [Live Entry] button adjacent to the wheel. If the Live indicator illuminates, then the wheel is now in real-time mode and continuously modifying the parameter selected—in this mode, there is no need to press the [Enter] button. Pressing [Live Entry] a second time toggles the live mode off. Note that live mode is only available when the TEC controller is on, or the laser diode driver is on.

Parameters with live entry available:

- Laser current setpoint (SILD, 4 – 20)
- Photodiode current setpoint (SIPD, 4 – 20)
- Photodiode power setpoint (SWPD, 4 – 21)
- Photodiode bias (BIAS, 4 – 26)
- Temperature setpoint (TEMP, 4 – 34)
- Resistance setpoint (TRTH, 4 – 34)
- TEC current setpoint (TCUR, 4 – 34)
- TEC P Gain (TPGN, 4 – 38)
- TEC I Gain (TIGN, 4 – 39)
- TEC D Gain (TDGN, 4 – 39)

1.6.4 Local/Remote

- (7) When the LDC500 is commanded over the remote GPIB interface, the *REM* indicator illuminates, showing that the instrument is in “remote” mode. While *REM* is lit, the LDC500 will not respond to front-panel key presses. To exit remote mode, press the [Utility/Local] button.

Note that if the [Utility/Local] button is pressed when *REM* is *not* illuminated, the Utility menu tree will be selected.

2 Getting Started

This chapter gives you the necessary information to get started quickly with the LDC500 Series Laser Diode Controllers.

In This Chapter

2.1 Preparation for Use	2-2
2.1.1 Power and ground	2-2
2.1.2 Laser diode connections	2-2
2.1.3 TEC module connections	2-2
2.1.4 Checking wiring	2-3
2.1.5 Turning on power	2-5
2.2 Operating the TEC controller	2-6
2.2.1 Sensor configuration	2-6
2.2.2 TEC settings	2-7
2.2.3 Verify TEC wiring polarity	2-8
2.2.4 Auto-tuning	2-9
2.2.5 TEC operation in CT mode	2-10
2.2.6 Thermal runaway	2-10
2.2.7 TEC operation in CC mode	2-11
2.2.8 TEC limit values	2-11
2.2.9 Monitoring the TEC	2-12
2.2.10 Configuring TEC trip-offs	2-12
2.3 Operating the Laser Diode Driver	2-14
2.3.1 Laser driver configuration	2-14
2.3.2 Laser settings	2-15
2.3.3 Operating the laser in CC mode	2-15
2.3.4 Operating the laser in CP mode	2-16
2.3.5 Modulation	2-17
2.3.6 Monitoring the LD	2-17
2.3.7 Optical power calibration	2-18
2.3.8 Configuring LD trip-offs	2-18
2.4 Factory Default Settings	2-19

2.1 Preparation for Use

Before using the instrument, your laser diode and TEC module should be properly wired. This section covers that process.

A male DB–9 connector is required for the laser connection, and a male DB–15 connector is required for the TEC connection.

2.1.1 Power and ground

Before connecting your laser and TEC cables to the LDC500 rear panel, make sure the power entry voltage selector is in the correct position for your region, and the rotary power key-switch is at “0” (off) position (see Figure 2.1).



Figure 2.1: Power entry module (with line selector).

Front-panel key switch, shown in the “on” position.

The instrument chassis is internally connected to power line earth. Be sure that the power cord ground is secure. Otherwise, the chassis should be grounded through the CHASSIS GND lug on the rear panel. Chassis ground should be tied to earth *before* any further connections are made.

2.1.2 Laser diode connections



CAUTION

Figure 2.2 shows the proper connections for the laser diode. Be certain that the connection from the LDC500 to your laser diode preserves the wiring polarity. In particular, pin 5 must connect to the laser diode *cathode* (–), and pin 9 must connect to the laser diode *anode* (+). Pins 4 and 8 are for 4-wire voltage measurement; if they are left disconnected, the LDC500 measures laser voltage between pins 5 and 9 internally.

The interlock function requires a low-resistance electrical connection between pin 1 and pin 2 for the laser to operate. Neither of these pins may be allowed to contact ground or any other signal.

2.1.3 TEC module connections

Figure 2.3 shows the proper connections for the TEC module. Power is delivered by current flowing (in parallel) through pins 1 and 2,

and returning through pins 3 and 4. This circuit may carry as much as $\pm 4.5\text{ A}$ at full current. Be careful to wire the TEC sense connection (pins 10 and 12) independently to the TEC module, so that ohmic drops across the current-carrying leads does not introduce errors in the TEC voltage sensing.

The temperature sense circuit is ideally suited to 4-wire (Kelvin lead) connection. Satisfactory results, however, may still be obtained in some cases by leaving the sense leads (pins 14 and 15) disconnected. If possible, better results will be obtained by connecting pin 14 to pin 7, and pin 15 to pin 8, ideally as close to the sensor as practical. Some improvement is still obtained even if the connection is made at the DB-15 connection at the LDC500 rear panel.

2.1.4 Checking wiring

Before installing your laser diode into the laser diode mount, it is important to verify that all wiring is correct. This is especially important with laser mounts that have user-configurable connection schemes. A good way to test the connections is to verify continuity (by “beeping”) using a hand-held multimeter. Figure 2.4 shows an example, in this case with a butterfly package mount.

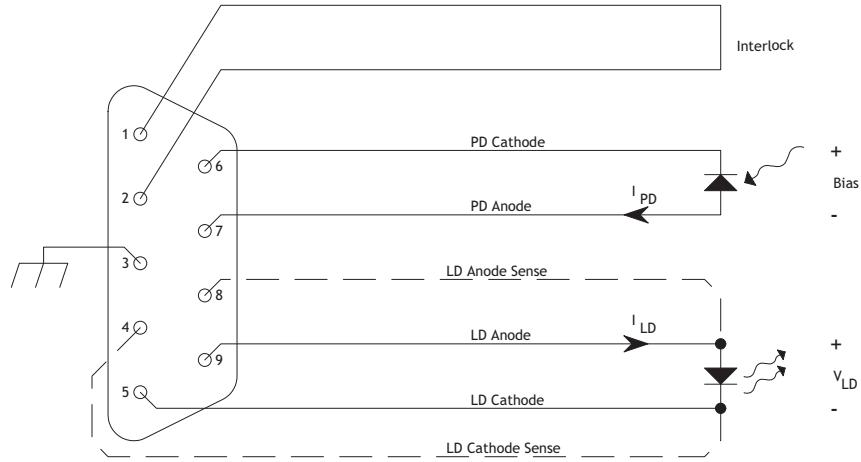


Figure 2.2: Wiring diagram for the Laser Diode. Pin 3 is internally connected to the chassis, and can be used for cable shielding. When the “dashed” connections are made, V_{LD} is a 4-wire measurement; otherwise, it is a 2-wire measurement.

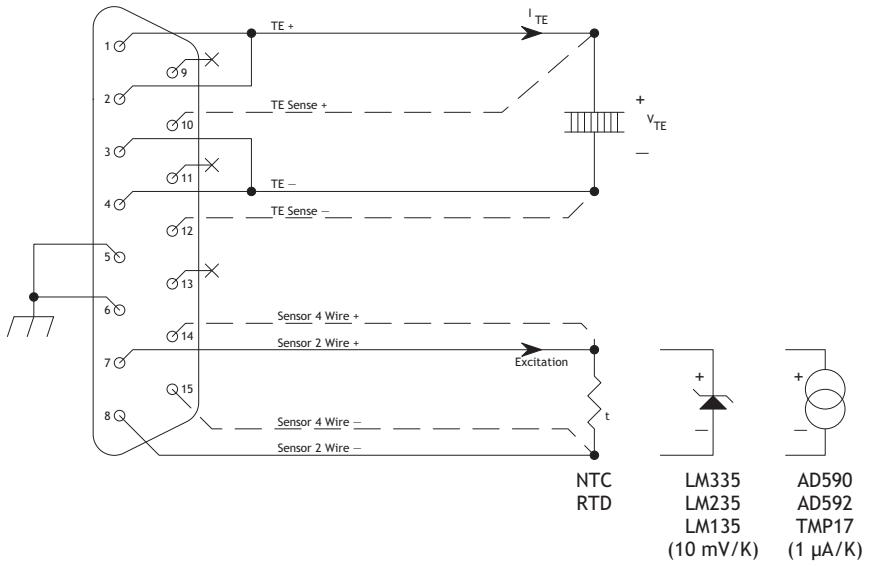


Figure 2.3: Wiring diagram for the TEC module. Pins 5 and 6 are internally connected to the chassis, and can be used for cable shielding. When the “dashed” connections are made from pins 10 and 12, V_{TE} is a 4-wire measurement; otherwise, it is a 2-wire measurement. When the “dashed” connections are made from pins 14 and 15, the temperature sensor is read with a 4-wire measurement; otherwise a 2-wire measurement.



Figure 2.4: Verifying correct wiring prior to use.

2.1.5 Turning on power

With the Laser Diode and TEC modules connected, turn the key switch to the “1” position to turn on the LDC500. An internal fan will spin up at full speed for several seconds, and then return to low speed mode. The fan speed is automatically controlled, and will increase when power dissipation in the LDC500 is significant.

The display will show the instruments serial number and firmware revision, and then after a short delay will be operating in idle mode.



CAUTION

Do not press the [LASER On/Off] or [TEC On/Off] buttons yet ; we first must configure limits and operating modes for your particular setup with the LDC500.

2.2 Operating the TEC controller

On the front panel, the “TEC Control” block has five buttons (see Figure 2.5).

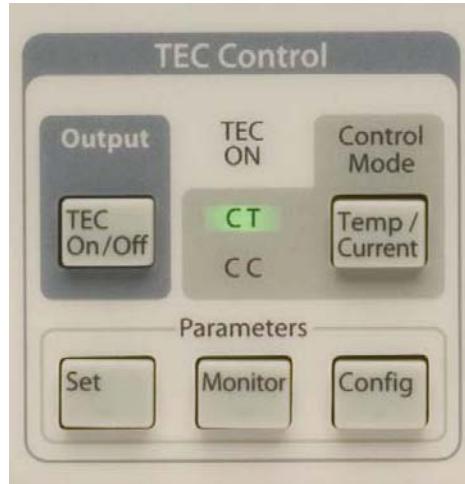


Figure 2.5: The TEC Control block.

With the TEC off, press the [Temp/Current] button to toggle between CT and CC modes. In CT mode (constant temperature), the TEC controller will measure the temperature of the stage, and delivers the proper current to the TEC module to servo the temperature to a constant value. In CC mode (constant current), the controller delivers a constant current to the TEC module, independent of the temperature reading.

Assuming you have a laser stage with a TEC module and temperature sensor, select CT mode.

2.2.1 Sensor configuration

Press the [Config] button to navigate to the TEC configuration menu tree.

- Press the [Δ] button (beside the 2-line text display) repeatedly to reach the top of the menu tree.
- Choose the appropriate temperature sensor type, from the list: NTC 10 μ A, NTC 100 μ A, NTC 1mA, NTC auto (automatic excitation current), RTD, LM335, or AD590. For now, we'll assume a 10 k Ω NTC thermistor sensor. Press [3] (or wheel to the value 3) followed by the [Enter] button.
- Press [∇] to choose the sensor calibration model. For NTC thermistors, the choices are: β -model, Steinhart-Hart model, or

no model (raw resistance units). If you have Steinhart-Hart coefficients for the sensor, select [1]; otherwise select the more-common β -model by pressing [0], followed by [Enter].

- Press [**¶**] to enter the sensor model coefficients, pressing [Enter] and then [**¶**] after each value. Stop when you reach the “Autotune” menu selection. The default coefficients correspond to commonly-used 10 k Ω NTC sensors.

Assuming you have correctly connected and configured your sensor, and placed the TEC controller in CT mode, you should now see the sensor temperature (generally around room temperature) displayed on the large green numeric display labeled “Thermoelectric Cooler.”

For more information about sensor types, models and parameters, see section 4.5.13.

2.2.2 TEC settings

After having configured the sensor, the operating settings for the TEC controller needs to be entered. These settings include the operating temperature, upper and lower temperature limits, the TEC voltage limit, and the TEC current limit.

Begin by pressing the [Set] button to navigate to the TEC Settings menu tree.

- Press the [**▲**] button repeatedly to reach the top of the menu tree.
- Enter the desired operating temperature setpoint (in degrees Celsius), say 25.005, using the numeric keypad or the wheel. Press the [Enter] button to accept the value.
- Press [**¶**], and enter the maximum TEC module current (in amperes), followed by [Enter].
- Press [**¶**], and enter the upper temperature limit (T_{\max} , in degrees Celsius), and press [Enter].
- Press [**¶**], and enter the lower temperature limit (T_{\min} , in degrees Celsius), and press [Enter]. Unless your laser assembly is in a dry-purged environment, be sure to set this value above the dew point to avoid undesired condensation on your laser.
- Press [**¶**], and enter the maximum operating voltage for your TEC module, followed by [Enter].

After the TEC controller is properly configured for your module and sensor, you still need to set the control-loop parameters (P , I , and D). The LDC500 provides a *PID* autotune function which can automatically optimize the loop parameters.

2.2.3 Verify TEC wiring polarity

If you are setting up a new TEC load, it is important to verify the TEC polarity. This can be done either manually or by performing an autotune (see section 2.2.4, below). The following procedure is a simple method to manually verify the TEC wiring polarity.

- Verify the temperature sensor is correctly configured. See section 2.2.1 for details.
- If on, turn off the TEC by pressing the [TEC On/Off] button.
- Place the instrument in constant current mode by pressing the [Temp/Current] button until the CC indicator is illuminated in the Control Mode section.
- Press the TEC [Monitor] button, and then press [Δ] or [∇] until the “TEC Monitor: T” display appears.
- If necessary, wait until the temperature stabilized near room temperature.
- Press the TEC [Set] button, and then press [Δ] or [∇] until the “TEC Settings: TE I.” display appears. Using the keypad, enter the value around 10% of the maximum current. Be sure to press [Enter] to complete the entry.
- Press the TEC [Monitor] button. The temperature display should reappear on the alphanumeric display.
- Press the [TEC On/Off] button to turn on the TEC output.
- Watch the temperature monitor display: the temperature should begin *decreasing* after a moment. Press the [TEC On/Off] button again to turn off the TEC current. In this case, the TEC wiring polarity is correct.
- If the temperature *increases*, turn off the TEC output by pressing [TEC On/Off]. In this case, the TEC wiring polarity is reversed.

2.2.3.1 Correcting the TEC polarity

If you discover the TEC wiring polarity is reversed, there are two approaches to fix the problem.

1. The preferred solution is to physically correct the wiring, reversing the current leads to the TEC element. This approach leaves the setup correctly configured for future use.
2. If it is inconvenient to physically rewire the TEC, the polarity assignment of the DB-15 TEC connector for TEC + current and TEC – current can be reversed with the TPOL command

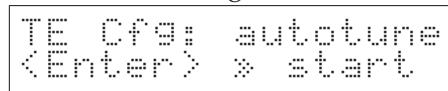
(see page 4 – 39 ; and section 3.3.3.10, page 3 – 12). The reversed polarity setting will be remembered by the LDC500 through power cycling and can be saved and recalled as part of user parameters (see SPAR and GPAR, page 4 – 48). The polarity setting will return to normal, however, in response to a hardware reset or the *RST command.

2.2.4 Auto-tuning

If you already have determined values for the P , I , and D loop gains (either from separate measurement or earlier operation with the LDC500), you can enter them directly from the TEC [Config] menu tree. In general, however, autotuning is recommended.

- Press the [Config] button to select the TEC configuration menu tree. Use the [Δ] and [∇] buttons to navigate to the “Autotune”

item:



- Pressing [Enter] now will initiate an autotuning cycle. The TEC controller will temporarily turn on, and a thermal step response is measured to estimate the optimum loop gains and time constants.
- The default current step used is 10 % of the maximum TEC module current (set previously). If a different current step is desired for autotuning, press [∇] to “Autotune tuneStep:”, and change the setting to the desired step size (in amperes). Press [Δ] to navigate back to the Autotune “start” item.
- If you need to cancel autotuning, you can press the [Clear/Cancel] button; otherwise wait until the display indicates that autotuning has completed.

For best initial results, the temperature should be stable at room temperature, and the TEC module should have been off for a few minutes (to allow the heat-sink side to also reach equilibrium). You can check the results by pressing [∇] to display the “PID vals” for P , I , and D . Note that all loop gain settings are given in physical units ($A/^{\circ}C$, $1/s$, or s). See section 4.5.12 for more details on the temperature control algorithm.

The time needed for autotuning is dependent on the thermal mass of the stage—the larger the thermal mass, the longer the autotuning process. If the thermal time constant is longer than around 60 seconds, default autotuning may fail because of a weak or noise signal. In this situation, a possible solution is to increase the tuning step size to a larger value (see above). The allowed range is from 0 to 25 %

of the TEC current limit value. Note that changing the TEC current limit will return the tuning step size back to its default value of 10 % of the limit.

Autotuning may also fail if the TEC polarity is incorrect. In this case, the message

TE Cfg: Autotune
Check Polarity

is displayed. Correct the TEC polarity (see section 2.2.3.1 above) and then repeat the autotune process.

2.2.5 TEC operation in CT mode

After entering the sensor configuration, TEC settings, and tuning the control loop, the TEC controller is ready for operation. Turn the TEC controller on by pressing the [TEC On/Off] button. The *TEC ON* indicator should illuminate. The temperature shown on the large green display should settle to your setpoint (in this example, 25.005 °C). The overshoot is typically less than 60 mK in magnitude.

You can change the temperature setpoint by navigating to the [Set] menu tree. Press [**▲**] repeatedly to reach the top item, “T:”. Turn the wheel or directly type a new temperature, say 20.000 °C, and press [Enter]. The TEC controller will adjust the output current and settle the temperature to the new setting.

Temperature can also be adjusted in “live” tracking mode. Press the [Live Entry] button to enter live tracking mode (the *Live* indicator will illuminate). Turning the wheel now will cause “on-the-fly” changes to the operating temperature. Pressing any button (including the [Live Entry] button) will exit live mode.

Once the temperature has stabilized at the desired operating point, many systems benefit from re-tuning. This is because of the inherent non-linearities in thermoelectric coolers, leading to a strong temperature-dependence on the overall loop gain. If desired, repeat the autotuning with the TEC on. The TEC controller will return to the original setpoint after autotuning has completed. This re-tune operation will often reduce the thermal drift significantly.

2.2.6 Thermal runaway

In general, it is possible to obtain outstanding temperature control with a thermoelectric cooler. At the limits of a TEC’s cooling power, however, the thermal efficiency of the cooler diminishes. At some point, a small increment in cooling current will actually lead to an

increase in stage temperature, due to a combination of heatsink limitations and TEC efficiency. At this point, a system under closed-loop control (such as the case with a LDC500 operating in CT mode) no longer has negative feedback, but instead now has *positive* electrothermal feedback. From this point forward, a fault condition known as “thermal runaway” begins. Left unchecked, thermal runaway can cause destructive overheating of the TEC and laser diode.

The LDC500 will automatically detect thermal runaway any time the TEC current is at or near the limit (in the cooling direction), but the temperature error is increasing (indicating the temperature is rising). If this condition persists, the LDC500 will turn off the TEC controller and report a “thermal runaway” fault.

2.2.7 TEC operation in CC mode

Typically, users will operate the TEC controller in CT mode. In some situations (often when characterizing a new TEC module), it may be desired to bypass the temperature control loop, and operate the TEC controller in simple constant-current (CC) mode.

If the TEC controller is off, pressing the [Temp/Current] button toggles the operating mode between CT and CC. In CC mode, press the TEC [Set] button and navigate to the top of the menu tree with [Δ], to reach the “TE I:” item. Enter the desired operating current (in amperes), either with the keypad or the wheel, pressing [Enter] to accept. Press [TEC On/Off] to turn the TEC controller on. The large green display will indicate the actual operating current, in amperes.

If the TEC controller is on, pressing the [Temp/Current] button *twice* will change the TEC controller to CC mode. Switching in this way causes the TEC current to be fixed at the last operating value from CT operation (“bumpless” transfer). Pressing [Temp/Current] twice again will return to CT mode, but now the temperature setpoint will be taken from the most recent measurement from CC operation (again, “bumpless” transfer). This “on-the-fly” switching between modes can be disabled from the TEC [Config] menu at item “CC–CT lock when on”.

Live adjusting of the operating current, by pressing [Live] in CC mode, operates similarly to live temperature control in CT mode.

2.2.8 TEC limit values

Limit values for the TEC controller, both electrical (V_{\max} and I_{\max}) and thermal (T_{\max} and T_{\min}) can be changed at any time from the TEC [Set] menu.

If a new limit value is more restrictive than the present setpoint, the setpoint is “dragged” along with the limit value. For instance, if the temperature setpoint in CT mode was 15.000 °C, and then the minimum temperature changed from 10.000 °C to 18.000 °C, the setpoint will automatically follow up to the new minimum. Conversely, attempting to change a setpoint outside of the present values of the limits will fail. For example, if the current setpoint in CC mode is 1.000 A, and the current limit is 2.000 A, an attempt to change the current setpoint to 2.125 A will fail. Stated another way, limit values always have priority over setpoint values.

2.2.9 Monitoring the TEC

The TEC controller’s working status may be monitored with the alphanumeric display. Press the TEC [Monitor] button, and then use [Δ] and [∇] to step between monitoring the TEC current, TEC voltage, temperature, and raw sensor output.

Items displayed on the Monitor tree are read-only.

2.2.10 Configuring TEC trip-offs

Under certain limit conditions, it is important to shut down the TEC controller output. To customize which events will lead to TEC shutdown, press the TEC [Config] button, and then press [∇] until you reach the first “TE Cfg: Trip-OFF” item.

Specific events can be armed to shut down the TEC controller by setting the “Trip-OFF” selection to “Y”; the events will be ignored for shut-down by selecting “N.”

- To shut down if the TEC current reaches its limit value, set “Trip-OFF at TE Ilim:” to “Y.” Note that for normal operation, this event is typically left at set to “N,” as the current source will never output a value greater than the programmed limit—the effect of reaching the limit is to “saturate” the temperature control loop, which will often happen during large temperature setpoint changes.
- To shut down if the TEC voltage reaches its limit value, set “Trip-OFF at TE Vlim:” to “Y.” This is an important limit, and should only be disabled by experienced users. *Note: there is no voltage-limiting in the TEC current source, so disabling the Vlim trip-OFF can lead to destruction of the user’s TEC module.*
- To shut down if the temperature goes above T_{max} , set “Trip-OFF at Tmax:” to “Y.”



CAUTION

- To shut down if the temperature goes below T_{\min} , set “Trip-OFF at Tmin:” to “Y.”
- To shut down when there is a sensor fault, set “Trip-OFF at SensFault:” to “Y.” Note that in CT mode, a sensor fault will *always* shut down the TEC controller.

For more details, see section 4.5.14.

2.3 Operating the Laser Diode Driver

On the front panel, the “Laser Diode Control” block has five buttons (see Figure 2.6).

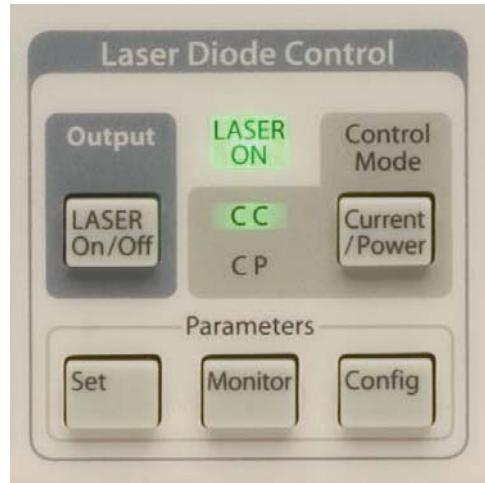


Figure 2.6: The Laser Diode Control block.

The laser control mode can be set to CC (constant current) or CP (constant power). In CP mode a photodiode is required to sense the optical intensity. By pressing the [Current/Power] button, you can toggle between modes. For this example we will assume CC mode.

2.3.1 Laser driver configuration

Press the [Config] button to select the laser diode (LD) configuration menu tree. Here the LD driver will be configured appropriately for your laser diode. Configurations include output current range, working bandwidth, photodiode bias voltage and responsivity, and more.

- Press [**]**] repeatedly to reach the top of the menu tree. Press [0] to select low range (0 – 250 mA), or press [1] to select high range (0 – 500 mA). Press [Enter] to accept. The wheel can also be used to make these selections. The range is indicated by the 250 mA or 500 mA indicator illuminated at the upper right block of the LDC500, just above the wheel.
- Press [**]**. Press [1] to enable the analog modulation input, or press [0] to disable modulation. For optimum noise performance, leave modulation disabled except when needed for actual analog modulation control.
- Press [**]** to the “CC BW” item. Press [0] for low bandwidth (DC – 10 kHz), or [1] for high bandwidth (DC – 1.2 MHz). Band-

width controls the intrinsic bandwidth of the current source, and limits the response to analog modulation. The effective output impedance of the current source is higher (stiffer) in high-bandwidth mode, but this comes at the cost of slightly higher current noise. For lowest output noise, select [0].

The next configuration menu items are specific to the photodiode circuit, and are optional for CC mode since photodiode feedback is not involved in this mode. To properly configure a photodiode for monitoring purposes in CC mode, see section 2.3.4

2.3.2 Laser settings

Press the [Set] button to select the LD Settings menu tree.

- Press [**▲**] repeatedly to reach the top of the menu tree.
- Press [**▼**] to the “LD Ilim:” item. Enter the desired current limit (in milli-amperes) for your laser diode, and press [Enter] to accept. The laser current will be limited to this value at all times, including when adding analog modulation.
- Press [**▼**] twice, to the “LD Vlim:” item. Enter the maximum voltage for your laser diode. The LD driver will unconditionally shut down if the operating voltage on the laser diode ever exceeds this value.
- Press [**▲**] repeatedly to return to “LD I:”. Now you may enter the desired operating current, followed by [Enter].

2.3.3 Operating the laser in CC mode

Before turning the laser driver on, determine whether active TEC cooling is required for your laser. If so, turn on the TEC controller and wait for the temperature to stabilize (see section 2.2). To turn on the laser driver, press the [LASER On/Off] button. This will begin a 3 second delay period, during which the *LASER ON* indicator will blink. To abort turning the laser on during this delay, press [LASER On/Off] again. Once the delay is completed, the shorting relay will be heard to open, and the laser current source will quickly ramp up to the programmed current setting.

To change the current setting, press [Set] to navigate to the LD Settings tree, and navigate (with [**▲**]) to the “LD I:” item. Enter a new current setting (either with the numeric keypad or the wheel) and press [Enter] to accept.

Output current can be dynamically adjusted with the wheel by pressing the [Live Entry] button, entering “live” mode. Pressing any key

will exit “live” mode.

The output current limit can be changed at any time. If the limit is changed to be smaller than the present value of the laser current, the setting will be “dragged” along with the limit value downwards.

Changing the voltage limit is allowed at any time. If the voltage limit is changed to be smaller than the present value of the laser operating voltage, the laser driver will immediately trip off.

2.3.4 Operating the laser in CP mode

To operate in CP (constant power) mode, a photodiode must be configured for the LDC500 to measure the laser optical power. This configuration includes the photodiode reverse bias voltage, responsivity value, and display units.

- Beginning with the LD driver off, select CP mode by pressing [Current/Power]. The mode indicator switches between *CC* and *CP*.
- Press [Config], and navigate with [**▲**] and [**▼**] to the menu item “LD Cfg: PD units.” To control the laser in (optical) milliwatt units, set “use mW:” to “Y”; to control the laser in raw microamperes of photodiode current, set “use mW:” to “N.” For this example, select “N.”
- Press [**▼**] to select “PD Bias:”, and set the photodiode reverse bias between 0.0 V and 5.0 V.
- If you know the photodiode responsivity (in $\mu\text{A}/\text{mW}$), you can enter the value directly by pressing [**▼**] twice to navigate to the “LD Cfg: PD resp” item.
- If you do not know the responsivity, leave the responsivity value unchanged and be sure to set the “PD units” item to “use mW: N.” See section 2.3.7 for how to use the LDC500 to calibrate a photodiode responsivity.
- Press [Set] to select the LD Settings menu tree, and navigate with [**▲**] and [**▼**] to the “LD Ilim:” item. This sets the *laser diode* limit current, and should be adjusted to ensure the safe operating current of the laser diode is never exceeded.
- Press [**▼**] repeatedly to select “LD Vlim:”, and set this to the safe maximum operating voltage for your laser diode.
- Press [**▲**] to select “PD Ilim:”. This item is the *photodiode* limit current, and corresponds to the maximum setpoint value that can be entered in CP mode. Note that the LD driver can be

configured to trip-off if this limit is exceeded, but there is no active “clamping” circuit to limit the photodiode current.

- Press [**▲**] repeatedly to select “PD I:”. This is the operating point setting in CP mode (using μA units for photodiode current). Enter the desired initial operating point, and press [Enter] to accept.

The laser can now be turned on by pressing [LASER On/Off].

If the laser was on and in CC mode, the LD driver can be switched to CP mode directly without turning off the laser first. To do this, press the [Current/Power] button; a confirmation message will appear, requesting you to press the button “again to confirm.” If you press [Current/Power] within 2 seconds, the LD driver mode will change between CC and CP “on-the-fly”, presetting the CP setpoint based on the most recent measurement of the photodiode current. This feature of switching “on-the-fly” can be disabled by setting the “LD Cfg” menu tree item, “CC/CP lock when on:” to “Y.”

2.3.5 Modulation

Analog modulation of the laser diode current is allowed in CC and CP modes when the “Modulate enable:” item in the LD Cfg menu tree (reached by the [Config] button) is set to “Y.” The front-panel BNC input accepts ± 10 V inputs, which imposes a modulation on the laser current in addition to the DC setpoint. See the specifications table on page ix for DC transfer functions (in mA/V) for the different models.

To achieve the highest bandwidth for modulation, the cable connecting the LDC500 to the laser should be as short as possible. Best results are obtained if the laser is electrically floating; the bandwidth can be affected if the laser cathode is grounded. The bandwidth for CC mode is set by “LD Config: CC BW”, and can be either “0)low” (DC – 10 kHz), or “1)high” (DC – 1.2 MHz). The bandwidth for CP mode is set by “LD Config: CP BW”, and can be either “0)low” (DC – 100 Hz), or “1)high” (DC – 5 kHz). Note that the actual bandwidth is strongly affected by physical characteristics of the laser, the photodiode (in CP mode), and the interconnect cabling.

2.3.6 Monitoring the LD

The LD driver’s status may be monitored in the alphanumeric display. Press the LD [Monitor] button, and then use [**▲**] and [**▼**] to step between monitoring I_{ld} (the laser diode current), I_{pd} (the photodiode current), P_{pd} (the photodiode power, = I_{pd} / responsivity), V_{ld} (the laser diode operating voltage), and the external interlock status.

Items displayed on the Monitor tree are read-only.

2.3.7 Optical power calibration

To successfully operate the LDC500 in optical power units (mW), a valid responsivity value is needed. If you already know the responsivity of your photodiode (by previous measurement or from the datasheet), you can directly enter the value by pressing the LD [Config] button, and navigating to the “LD Cfg: PD resp” item.

Alternatively, you can use the LDC500 to measure and set the photodiode responsivity. To do this, you will need to be able to operate your laser diode, and have access to a laser power meter to measure the actual optical power being generated by the laser.

For best results when calibrating responsivity, the LD driver should be operated in CP mode, with “PD units: use mW:” set to “N” (raw μ A photodiode units). Alternatively, the LD driver can be operated in CC mode, but the photodiode readings may drift slightly during calibration.

- Make sure the LD driver is ON, preferably in CP mode (with “PD units: use mW:” set to “N”), or else in CC mode.
- Adjust the LD output so that a good, stable optical power reading can be obtained with the laser power meter.
- Press [Config], and navigate to the “LD Cfg: PD calib at:” item.
- Note the (stable) optical power reading, in mW, and enter the value using the keypad or wheel.
- Pressing [Enter] will cause the LDC500 to take the most recent (internal) reading of photodiode current, and divide it by the power calibration just entered, to calculate a new value for the PD responsivity.
- If the calibration is successful, the LDC500 will play a short 4-note tune. The new value of responsivity can be checked by pressing [¶] to select “LD Cfg: PD resp”.

Note that active responsivity calibration (using the “LD Cfg: PD calib at:” item) is prohibited when the LD driver is off, or when operating in CP mode with mW units.

2.3.8 Configuring LD trip-offs

Under certain limit conditions, it is important to shut down the LD driver output. To customize which events will lead to shutdown,

press the LD [Config] button, and then press [**▼**] until you reach the first “LD Cfg: Trip-off” item.

Specific events can be armed to shut down the LD controller by setting the “Trip-off” selection to “Y”; the events will be ignored for shut-down by selecting “N.”

- To shut down if the LD current reaches its limit value, set “Trip-off at LD Ilim:” to “Y.” Note that for normal operation, this event is typically left at set to “N,” as the current source will clamp the output before exceeding Ilim value.
- To shut down if the photodiode reading (in either μA or mW) exceeds its limit value in CP mode, set “Trip-off at CP Plim:” to “Y.”
- To shut down if the photodiode reading (in either μA or mW) exceeds its limit value in CC mode, set “Trip-off at CC Plim:” to “Y.”
- To shut down at any time that the TEC controller is not on (either not turned on, or tripped off, or turned off), set “Trip-off at TE Off:” to “Y.”
- To shut down if the temperature goes above T_{\max} , set “Trip-off at Tmax:” to “Y.” Note that this condition can operate independent of the TEC controller, and even operate if there is *no* TEC module. However, if enabled, a sensor fault will also cause the LD driver to trip off.
- To shut down if the temperature goes below T_{\min} , set “Trip-off at Tmin:” to “Y.” Again, this condition can operate independent of the TEC module.

2.4 Factory Default Settings

Instrument settings (but not network configuration or remote interface setup) can be restored to their default settings using the Recall configuration menu, and recalling configuration “9” (Default). See section 3.4.1.2 for details.

The LDC500 can be returned to its factory default state by holding the [Clear/Cancel] button while turning the Power key from the “0” (off) position to the “1” (on) position. Keep the [Clear/Cancel] button depressed until the reset message appears on the alphanumeric display.

Note that resetting the instrument to factory defaults will erase all saved user configurations, as well as any saved network parameters. The factory defaults are shown below.

	Item	Value	Notes
Laser Diode Settings	LD I	0 mA	Laser current setpoint
	LD Ilim	20 mA	Laser current limit
	PD Ilim	5000 μ A	Photodiode current limit
	PD I	0 μ A	Photodiode current setpoint
	LD Vlim	5 V	Laser voltage limit
Laser Diode Config	I Range	high	Laser current range
	BW	high	Modulation bandwidth
	Modulate	no	Modulation input not enabled
	PD unit use mW	no	CP mode uses μ A, not mW
	PD bias	2.5 V	Photodiode reverse bias
	PD resp.	1 μ A/mW	Photodiode responsivity
	CC/CP lock	no	CC/CP transitions allowed
	Trip-off @ LD Ilim	no	Do not trip off when laser current limit is reached
	Trip-off @ CP Plim	no	Do not trip off when laser power limit is reached in CP mode
	Trip-off @ CC Plim	no	Do not trip off when laser power limit is reached in CC mode
	Trip-off @ TE off	no	Do not trip off when when the TEC controller is off
	Trip-off @ Tmax	no	Do not trip off when when max. temperature is reached
	Trip-off @ Tmin	no	Do not trip off when when min. temperature is reached

	Item	Value	Notes
TEC Controller Settings	T	25°C	TEC temperature setpoint
	TE I	0 A	TEC current setpoint
	TE Ilim	2.25 A	TEC module current limit
	Tmax	50°C	Upper temperature limit for stage
	Tmin	0°C	Lower temperature limit for stage
	TE Vlim	8 V	Maximum TEC operating voltage
TEC Controller Config	Sensor type	NTC auto	NTC thermistor w/ automatic excitation current
	Sensor model	β -model	Model for calculating temperature from resistance
	β	3800°C	Exponent factor for sensor model
	R0	10 kΩ	Resistance scale for sensor model
	T0	25°C	Reference temperature for sensor model
	PID P	-0.5 A/°C	Proportional gain (temperature control)
	PID I	0.36/second	Integral gain
	PID D	0.65 second	Derivative gain
	Auto tune step	0.225 A	Step size for autotuning
	CC/CT lock	no	CC/CT transitions allowed
Utility	Trip-off @ TE Ilim	no	Do not trip off when TEC current limit is reached
	Trip-off @ TE Vlim	YES	Trip off when TEC voltage limit is reached
	Trip-off @ Tmax	YES	Trip off when upper temperature limit is reached
	Trip-off @ Tmin	YES	Trip off when lower temperature limit is reached
	Trip-off @ fault	YES	Trip off when temperature sensor is open, or wrong type, or illegal model parameters
	TEC Polarity Reversed	NO	TEC output current uses standard (non-reversed) polarity.
	IP address	169.254.46.27	Should be reset for your local network environment
	IP netmask	255.255.0.0	
	Gateway	0.0.0.0	may need to be set for your network
	GPIB address	2	
	Ethernet speed	100 Base-T	may need to be changed for older networks
	RS-232 baudrate	9600	
	Brightness	50%	Alphanumeric display brightness

3 Menus

This chapter lists the contents of all seven menu trees accessible from the front panel.

In This Chapter

3.1	Menu Navigation	3–2
3.2	Laser Menus	3–2
3.2.1	LD settings	3–2
3.2.2	LD monitor	3–4
3.2.3	LD configuration	3–5
3.3	TEC Menus	3–7
3.3.1	TEC settings	3–7
3.3.2	TEC monitor	3–8
3.3.3	TEC configuration	3–9
3.4	Other Menus	3–12
3.4.1	Utility	3–13
3.4.2	Other messages	3–14

3.1 Menu Navigation

This chapter documents the menu items under each of the seven menu trees. Further details on many of these instrument settings are in the remote programming chapter; the remote command equivalent, with page number, is given as (SILD, 4 – 20).

Within a single menu tree, navigation between menu items is by pressing the [**▲**] and [**▼**] buttons.



Figure 3.1: The menu navigation buttons

3.2 Laser Menus

The three menu trees described here are all accessed by pressing the “Parameter” buttons under the “Laser Diode Control” block of the front panel.

3.2.1 LD settings

The LD settings menu tree is selected by pressing the [Set] button under “Laser Diode Control”.

3.2.1.1 Laser current setpoint

LD Settings:
LD I: 500.00mA

(SILD, 4 – 20)
Only visible in CC mode.

3.2.1.2 Photodiode current setpoint

LD Settings:
PD I: 123.4μA

(SIPD, 4 – 20)
Only visible in CP mode, with PDMW = “N.”



Figure 3.2: The LD settings menu selection.

3.2.1.3 Photodiode power setpoint

LD Settings:
PD P: 23.10mW (SWPD, 4 – 21)
Only visible in CP mode, with PDMW = "Y."

3.2.1.4 Laser current limit

LD Settings:
LD Ilimit: 123.0mA (SILM, 4 – 18)

3.2.1.5 Photodiode current limit

LD Settings:
PD Ilimit: 5000μA (PILM, 4 – 19)
Only visible with PDMW = "N."

3.2.1.6 Photodiode power limit

LD Settings:
PD Plimit: 500mW (PWLM, 4 – 19)
Only visible with PDMW = "Y."

3.2.1.7 Laser voltage limit

LD Settings:
LD Ulimit: 5.25V (SVLM, 4 – 18)

3.2.2 LD monitor

The LD monitor menu tree is selected by pressing the [Monitor] button under “Laser Diode control”. Note that monitor selections are read only, and cannot be set.



Figure 3.3: The LD monitor menu selection.

3.2.2.1 Laser operating current

```
LD Monitor:
Ild= 100.03mA (RILD?, 4-22 )
```

3.2.2.2 Photodiode current

```
LD Monitor:
IPd= 2003.0μA (RIPD?, 4-23 )
```

3.2.2.3 Photodiode power

```
LD Monitor:
Ppd= 307.00mW (RWPD?, 4-23 )
```

3.2.2.4 Laser operating voltage

```
LD Monitor:
Vld= 1.302V (RVLD?, 4-23 )
```

3.2.2.5 Interlock

LD Monitor:
Interlock=Closed (ILOC?, 4 – 24)

3.2.3 LD configuration

The LD configuration menu tree is selected by pressing the [Config] button under “Laser Diode control”.



Figure 3.4: The LD configuration menu selection.

3.2.3.1 Output range

LD Config:
IRange: *1>500mA (RNGE, 4 – 24)

3.2.3.2 Modulate Enable

LD Cfg: Modulate
enable: *N (MODU, 4 – 24)

3.2.3.3 Modulation bandwidth

LD Config: CC BW
*1)high 1.2MHz (SIBW, 4 – 25)

3.2.3.4 Photodiode units

LD Cfg: PD units
use mW: *N (PDMW, 4 – 26)

3.2.3.5 Photodiode bias

LD Config:	PD Bias:	2.5V
------------	----------	------

(BIAS, 4 – 26)

3.2.3.6 Calibrate photodiode responsivity

LD Cfg:	PD calib
at:	12.04mW

(CALP, 4 – 27)

3.2.3.7 Photodiode responsivity

LD Cfg:	PD resp
	1.000 μ A/mW

(RESP, 4 – 27)

3.2.3.8 Control mode locking

LD Config:	CC/CP
lock when on:	*N

(SMLK, 4 – 28)

3.2.3.9 Laser trip-off configuration

Several conditions can be enabled to trip off the laser current source.

- LD Cfg: Trip-OFF
at LD ILim: *N

(AILM, 4 – 29)

- LD Cfg: Trip-OFF
at CP PLim: *N

(APLP, 4 – 29)

- LD Cfg: Trip-OFF
at CC PLim: *N

(APLC, 4 – 29)

- LD Cfg: Trip-OFF
at TE Off: *Y

(ATOI, 4 – 30)

- LD Cfg: Trip-OFF
at Tmax: *Y

(ATMX, 4 – 30)

- LD Cfg: Trip-OFF
at Tmin: *N

(ATMN, 4 – 31)

3.3 TEC Menus

The three menu trees described here are all accessed by pressing the “Parameter” buttons under the “TEC Control” block of the front panel.

3.3.1 TEC settings

The TEC settings menu tree is selected by pressing the [Set] button under “TEC Control” block.



Figure 3.5: The TEC settings menu selection.

3.3.1.1 Temperature setpoint

TEC Settings:	
T:	22.000 °C
(TEMP, 4 – 34)	

Only displayed in CT mode.

3.3.1.2 Resistance setpoint

TEC Settings:	
R:	10.000 k Ω
(TRTH, 4 – 34)	

Only displayed in CT mode, without a sensor model.

3.3.1.3 TEC current setpoint

TEC Settings:	
TE I:	1.123 A
(TCUR, 4 – 34)	

Only displayed in TEC CC mode.

3.3.1.4 TEC current limit

TEC Settings:	TE Ilim: 3.000A	(TILM, 4-31)
---------------	-----------------	--------------

3.3.1.5 Maximum temperature

TEC Settings:	Tmax: 65.000°C	(TMAX, 4-32)
---------------	----------------	--------------

3.3.1.6 Minimum temperature

TEC Settings:	Tmin: 7.500°C	(TMIN, 4-32)
---------------	---------------	--------------

3.3.1.7 Maximum resistance

TEC Settings:	Rmax: 12.500kΩ	(TRMX, 4-33)
---------------	----------------	--------------

Only displayed without a sensor model.

3.3.1.8 Minimum resistance

TEC Settings:	Rmin: 9.500kΩ	(TRMN, 4-33)
---------------	---------------	--------------

Only displayed without a sensor model.

3.3.1.9 TEC voltage limit

TEC Settings:	TE Ulim: 8.500V	(TVLM, 4-32)
---------------	-----------------	--------------

3.3.2 TEC monitor

The TEC monitor menu tree is selected by pressing the [Monitor] button under “TEC control”. Note that monitor selections are read only, and cannot be set.

3.3.2.1 TEC current

TEC Monitor:	Ite= -1.999A	(TIRD?, 4-35)
--------------	--------------	---------------



Figure 3.6: The TEC monitor menu selection.

3.3.2.2 TEC voltage

```
TEC Monitor:  
Ute= 1.609V (TVRD?, 4 – 35 )
```

3.3.2.3 Temperature reading

```
TEC Monitor:  
T= 22.8910 °C (TTRD?, 4 – 35 )
```

3.3.2.4 Raw thermometer reading

```
TEC Monitor:  
R= 10.967kΩ (TRAW?, 4 – 35 )
```

3.3.3 TEC configuration

The TEC configuration menu tree is selected by pressing the [Config] button under "TEC control".

3.3.3.1 Thermometer sensor type

```
TE Cfg: Sensor  
*3) NTC auto (TSNR, 4 – 40 )
```



Figure 3.7: The TEC configuration menu selection.

3.3.3.2 Sensor models

- TE Cfg: Model
*0) NTC β , $R(t)$, t (TMDN, 4 – 41)
For NTC thermistors
- TE Cfg: Model
*0) RTD $R/R_0 = 1 + \alpha T$ (TMDR, 4 – 41)
For RTDs

3.3.3.3 Model parameters for NTC β

These items are only visible for NTC sensors, when the calibration model is set to BETA.

- TE Cfg: β :
3800.000K (TNB, 4 – 43)
- TE Cfg: $R(T_0)$:
10.000k Ω (TNTR, 4 – 42)
- TE Cfg: T_0 :
25.00°C (TNNT, 4 – 43)

3.3.3.4 Model parameters for NTC Steinhart-Hart

These items are only visible for NTC sensors, when the calibration model is set to SHH. Note that the scale factors shown in the display (E-3, E-4, and E-7) are fixed, and cannot be modified; to enter the value 3.14×10^{-4} for the A coefficient, you would type “0.31400E-3”.

- TE Cfg: S-H A:
1.12500E-3 (TSHA, 4 – 42)
- TE Cfg: S-H B:
2.34700E-4 (TSHB, 4 – 42)
- TE Cfg: S-H C:
0.85500E-7 (TSCH, 4 – 42)

3.3.3.5 Model parameters for RTD α

These items are only visible for RTD sensors, when the calibration model is set to ALPHA.

- TE Cfg: α :
0.00385 $\alpha/\alpha^{\circ}\text{C}$ (TRTA, 4 – 43)
- TE Cfg: $R_0(0^{\circ}\text{C})$:
0.1000k Ω (TRTR, 4 – 43)

3.3.3.6 Autotuning

Autotuning is typically performed simply with the TUNE command. For special situations requiring user control of the step size used to measure the thermal step response, the TATS command is also available.

- TE Cfg: autotune
<Enter> > start (TUNE, 4 – 37)
- TE Cfg: autotune
tuneStep: 0.225A (TATS, 4 – 38)

3.3.3.7 PID parameters

Temperature control loop parameters are typically set automatically by autotuning. Users can inspect and modify the results with these menu items:

- TE Cfg: PIDvals
P: -1.24A/ $^{\circ}\text{C}$ (TPGN, 4 – 38)
- TE Cfg: PIDvals
I: 0.36/s (TIGN, 4 – 39)

- TE Cfg: PIDvals
D: 0.65s (TDGN, 4 – 39)

3.3.3.8 Control mode locking

- TE Cfg: CC/CT
lock when on: *N (TMLK, 4 – 37)

3.3.3.9 TEC trip-off configuration

Several conditions can be enabled to trip off the TEC current source.

- TE Cfg: Trip-OFF
at TE Ilimi: *N (TTIL, 4 – 46)
- TE Cfg: Trip-OFF
at TE Ulimi: *Y (TTVL, 4 – 46)
- TE Cfg: Trip-OFF
at Tmaxi: *Y (TTMX, 4 – 45)
- TE Cfg: Trip-OFF
at Tmini: *Y (TTMN, 4 – 45)
- TE Cfg: Trip-OFF
at SensFault: *Y (TTSF, 4 – 45)

3.3.3.10 TEC polarity

The sense of the TEC current output polarity can be reversed for TE elements that are wired backwards, so that *positive* current leads to *heating* of the stage.

- TE Cfg: Polarity
reversed: *N (TPOL, 4 – 39)

3.4 Other Menus

In addition to the Utility menu (described below), additional messages that may appear on the alphanumeric display are also described in this section.

3.4.1 Utility

General housekeeping and utility functions are found under the Utility menu, which can be reached by pressing the [Utility/Local] button to the left of the alphanumeric display.



Figure 3.8: The Utility menu selection.

3.4.1.1 Save parameters

```
Util: Save cfg:  
Overwrite: User3 (SPAR, 4 – 48 )
```

3.4.1.2 Restore parameters

```
Util: Recall cfg  
Read from: User2 (GPAR, 4 – 48 )
```

3.4.1.3 IP address

The numerical IP address, netmask, and default gateway are each configured with successive menu items (3 in all).

```
Util: IP Address  
• 169.254.46.27 (IPAD, 4 – 50 )
```

```
Util: IP Netmask  
• 255.255.0.0 (NMSK, 4 – 50 )
```

```
Util: Gateway  
• 0.0.0.0 (GWAY, 4 – 50 )
```

3.4.1.4 GPIB address

```
Util: GPIB  
Address: 2
```

3.4.1.5 Ethernet speed

```
Util: Enet Speed  
2) 100Base-T (ENET, 4 – 51)
```

3.4.1.6 Baud rate

```
Util: RS-232  
Baud: *7) 57600 (BAUD, 4 – 49)
```

3.4.1.7 Display brightness

```
Util: Brightness  
Level: *3) 50.0% (BLVL, 4 – 49)
```

3.4.1.8 Ethernet MAC address

```
Util: MACaddress  
0019:b303:ffff (MACA?, 4 – 50)
```

3.4.2 Other messages

In addition to the menu selections described above, the alphanumeric display may also display various error or status messages, such as

```
-TE Tripped OFF-  
Thermal Runaway
```

To clear a message and return to the menu selection, press the [Clear/Cancel] button.

4 Remote Operation

This chapter describes operating the LDC500 over the remote interfaces.

In This Chapter

4.1	Index of Common Commands	4-2
4.2	Alphabetic List of Commands	4-6
4.3	Introduction	4-10
4.3.1	Interface configuration	4-10
4.3.2	Buffers	4-10
4.4	Ethernet	4-10
4.4.1	Connection example	4-11
4.5	Commands	4-16
4.5.1	Command syntax	4-16
4.5.2	Notation	4-17
4.5.3	Examples	4-17
4.5.4	Laser limit commands	4-18
4.5.5	Laser setting commands	4-20
4.5.6	Laser monitor commands	4-22
4.5.7	Laser configuration commands	4-24
4.5.8	Laser trip-off commands	4-29
4.5.9	TEC limit commands	4-31
4.5.10	TEC setting commands	4-33
4.5.11	TEC monitor commands	4-35
4.5.12	TEC configuration commands	4-36
4.5.13	TEC sensor commands	4-40
4.5.14	TEC trip-off commands	4-45
4.5.15	Interface commands	4-46
4.5.16	Status commands	4-52
4.6	Status Model	4-57
4.6.1	Status byte (SB)	4-58
4.6.2	Service request enable (SRE)	4-59
4.6.3	Standard event status (ESR)	4-59
4.6.4	Laser diode condition (LDCR)	4-60
4.6.5	TEC controller condition (TECR)	4-61

4.1 Index of Common Commands

Symbol	Definition
<i>f, g, h</i>	Floating-point value
<i>i, j</i>	Unsigned integer
<i>z</i>	Literal token
(?)	Required for queries; illegal for set commands
<i>var</i>	Parameter always required
{ <i>var</i> }	Required parameter for set commands; illegal for queries
[<i>var</i>]	Optional parameter for both set and query forms

Laser limits

SVLM(?) { <i>f</i> }	4 – 18 Laser Diode Voltage Limit
SILM(?) { <i>f</i> }	4 – 18 Laser Diode Current Limit
PILM(?) { <i>f</i> }	4 – 19 Photodiode Current Limit
PWLM(?) { <i>f</i> }	4 – 19 Photodiode Power Limit

Laser settings

LDON(?) { <i>z</i> }	4 – 20 Laser Diode Current On/Off
SILD(?) { <i>f</i> }	4 – 20 Laser Diode Current Setpoint
SIPD(?) { <i>f</i> }	4 – 20 Photodiode Current Setpoint
SWPD(?) { <i>f</i> }	4 – 21 Photodiode Power Setpoint
SCAN(?) { <i>f, i, g</i> }	4 – 21 Multi-step Scan of Laser Setpoint
SYND(?) { <i>h</i> }	4 – 22 Sync delay for scans

Laser monitor

RILD?	4 – 22 Laser Diode Current Reading
RVLD?	4 – 23 Laser Diode Voltage Reading
RIPD?	4 – 23 Photodiode Current Reading
RWPD?	4 – 23 Photodiode Power Reading
ILOC?	4 – 24 Interlock

Laser configuration

RNGE(?) { <i>z</i> }	4 – 24 Laser Diode Current Range
MODU(?) { <i>z</i> }	4 – 24 Modulate Enable
SMOD(?) { <i>z</i> }	4 – 25 Laser Control Mode
SIBW(?) { <i>z</i> }	4 – 25 Laser Modulation Bandwidth
PDMW(?) { <i>z</i> }	4 – 26 Photodiode Milliwatt Units
BIAS(?) { <i>f</i> }	4 – 26 Photodiode Bias Voltage
CALP <i>f</i>	4 – 27 Calibrate Photodiode Responsivity
RESP(?) { <i>f</i> }	4 – 27 Photodiode Responsivity
SMLK(?) { <i>z</i> }	4 – 28 Lock Laser Control Mode When On

Laser trip-off

AILM(?) {z}	4 – 29 Laser Trip-off on Current Limit
APLP(?) {z}	4 – 29 Laser Trip-off on Photodiode (CP)
APLC(?) {z}	4 – 29 Laser Trip-off on Photodiode (CC)
ATOF(?) {z}	4 – 30 Laser Trip-off on TEC Off
ATMX(?) {z}	4 – 30 Laser Trip-off on Max Temperature
ATMN(?) {z}	4 – 31 Laser Trip-off on Min Temperature

TEC limits

TILM(?) {f}	4 – 31 TEC Current Limit
TVLM(?) {f}	4 – 32 TEC Voltage Limit
TMIN(?) {f}	4 – 32 Lower Temperature Limit
TMAX(?) {f}	4 – 32 Upper Temperature Limit
TRMN(?) {f}	4 – 33 Lower Resistance Limit
TRMX(?) {f}	4 – 33 Upper Resistance Limit

TEC settings

TEON(?) {z}	4 – 34 TEC Current On/Off
TCUR(?) {f}	4 – 34 TEC Current Setpoint
TEMP(?) {f}	4 – 34 TEC Temperature Setpoint
TRTH(?) {f}	4 – 34 TEC Resistance Setpoint

TEC monitor

TIRD?	4 – 35 TEC Current Reading
TVRD?	4 – 35 TEC Voltage Reading
TRAW?	4 – 35 Raw Thermometer Reading
TTRD?	4 – 35 Celsius Thermometer Reading
TSNS?	4 – 36 Temperature Sensor Status

TEC configuration

TMOD(?) {z}	4 – 36 TEC Control Mode
TMLK(?) {z}	4 – 37 Lock TEC Control Mode When On
TUNE(?) {z}	4 – 37 TEC Autotune
TATS(?) {f}	4 – 38 TEC Autotune Step Size
TPGN(?) {f}	4 – 38 TEC Control Loop <i>P</i> Gain
TIGN(?) {f}	4 – 39 TEC Control Loop <i>I</i> Gain
TDGN(?) {f}	4 – 39 TEC Control Loop <i>D</i> Gain
TPOL(?) {z}	4 – 39 TEC Polarity Reverse Mode

TEC sensor

TSNR(?) {z}	4 – 40 Thermometer Type
TIEX(?) {z}	4 – 40 Thermometer Excitation Current
TMDN(?) {z}	4 – 41 NTC Calibration Model
TMDR(?) {z}	4 – 41 RTD Calibration Model

TSHA(?) {f}	4 – 42 Steinhart-Hart Coefficient A
TSHB(?) {f}	4 – 42 Steinhart-Hart Coefficient B
TSHC(?) {f}	4 – 42 Steinhart-Hart Coefficient C
TNTR(?) {f}	4 – 42 NTC β -model R_0 Parameter
TNTB(?) {f}	4 – 43 NTC β -model β Parameter
TNTT(?) {f}	4 – 43 NTC β -model T_0 Parameter
TRTR(?) {f}	4 – 43 RTD Linear Model R_0 Parameter
TRTA(?) {f}	4 – 43 RTD Linear Model α Parameter
TLMS(?) {f}	4 – 44 LM335 Slope Parameter
TLMY(?) {f}	4 – 44 LM335 Offset Parameter
TADS(?) {f}	4 – 44 AD590 Slope Parameter
TADY(?) {f}	4 – 44 AD590 Offset Parameter

TEC trip-off

TTSF(?) {z}	4 – 45 TEC Trip-off on Thermometer Fault
TTMX(?) {z}	4 – 45 TEC Trip-off on Max Temperature
TTMN(?) {z}	4 – 45 TEC Trip-off on Min Temperature
TTVL(?) {z}	4 – 46 TEC Trip-off on Voltage Limit
TTIL(?) {z}	4 – 46 TEC Trip-off on Current Limit

Interface

*IDN?	4 – 46 Identify
TOKN(?) {z}	4 – 47 Token Mode
TERM(?) {z}	4 – 47 Response Termination
*OPC(?)	4 – 47 Operation Complete
ULOC(?) {i}	4 – 48 Unlock Ethernet
SPAR {z}	4 – 48 Save User Parameters
GPAR {z}	4 – 48 Restore User Parameters
LOCK(?) {z}	4 – 49 Local Lockout
BLVL(?) {z}	4 – 49 Display Brightness Level
BAUD(?) {z}	4 – 49 Serial Baud Rate
IPAD(?) i {, j}	4 – 50 IP Address
NMSK(?) i {, j}	4 – 50 Netmask
GWAY(?) i {, j}	4 – 50 Default Gateway
MACA?	4 – 50 Ethernet hardware address
ENET(?) {z}	4 – 51 Ethernet speed
*RST	4 – 51 Reset

Status

*STB? [i]	4 – 52 Status Byte
*SRE(?) [i,] {j}	4 – 52 Service Request Enable
*ESR? [i]	4 – 52 Standard Event Status
*ESE(?) [i,] {j}	4 – 53 Standard Event Status Enable
*CLS	4 – 53 Clear Status
LEXE?	4 – 53 Last Execution Error

LCME?	4 – 54 Last Command Error
LDCR? [i]	4 – 54 Laser Diode Condition
LDPT(?) {i,} {j}	4 – 54 Laser Diode Positive-Transition
LDNT(?) {i,} {j}	4 – 54 Laser Diode Negative-Transition
LDEV? [i]	4 – 55 Laser Diode Event
LDEN(?) {i,} {j}	4 – 55 Laser Diode Event Enable
TECR? [i]	4 – 55 TEC Condition
TEPT(?) {i,} {j}	4 – 55 TEC Positive-Transition
TENT(?) {i,} {j}	4 – 55 TEC Negative-Transition
TEEV? [i]	4 – 55 TEC Event
TEEN(?) {i,} {j}	4 – 56 TEC Event Enable

4.2 Alphabetic List of Commands

★

*CLS	4 – 53 Clear Status
*ESE(?) {i,} {j}	4 – 53 Standard Event Status Enable
*ESR? [i]	4 – 52 Standard Event Status
*IDN?	4 – 46 Identify
*OPC(?)	4 – 47 Operation Complete
*RST	4 – 51 Reset
*SRE(?) {i,} {j}	4 – 52 Service Request Enable
*STB? [i]	4 – 52 Status Byte

A

AILM(?) {z}	4 – 29 Laser Trip-off on Current Limit
APLC(?) {z}	4 – 29 Laser Trip-off on Photodiode (CC)
APLP(?) {z}	4 – 29 Laser Trip-off on Photodiode (CP)
ATMN(?) {z}	4 – 31 Laser Trip-off on Min Temperature
ATMX(?) {z}	4 – 30 Laser Trip-off on Max Temperature
ATOI(?) {z}	4 – 30 Laser Trip-off on TEC Off

B

BAUD(?) {z}	4 – 49 Serial Baud Rate
BIAS(?) {f}	4 – 26 Photodiode Bias Voltage
BLVL(?) {z}	4 – 49 Display Brightness Level

C

CALP <i>f</i>	4 – 27 Calibrate Photodiode Responsivity
---------------	--

E

ENET(?) {z}	4 – 51 Ethernet speed
-------------	-----------------------

G

GPAR {z}	4 – 48 Restore User Parameters
GWAY(?) i {, j}	4 – 50 Default Gateway

I

ILOC?	4 – 24 Interlock
IPAD(?) i {, j}	4 – 50 IP Address

L

LCME?	4 – 54 Last Command Error
LDCR? [i]	4 – 54 Laser Diode Condition
LDEN(?) {i,} {j}	4 – 55 Laser Diode Event Enable

LDEV? [i]	4 – 55 Laser Diode Event
LDNT(?) [i,] {j}	4 – 54 Laser Diode Negative-Transition
LDON(?) {z}	4 – 20 Laser Diode Current On/Off
LDPT(?) [i,] {j}	4 – 54 Laser Diode Positive-Transition
LEXE?	4 – 53 Last Execution Error
LOCK(?) {z}	4 – 49 Local Lockout

M

MACA?	4 – 50 Ethernet hardware address
MODU(?) {z}	4 – 24 Modulate Enable

N

NMSK(?) i {, j}	4 – 50 Netmask
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P

PDMW(?) {z}	4 – 26 Photodiode Milliwatt Units
PILM(?) {f}	4 – 19 Photodiode Current Limit
PWLM(?) {f}	4 – 19 Photodiode Power Limit

R

RESP(?) {f}	4 – 27 Photodiode Responsivity
RILD?	4 – 22 Laser Diode Current Reading
RIPD?	4 – 23 Photodiode Current Reading
RNGE(?) {z}	4 – 24 Laser Diode Current Range
RVLD?	4 – 23 Laser Diode Voltage Reading
RWPD?	4 – 23 Photodiode Power Reading

S

SCAN(?) {f, i, g}	4 – 21 Multi-step Scan of Laser Setpoint
SIBW(?) {z}	4 – 25 Laser Modulation Bandwidth
SILD(?) {f}	4 – 20 Laser Diode Current Setpoint
SILM(?) {f}	4 – 18 Laser Diode Current Limit
SIPD(?) {f}	4 – 20 Photodiode Current Setpoint
SMLK(?) {z}	4 – 28 Lock Laser Control Mode When On
SMOD(?) {z}	4 – 25 Laser Control Mode
SPAR {z}	4 – 48 Save User Parameters
SVLM(?) {f}	4 – 18 Laser Diode Voltage Limit
SWPD(?) {f}	4 – 21 Photodiode Power Setpoint
SYND(?) {h}	4 – 22 Sync delay for scans

T

TADS(?) {f}	4 – 44 AD590 Slope Parameter
TADY(?) {f}	4 – 44 AD590 Offset Parameter
TATS(?) {f}	4 – 38 TEC Autotune Step Size

TCUR(?) {f}	4 – 34 TEC Current Setpoint
TDGN(?) {f}	4 – 39 TEC Control Loop D Gain
TECR? [i]	4 – 55 TEC Condition
TEEN(?) [i,] {j}	4 – 56 TEC Event Enable
TEEV? [i]	4 – 55 TEC Event
TEMP(?) {f}	4 – 34 TEC Temperature Setpoint
TENT(?) [i,] {j}	4 – 55 TEC Negative-Transition
TEON(?) {z}	4 – 34 TEC Current On/Off
TEPT(?) [i,] {j}	4 – 55 TEC Positive-Transition
TERM(?) {z}	4 – 47 Response Termination
TIEX(?) {z}	4 – 40 Thermometer Excitation Current
TIGN(?) {f}	4 – 39 TEC Control Loop I Gain
TILM(?) {f}	4 – 31 TEC Current Limit
TIRD?	4 – 35 TEC Current Reading
TLMS(?) {f}	4 – 44 LM335 Slope Parameter
TLMY(?) {f}	4 – 44 LM335 Offset Parameter
TMAX(?) {f}	4 – 32 Upper Temperature Limit
TMDN(?) {z}	4 – 41 NTC Calibration Model
TMDR(?) {z}	4 – 41 RTD Calibration Model
TMIN(?) {f}	4 – 32 Lower Temperature Limit
TMLK(?) {z}	4 – 37 Lock TEC Control Mode When On
TMOD(?) {z}	4 – 36 TEC Control Mode
TNTB(?) {f}	4 – 43 NTC β -model β Parameter
TNTR(?) {f}	4 – 42 NTC β -model R_0 Parameter
TNTT(?) {f}	4 – 43 NTC β -model T_0 Parameter
TOKN(?) {z}	4 – 47 Token Mode
TPGN(?) {f}	4 – 38 TEC Control Loop P Gain
TPOL(?) {z}	4 – 39 TEC Polarity Reverse Mode
TRAW?	4 – 35 Raw Thermometer Reading
TRMN(?) {f}	4 – 33 Lower Resistance Limit
TRMX(?) {f}	4 – 33 Upper Resistance Limit
TRTA(?) {f}	4 – 43 RTD Linear Model α Parameter
TRTH(?) {f}	4 – 34 TEC Resistance Setpoint
TRTR(?) {f}	4 – 43 RTD Linear Model R_0 Parameter
TSHA(?) {f}	4 – 42 Steinhart-Hart Coefficient A
TSHB(?) {f}	4 – 42 Steinhart-Hart Coefficient B
TSHC(?) {f}	4 – 42 Steinhart-Hart Coefficient C
TSNR(?) {z}	4 – 40 Thermometer Type
TSNS?	4 – 36 Temperature Sensor Status
TTIL(?) {z}	4 – 46 TEC Trip-off on Current Limit
TTMN(?) {z}	4 – 45 TEC Trip-off on Min Temperature
TTMX(?) {z}	4 – 45 TEC Trip-off on Max Temperature
TTRD?	4 – 35 Celsius Thermometer Reading
TTSF(?) {z}	4 – 45 TEC Trip-off on Thermometer Fault
TTVL(?) {z}	4 – 46 TEC Trip-off on Voltage Limit
TUNE(?) {z}	4 – 37 TEC Autotune

TVLM(?) {f}	4 – 32 TEC Voltage Limit
TVRD?	4 – 35 TEC Voltage Reading

U

ULOC(?) {i}	4 – 48 Unlock Ethernet
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4.3 Introduction

Remote operation of the LDC500 is through a simple command language documented in this chapter. Both set and query forms of most commands are supported, allowing the user complete control of the controller from a remote computer, through the GPIB, RS-232, or ethernet interface.

Where applicable, the corresponding front-panel interface to each command is also indicated.

4.3.1 Interface configuration

All three remote interfaces have configuration settings that may need adjusting from the front panel. These are accessed from the [Util] menu.

The factory default settings for the RS-232 interface are 9600 baud with no parity and no flow control. The GPIB bus address defaults to 2. The IP address, netmask, and default gateway all must be configured (either from the front panel, or RS-232 or GPIB) prior to ethernet operation.

Most instrument settings are retained in non-volatile memory. Upon power-on, these settings are restored to their values before the power was turned off.

Where appropriate, the default or power-on value for parameters is listed in **boldface** in the command descriptions.

4.3.2 Buffers

The LDC500 stores incoming bytes from the remote interfaces in separate 64-byte input buffers. Characters accumulate in the input buffer until a command terminator ((CR), (LF), or GPIB-EOI signal) is received, at which point the message is parsed and enqueued for execution. Query responses from the LDC500 are buffered in interface-specific 256-byte output queues.

If an input buffer overflows, then all data in the input buffer are discarded, and an error is recorded in the ESR status register.

4.4 Ethernet

To connect to the LDC500 via the ethernet interface, the user must first configure the network parameters. Once connected to local network (or simple ethernet crossover cable), establish a socket connection to TCP/IP port 8888. Send a blank line to initialize the connection, and then send the ULOC 1 command to unlock the ethernet command

processor (see page 4 – 48). Next, the *IDN? query should be sent. The LDC500 should reply with the response string described on page 4 – 46 .

Debugging messages are also available over the ethernet connection. To monitor the debugging stream, open a second TCP/IP socket connection to port 8886 (note the different port number). The debugging port can be used independently of the commanding port, allowing convenient debugging of user applications controlling the LDC500 over GPIB, RS-232, or the ethernet port.

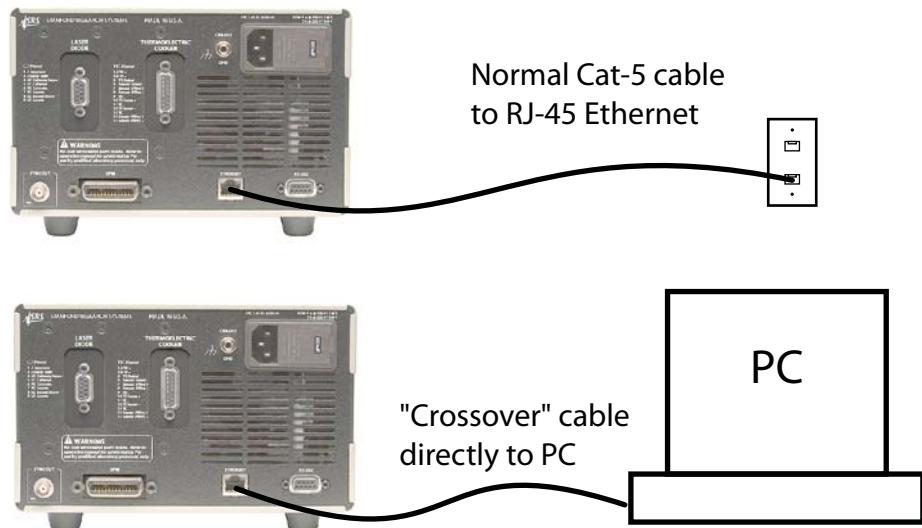
4.4.1 Connection example

The following example may help clarify how to establish Ethernet-based communications with the LDC500. This example assumes a Windows-based computer with HyperTerminal available for direct TCP/IP connections.

4.4.1.1 Network address configuration

If the LDC500 is being connected to an existing network, first obtain a network address for the instrument. You will also need to determine the netmask value and default gateway; these should then be programmed into the LDC500 from the front panel. See sections 3.4.1.3 and 3.4.1.5.

It is also possible to directly connect the LDC500 to a computer using an Ethernet “crossover” cable. In this case, it is usually sufficient to use the default network configuration, beginning with the IP number 169.254.xxx.xxx (the so-called “link local” address range).



4.4.1.2 Starting HyperTerminal

Once the LDC500 is connected, either to your local network or directly to your computer, turn on the LDC500. Then, on your computer, open the HyperTerminal application. This is often found from the “Start” menu, under Programs:: Accessories:: Communications:: HyperTerminal. When the application begins, it will ask you for a Connection Description. Choose something like LDC_ethernet and click “OK”.



When the “Connect To” window pops up, choose the “Connect using:” method as “TCP/IP (Winsock)” from the pull-down menu. Enter the IP address for the LDC500 under “Host address:”. For this example, enter 8886 for “Port number:” (this will connect to the “debugging” port). To connect to the main command port (which does not receive debugging messages), change the port number to 8888.

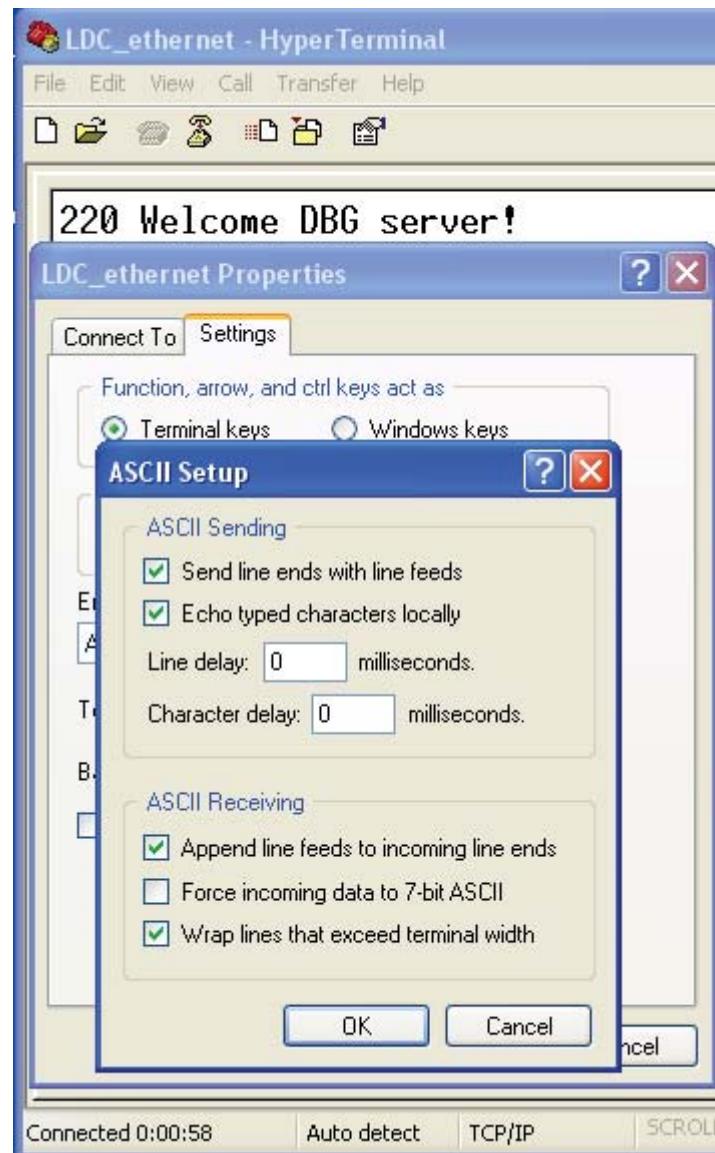


After clicking “OK” in the “Connect To” window, you should see the following message from the LDC500 displayed by HyperTerminal.



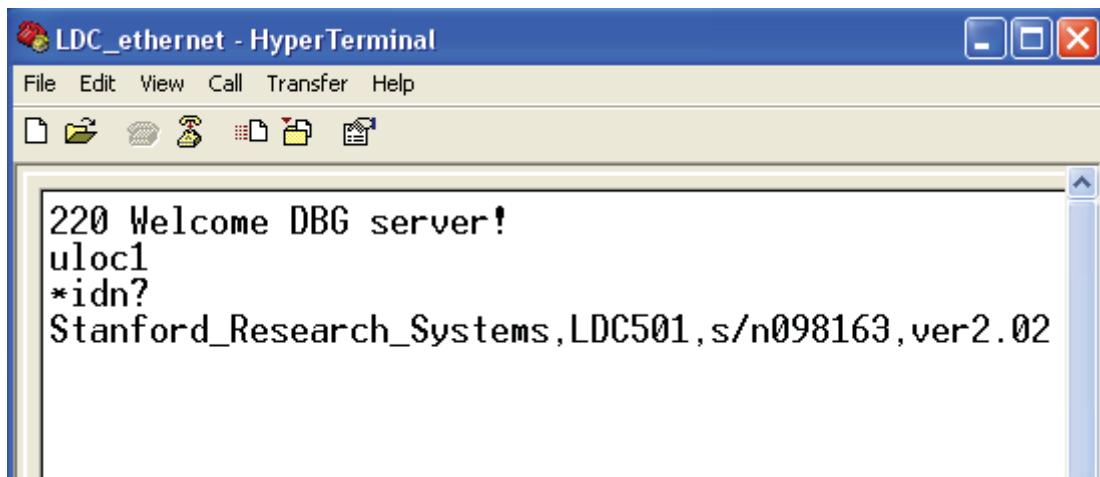
4.4.1.3 HyperTerm settings

To be able to view your local typing, you'll need to change some settings under HyperTerminal. Select File::Properties, and then click the "Settings" tab. Press the "ASCII Setup..." button to bring up the "ASCII Setup" window. Select "Send line ends with line feeds", "Echo typed characters locally", "Append line feeds to incoming line ends", and "Wrap lines that exceed terminal width".



4.4.1.4 Unlocking the interface

Finally, send the “ULOC 1” command (see section 4.5.15) to enable the Ethernet interface for use. Type ULOC 1 followed by the [Enter] key. You can then test the interface, for example, by sending the *IDN? query.



4.5 Commands

This section provides syntax and operational descriptions for remote commands.

4.5.1 Command syntax

The four letter mnemonic (shown in CAPS) in each command sequence specifies the command. The rest of the sequence consists of parameters.

Commands may take either *set* or *query* form, depending on whether the “?” character follows the mnemonic. *Set only* commands are listed without the “?”, *query only* commands show the “?” after the mnemonic, and *optionally query* commands are marked with a “(?)”.

Parameters shown in { } and [] are not always required. Parameters in { } are required to set a value, and should be omitted for queries. Parameters in [] are optional in both set and query commands. Parameters listed without surrounding characters are always required.

Do *not* send () or { } or [] as part of the command.

Multiple parameters are separated by commas. Multiple commands may be sent on one command line by separating them with semicolons (;) so long as the input buffer does not overflow. Commands are terminated by either <CR> or <LF> characters. Null commands and whitespaces are ignored. Execution of the command does not begin until the command terminator is received.

tokens *Token* parameters (generically shown as *z* in the command descriptions) can be specified either as a keyword or as an integer value. Command descriptions list the valid keyword options, with each keyword followed by its corresponding integer value. For example, to set the response termination sequence to <CR>+<LF>, the following two commands are equivalent:

TERM CRLF —or— TERM 3

For queries that return token values, the return format (keyword or integer) is specified with the TOKN command.

4.5.2 Notation

The following table summarizes the notation used in the command descriptions:

Symbol	Definition
f, g, h	Floating-point value
i, j	Unsigned integer
z	Literal token
(?)	Required for queries; illegal for set commands
var	Parameter always required
{ var }	Required parameter for set commands; illegal for queries
[var]	Optional parameter for both set and query forms

4.5.3 Examples

Each command is provided with a simple example illustrating its usage. In these examples, all data sent by the host computer to the LDC500 are set as *straight teletype font*, while responses received by the host computer from the LDC500 are set as *slanted teletype font*.

The usage examples vary with respect to set/query, optional parameters, and token formats. These examples are not exhaustive, and are intended to provide a convenient starting point for user programming.

4.5.4 Laser limit commands

SVLM(?) {f}

Laser Diode Voltage Limit

Set (query) the laser compliance voltage limit {to f}, in V.

The voltage limit is an essential protection feature for the laser diode. Typically, the user will program **SVLM** to a value slightly greater than the expected maximum operating voltage, and always less than the rated maximum voltage, for the laser diode under control.

The current source will *always* turn off when the measured laser voltage exceeds the **SVLM** value. If the measured voltage is within 250 mV of the limit, the laser diode **VLim** indicator will flash.

LD Settings:	
Front panel:	LD Vlim: 5.250

Example: SVLM 5.25

SILM(?) {f}

Laser Diode Current Limit

Set (query) the laser diode current limit {to f}, in mA.

The current limit has two related, but independent effects. Most importantly, the output current is clamped (by hardware) to never exceed the **SILM** value under any conditions. The second effect is to limit the current setpoint value, **SILD**. These are not exactly equivalent, since an additional current offset can be generated above **SILD** via the analog modulate input.

Note that lowering the **SILM** value below the present value of **SILD** has the side effect of “dragging” the **SILD** setting downwards with it. Also note that if the output range is lowered from 500 mA to 250 mA (100 mA to 50 mA for LDC500) and the **SILM** value is greater than 250 mA, (100 mA) **SILM** will be lowered to 250 (50).

If the laser current is being actively limited to **SILM**, the laser diode **ILim** indicator will light steadily. The current source can optionally turn off when the current limit is reached; this option is configured by the **AILM** command.

LD Settings:	
Front panel:	LD ILim: 123.0mA

Example: SILM 123;SILM?
123.000

PILM(?) {f}**Photodiode Current Limit**

Set (query) the monitor photodiode current limit {to *f*}, in μA .

The photodiode is used to control the laser output in CP control mode. When PDMW NO is set, the LDC500 user raw photodiode current (in μA) for monitoring laser power. With PDMW NO, the value for PILM provides an upper bound on setting the CP operating point, SIPD.

The photodiode current limit is implemented in firmware, and so will not clamp the actual operating point if an additional offset is commanded via the analog modulate input.

Note that lowering the PILM value below the present value of SIPD has the side effect of “dragging” the SIPD setting downwards with it.

Regardless of the LD control mode (CC or CP), the current source limit will always clamp the operating current of the laser diode, and the voltage limit protection will always turn off the LD driver upon over voltage. Users should be certain to set these important device protection parameters, even when operating in CP mode. Also, in either control mode (CC or CP), the LD driver can optionally turn off when the photodiode current is reached. This is configured by APLP (in CP mode), or APLC (in CC mode).

Front panel:	LD Settings: PD Ilimit 5000 μA
--------------	--

Example: PILM?
5000.0

PWLM(?) {f}**Photodiode Power Limit**

Set (query) the monitor photodiode power limit {to *f*}, in mW.

The photodiode is used to control the laser output in CP control mode. When PDMW YES is set, the LDC500 uses optical power (in mW), scaled from the photodiode with the RESP value. When in this calibrated photodiode power mode, the PWLM value limits the operating setpoint SWPD. The photodiode power limit is implemented in firmware, and so will not clamp the actual operating point if an additional offset is commanded via the analog modulate input.

Note that lowering the PWLM value below the present value of SWPD has the side effect of “dragging” the SWPD setting downwards with it.

See PILM, above, for a discussion of current and voltage limiting when controlling a laser with a photodiode.

Front panel:	LD Settings: PD Plim: 500mW
--------------	--------------------------------

Example: PWLM500.0

4.5.5 Laser setting commands

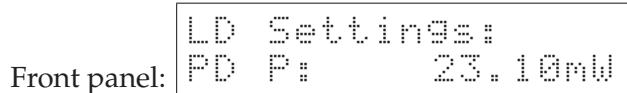
LDON(?) {z}	Laser Diode Current On/Off Set (query) the laser diode excitation source {to z=(OFF 0, ON 1)}. The laser diode is turned on by issuing LDON ON; following a 3-second safety delay, the shunting relay is opened and the current source is ramped up to the setpoint value. Turning the laser off, via LDON OFF, is immediate. Front-panel control is by the [LASER On/Off] button.
<i>Example:</i> LDON ON	
SILD(?) {f}	Laser Diode Current Setpoint Set (query) the laser diode current setpoint {to f}, in mA. When the laser is operating in CC mode, the laser current setpoint is controlled by SILD.
<i>Example:</i> SILD? 500.000	
SIPD(?) {f}	Photodiode Current Setpoint Set (query) the monitor photodiode current setpoint {to f}, in μ A. When the laser is operating in CP mode, and PDMW NO is set, the laser current is controlled to maintain a constant photodiode current at the level set by SIPD.
<i>Example:</i> SIPD 123.4	

SWPD(?) {f}

Photodiode Power Setpoint

Set (query) the monitor photodiode optical power setpoint {to f}, in mW.

When the laser is operating in CP mode, and PDMW YES is set, the laser current is controlled to maintain a constant optical power, as measured by the photodiode, at the level set by SWPD.



Example: SWPD 23.1

SCAN(?) {f, i, g}

Multi-step Scan of Laser Setpoint

Start (query) an output scan of the laser diode output setpoint {with stepsize f, i steps, and dwell-time g, in ms}.

In any control mode, the SCAN command may be used to initiate an automated sweep of the laser operating point; this can be useful, for instance, to obtain L–I curves of a device under characterization. The first parameter, *f*, is the increment (or decrement, if negative) in the setpoint variable currently in use. If the instrument is in CC mode, *f* is a current step in mA; if CP mode, it is raw photodiode current step (in μ A), regardless of the value of PDMW. The scan begins immediately after receipt of the SCAN command, starting at the previous setpoint.

The second parameter, *i*, gives the total number of steps. Note that if $S + i \cdot f > S_{\max}$ or $S + i \cdot f < 0$, where *S* is the starting operating point, then the SCAN command will generate an execution error and no changes in output will occur.

The third parameter, *g*, is the dwell time for each step in the scan, in ms. The dwell time must be set larger than the sync delay h_{sync} , which is set by the SYND command. Note that the total time between setpoint steps is simply *g*.

Following a time h_{sync} ms after each output step, the rear-panel SYNC OUT BNC has a $\sim 10 \mu\text{s}$ long, negative-going TTL pulse. This pulse can be used to synchronize other test equipment during the scan.

The query form SCAN? returns a token value of either OFF 0, or ON 1, based on whether a scan is currently in progress.

SCAN can only be initiated from the remote interface.

Example: SILD 50

SCAN 10,25,100

This example sets the output current to 50 mA, and then initiates a 25-step scan in 10 mA steps up to 300 mA, pausing 100 ms at each setting. The entire scan will take 2.5 s.

SYND(?) {h}

Sync delay for scans

Set (query) the sync-pulse delay for multi-step scans {to h }, in ms. The minimum value for h is 5.

The analog circuit for setting the output has a one-pole low-pass filter with a settling time-constant of $\tau \sim 2.5$ ms for CC mode, and $\tau \sim 5$ ms for CP mode. When programming a multi-step scan, the user can choose how much settling time to allow after each setpoint step before the LDC500 generates the output sync pulse (on the rear-panel “SYNC OUT” connector).

To estimate the settling time required for a particular application, consider the step size Δ and the required tolerance δ . For $\delta \ll \Delta$, this requirement is given by

$$\delta < \Delta e^{-h/\tau}$$

where h is the SYND delay value. This can be rearranged to give

$$h > -\tau \ln \frac{\delta}{\Delta}$$

For example, if a scan will have 10 mA steps (CC mode), and the current must be stabilized to 10 μ A before triggering an external measurement, then $h > 17.3$ ms.

This flexibility allows users to best optimize the tolerance and throughput trade-offs when configuring multi-point scans.

Example: SYND 18

4.5.6 Laser monitor commands

RILD?

Laser Diode Current Reading

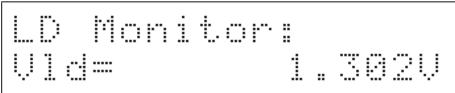
Query the output current reading to the laser diode, in mA.

RILD? always returns the excitation current flowing to the laser diode, independent of control mode (CC or CP). The actual current, as measured by RILD?, may be different than the current setpoint SILD if there is an input connected to the analog modulate connector.

Front panel:	LD Monitor: Ild= 100.03mA
--------------	------------------------------

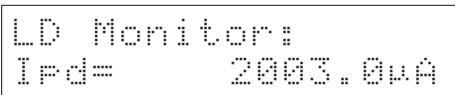
Example: RILD?
100.0309

RVLD? Laser Diode Voltage Reading
Query the operating voltage reading of the laser diode, in V.

Front panel:  LD Monitor:
Vld= 1.302U

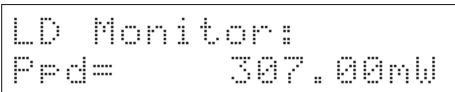
Example: RVLD?
1.302183

RIPD? Photodiode Current Reading
Query the monitor photodiode current reading, in μ A.
RIPD? always returns the measured photodiode current, in μ A, regardless of control mode (CC or CP), optical power units (PDMW) or even laser current source on/off.

Front panel:  LD Monitor:
IPd= 2003.0 μ A

Example: RIPD?
2003.021

RWPD? Photodiode Power Reading
Query the monitor photodiode optical power reading, in mW.
RWPD? returns the measured optical power, in mW, regardless of control mode (CC or CP) or laser current source on/off. If the responsivity (RESP) is not set to a good value, then RWPD? may return nonsense.

Front panel:  LD Monitor:
Pfd= 307.00mW

Example: RWPD?
307.001

ILOC?	Interlock Query the state of the external laser interlock. ILOC? returns the token value CLOSED 0 or OPEN 1. The laser diode cannot be turned on if ILOC? is OPEN, and will trip off unconditionally should the interlock open at any time.
-------	---

LD Monitor:
Front panel: Interlock=Closed

Example: ILOC?
CLOSED

4.5.7 Laser configuration commands

RNGE(?) {z}	Laser Diode Current Range Set (query) the laser diode current source range {to z=(LOW 0, HIGH 1)}. The controller has two operating ranges for the laser diode current source. Setting RNGE LOW sets the maximum output current to 250 mA (LDC501) or 50 mA (LDC500), while RNGE HIGH sets it to 500 mA (LDC501) or 100 mA (LDC500). The RNGE command cannot be executed while the laser is on.
-------------	---

LD Config:
Front panel: IRange: *1>500mA

Example: RNGE HIGH

MODU(?) {z}	Modulate Enable Set (query) the laser diode analog modulation input {to z=(OFF 0, ON 1)}. The LDC500 has an input relay to disconnect the modulate input BNC connector from the LD driver circuitry. Setting MODU OFF opens this relay, disconnecting the connector (and any user cable) from the driver. When using modulation, the user must send the MODU ON command.
-------------	--

For an important discussion of grounding issues when using analog modulation, see section 1.2.2.1

LD Cfg: Modulate
Front panel: enable: *N

Example: MODU ON

SMOD(?) {z}

Laser Control Mode

Set (query) the laser diode control mode {to z=(CC 0, CP 1)}.

If the laser is on when an SMOD command is issued that changes the operating mode, the controller performs a “bumpless transfer” to switch control modes on-the-fly. If the laser is originally operating in CC mode, and SMOD CP is received, the present value of the photodiode current (or equivalently, optical power) is measured, and the CP setpoint is set equal to the measurement. If the measured photodiode current or power exceeds the setpoint limit (either PILM or PWLM), the SMOD command fails with an execution error; otherwise, the control mode is switched seamlessly to CP.

If the laser is originally operating in CP mode, and SMOD CC is set, the present value of the laser current is measured, the CC setpoint is set equal to that measurement, and the control mode switched to CC. Note that, by hardware design, the measured laser current can never exceed the setpoint limit.

Front-panel control is by the [CC/CP] button. Note that if the mode is switched from the front panel while the laser is on, a confirmation message appears on the screen requesting a second press of the [CC/CP] button; after a ~3 s timeout, the command expires if not confirmed.

The remote form of the command SMOD does *not* impose any delay or confirmation request; the control mode is changed immediately.

Regardless of the source of the request, changing control mode while the laser is on can be inhibited with the SMLK command.

Example: SMOD CC

SIBW(?) {z}

Laser Modulation Bandwidth

Set (query) the laser modulation bandwidth {to z=(LOW 0, HIGH 1)}.

Both laser control modes, CC and CP, have a high-bandwidth and low-bandwidth setting, which can be set or queried by SIBW?. The bandwidth setting can be changed at any time.

The analog modulation input is DC coupled, with the -3 dB roll-off frequency dependent on control mode and SIBW:

—SIBW—		
	LOW	HIGH
CC mode	10 kHz	1.2 MHz
CP mode	100 Hz	5 kHz

When controlling a laser diode in CP mode, phase shifts introduced either from photodiode bandwidth or cable capacitance can influence overall stability. For some configurations, SIBW HIGH might lead to instability and oscillations; in these cases, the LDC500 should be left set to SIBW LOW.

LD Config: CC BW
Front panel: *1)high 1.2MHz

Example: SIBW?
HIGH

PDMW(?) {z}

Photodiode Milliwatt Units

Set (query) the CP mode power units selection {to z=(NO 0, YES 1)}.

When set to PDMW YES, the LDC500 will display mW units when controlling in CP mode. When set to PDMW NO, the CP mode display is μ A (photodiode current).

Note that the value of PDMW has a subtle effect on the photodiode setpoint parameters SIPD and SWPD, and the limit values PILM and PWLM. If PDMW YES, and the value of RESP is changed (either directly, or as a result of the CALP command), then the mW parameters (SWPD and PWLM) remain unchanged, and the μ A parameters (SIPD and PILM) are adjusted accordingly. The converse is true when PDMW NO is set.

LD Cfg: PD units
Front panel: YES mW: *N

Example: PDMW?
NO

BIAS(?) {f}

Photodiode Bias Voltage

Set (query) the monitor photodiode bias voltage {to f}, in V.

The valid range is 0 < f < 5.0; setting BIAS 0 operates the photodiode in the “photovoltaic” mode.

LD Config:
Front panel: PD Bias: 2.5V

Example: BIAS 2.5

CALP <i>f</i>	Calibrate Photodiode Responsivity
	Set the photodiode responsivity to correspond to a (real-time) optical power measurement of <i>f</i> , in mW. There is no query form of CALP.
	The CALP command requires an external laser power meter, and will cause the LDC500 to recalculate the responsivity parameter (RESP) to correspond to the externally-measured optical power, <i>f</i> .
	See section 2.3.7 for further discussion of photodiode calibration.

LD Cfg: PD calib
Front panel: at: 12.04mW

Example: CALP 12.04

RESP(?) { <i>f</i> }	Photodiode Responsivity
	Set (query) the monitor photodiode responsivity {to <i>f</i> }, in $\mu\text{A}/\text{mW}$.
	The responsivity determines the conversion from photodiode current (in μA) to optical power (in mW). The minimum possible value for RESP is 0.0051 $\mu\text{A}/\text{mW}$.
	Changing the value of RESP, either directly or through the CALP command, will cause indirect changes to either SIPD and PILM (if PDMW YES), or SWPD and PWLM (if PDMW NO). This is because the LDC500 always enforces the two relationships

$$\text{SIPD} = \text{SWPD} \times \text{RESP}$$

and

$$\text{PILM} = \text{PWLM} \times \text{RESP}$$

Note that the responsivity cannot be changed while the laser is on, and in CP control mode, and in mW units (PDMW YES).

LD Cfg: PD resp
Front panel: 1.000 $\mu\text{A}/\text{mW}$

Example: RESP?
1.000

SMLK(?) {z}

Lock Laser Control Mode When On

Set (query) the control mode lock-out {to z=(NO 0, YES 1)}.

When SMLK YES is set, the LDC500 will prevent the SMOD command from operating if the laser is on. The front-panel [CC/CP] key is similarly inhibited.

Front panel: 
LD Config: CC/CP
lock when on: *N

Example: SMLK?
NO

4.5.8 Laser trip-off commands

AILM(?) {z}

Laser Trip-off on Current Limit

Set (query) the laser to trip off upon current limit {to z=(**NO 0**, YES 1)}.

Typically, this trip condition is left disabled by the user, since the hardware current limit prevents the LD current from ever exceeding the limit. If the user wants the LDC500 to automatically turn off the laser current if the laser current reaches the limit current, set AILM YES.

LD Cfg: Trip-Off
Front panel: at LD ILim: *N

Example: AILM?
0

APLP(?) {z}

Laser Trip-off on Photodiode (CP)

Set (query) the laser to trip off in CP mode upon monitor photodiode limit {to z=(**NO 0**, YES 1)}.

This condition applies regardless of the PDMW setting, but only for CP control mode. If the measured photodiode current (or optical power) exceeds the corresponding limit, APLP YES causes the laser current source to shut down.

Note that this trip is implemented in firmware, and can only respond after several hundred ms; if a fast overload occurs (for instance, due to the analog modulation input), APLP cannot assure safe shutdown. The user should always rely on voltage limiting (SVLM) and current limiting (SILM) of the laser diode itself to assure safe device operation.

LD Cfg: Trip-Off
Front panel: at CP PLim: *N

Example: APLP NO

APLC(?) {z}

Laser Trip-off on Photodiode (CC)

Set (query) the laser to trip off in CC mode upon monitor photodiode limit {to z=(**NO 0**, YES 1)}.

This condition applies regardless of the PDMW setting, whether RESP is zero or non-zero, but only for CC control mode. If the measured photodiode current (or optical power) exceeds the corre-

sponding limit, APLC YES causes the laser current source to shut down.

Note that this trip is implemented in firmware, and can only respond over several hundred ms. The user should always rely on voltage limiting (SVLM) and current limiting (SILM) of the laser diode itself to assure safe device operation.

LD Cfg: Trip=OFF
Front panel: at CC PLim: *N

Example: APLC NO

ATOF(?) {z}

Laser Trip-off on TEC Off

Set (query) the laser to trip off if the TEC turns off {to z=(NO 0, YES 1)}.

If set to ATOF YES, the LDC500 requires the TEC controller to be active for the laser to operate. If the TEC is turned off or trips off for any reason, ATOF YES causes the laser diode to shut down as well.

LD Cfg: Trip=OFF
Front panel: at TE Off: *Y

Example: ATOF YES

ATMX(?) {z}

Laser Trip-off on Max Temperature

Set (query) the laser to trip off if the maximum temperature is exceeded {to z=(NO 0, YES 1)}.

If set to ATMX YES, the LDC500 requires the TEC temperature sensor to remain below the TMAX setting. Note that the TEC controller does not need to be active, but the temperature sensor must remain connected and in-range, as well as reading below TMAX, if ATMX YES is set.

Note that if the LDC500 is operating with the sensor model set to “none” (resistance units), then arming ATMX will cause shut-down if the sensor TRAW? value is greater than TRMX, in kΩ. If the sensor has a negative temperature coefficient, this will correspond to the *lowest* temperature of the operating band, *not* the greatest.

LD Cfg: Trip=OFF
Front panel: at Tmax: *Y

Example: ATMX YES

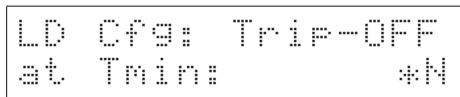
ATMN(?) {z}

Laser Trip-off on Min Temperature

Set (query) the laser to trip off if the minimum temperature is exceeded {to z=(NO 0, YES 1)}.

If set to ATMN YES, the LDC500 requires the TEC temperature sensor to remain above the TMIN setting. Note that the TEC controller does not need to be active, but the temperature sensor must remain connected and in-range, as well as reading above TMIN, if ATMN YES is set.

Note that if the LDC500 is operating with the sensor model set to “none” (resistance units), then arming ATMN will cause shut-down if the sensor TRAW? value is less than TRMN, in kΩ. If the sensor has a negative temperature coefficient, this will correspond to the *greatest* temperature of the operating band, *not* the lowest.

Front panel: 

Example: ATMN NO

4.5.9 TEC limit commands

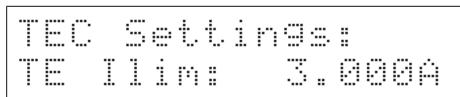
TILM(?) {f}

TEC Current Limit

Set (query) the TEC current limit {to f}, in A.

The absolute value of the TEC current is limited to the value set by TILM. When the TEC is in CT mode, the PID temperature loop will saturate when the current limit is reached, and the TEC ILim indicator will light steadily. In TEC CC mode, the current setpoint is limited to this value.

Note that lowering the TILM value below the (absolute) value of TCUR has the side effect of “dragging” the TCUR setting with it, towards zero.

Front panel: 

Example: TILM 3.0

TVLM(?) {f}**TEC Voltage Limit**

Set (query) the TEC voltage limit {to f}, in V.

The TEC current source has an intrinsic compliance voltage of ± 8.5 V. If the user needs to assure that the TEC voltage cannot reach that hardware limit, then **TVLM**, *together with* the **TTVL** command, can configure the TEC to turn off when the voltage exceeds the **TVLM** value.

Note that there is no separate voltage clamping of the TEC driver—setting **TVLM**, while leaving **TTVL N0**, has no operational effect on the LDC500.

Front panel: **TEC Settings:**
TE Ulim: 8.5000V

Example: **TVLM?**
8.50000E+00

TMIN(?) {f}**Lower Temperature Limit**

Set (query) the lower temperature limit {to f}, in $^{\circ}\text{C}$.

The LDC500 provides both lower and upper user-defined temperature limits for normal operation. If the user must assure the device is not operated below some minimum temperature (for instance, near the condensation point), setting **TMIN** together with **ATMN** and/or **TTMN** will provide an automatic shut-off if this minimum temperature is exceeded.

Note that the temperature limits are not effective if the sensor model is set to “none” (resistance units).

Front panel: **TEC Settings:**
Tmin: 7.500 $^{\circ}\text{C}$

Example: **TMIN 7.5**

TMAX(?) {f}**Upper Temperature Limit**

Set (query) the upper temperature limit {to f}, in $^{\circ}\text{C}$.

The LDC500 provides both lower and upper user-defined temperature limits for normal operation. If the user must assure the device is not operated above some maximum temperature, setting **TMAX** together with **ATMX** and/or **TTMX** will provide an automatic shut-off if this maximum temperature is exceeded.

Note that the temperature limits are not effective if the sensor model is set to “none” (resistance units).

Front panel:	TEC Settings: Tmax: 65.000 °C.
--------------	-----------------------------------

Example: TMAX 65.0

TRMN(?) {f}

Lower Resistance Limit

Set (query) the lower resistance limit {to f}, in kΩ.

When the LDC500 is operated with the sensor model set to “none” (resistance units), then TRMN establishes the minimum sensor resistance for normal operation. If the resistance goes below TRMN, and TTMIN is set, then the TEC shall turn off; if ATMN is set, then the LD shall turn off.

Note that TRMN establishes the lower bound on resistance, regardless of whether the sensor has a negative or positive temperature coefficient.

Front panel:	TEC Settings: Rmin: 9.500kΩ.
--------------	---------------------------------

Example: TRMN 9.50

TRMX(?) {f}

Upper Resistance Limit

Set (query) the upper resistance limit {to f}, in kΩ.

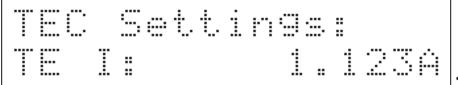
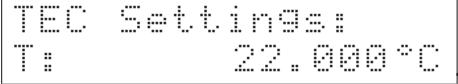
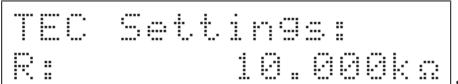
When the LDC500 is operated with the sensor model set to “none” (resistance units), then TRMX establishes the maximum sensor resistance for normal operation. If the resistance goes above TRMX, and TTMAX is set, then the TEC shall turn off; if ATMX is set, then the LD shall turn off.

Note that TRMX establishes the upper bound on resistance, regardless of whether the sensor has a negative or positive temperature coefficient.

Front panel:	TEC Settings: Rmax: 12.500kΩ.
--------------	----------------------------------

Example: TRMX 12.50

4.5.10 TEC setting commands

TEON(?) {z}	TEC Current On/Off Set (query) the TEC current source {to z=(OFF 0, ON 1)}. Front-panel control is by the [TEC On/Off] button.
	<i>Example:</i> TEON? ON
TCUR(?) {f}	TEC Current Setpoint Set (query) the TEC current setpoint {to f}, in A. When the TEC is operated in TEC-CC mode, the TEC current is set by TCUR. Note that queries return the CC-mode setpoint, <i>not</i> the measured operating current. When properly wired, a positive TCUR will (tend to) cool the device, while a negative TCUR will heat it.
	Front panel: 
	<i>Example:</i> TCUR? 1.234000E+00.
TEMP(?) {f}	TEC Temperature Setpoint Set (query) the TEC temperature setpoint {to f}, in °C. When the TEC is operated in CT mode, the TEC current is adjusted by the control loop to maintain the sensor at a constant temperature, set by TEMP. Note that queries return the CT-mode setpoint, <i>not</i> the measured operating temperature.
	Front panel: 
	<i>Example:</i> TEMP 22.0
TRTH(?) {f}	TEC Resistance Setpoint Set (query) the TEC resistance setpoint {to f}, in kΩ. When the TEC is operated in CT mode, <i>and</i> the sensor model is set to “none” (resistance units), the TEC current is adjusted by the control loop to maintain the sensor at a constant resistance, set by TRTH.
	Front panel: 
	<i>Example:</i> TRTH 10.000

4.5.11 TEC monitor commands

TIRD? TEC Current Reading
 Query the TEC operating current, in A.
 TIRD? always returns the operating current flowing to the TEC module, independent of TEC control mode (CT or CC).

TEC Monitor:
Front panel: I_{te}= -1.999A.

Example: TIRD?
 -1.999976E+00

TVRD? TEC Voltage Reading
 Query the TEC voltage, in V.

TEC Monitor:
Front panel: U_{te}= 1.609V.

Example: TVRD?
 1.608900E+00

TRAW? Raw Thermometer Reading
 Query the raw sensor value, in kΩ, V, or μA (depending on the sensor type).

TEC Monitor:
Front panel: R= 10.967kΩ.

Example: TRAW?
 1.096738E+01

TTRD? Celsius Thermometer Reading
 Query the sensor temperature, in °C.
 Note that TTRD? is not legal, and will generate an execution error, when the sensor model is configured to “none” (resistance mode).

TEC Monitor:
Front panel: T= 22.8910 °C.

Example: TTRD?
 2.289103E+01

TSNS?	<p>Temperature Sensor Status</p> <p>Query the sensor status.</p> <p>Returns OK 1 or FAULT 0, based on whether the sensor reading is within hardware bounds.</p> <p>There is no front-panel equivalent, although the temperature display will show dashes, and an error message appears, when a sensor fault occurs.</p>
<i>Example:</i>	TSNS? OK

4.5.12 TEC configuration commands

TMOD(?) {z}	<p>TEC Control Mode</p> <p>Set (query) the TEC control mode {to z=(CC 0, CT 1)}.</p> <p>If the TEC module is on when a TMOD command is issued that changes the operating mode, the controller performs a “bumpless transfer” to switch control modes on-the-fly. If the TEC was originally operating in CT mode, and TMOD CC is set, the present value of the TEC current is taken as the CC setpoint. If the TEC is originally operating in CC mode, and TMOD CT is set, the present value of the temperature sensor is measured, the CT setpoint is set equal to that measurement, and the control mode is switched to CT.</p> <p>Front-panel control is by the [CT/CC] button. Note that if the mode is switched from the front panel while the TEC module is on, a confirmation message appears on the screen requesting a second press of the [CT/CC] button; after a ~3s timeout, the command expires if not confirmed.</p> <p>The remote form of the command TMOD does <i>not</i> impose any delay or confirmation request; the control mode is changed immediately.</p> <p>Regardless of the source of the request, changing control mode while the TEC is on can be inhibited with the TMLK command.</p>
<i>Example:</i>	TMOD CT

TMLK(?) {z}

Lock TEC Control Mode When On

Set (query) the TEC control mode lock-out {to z=(NO 0, YES 1)}.

When TMLK YES is set, the LDC500 will prevent the TMOD command from operating if the laser is on. The front-panel [CT/CC] key is similarly inhibited.

TE Cfg: CC/CT
Front panel: lock when on: *N.

Example: TMLK?
NO

TUNE(?) {z}

TEC Autotune

Set (query) the temperature control autotune process {to z=(OFF 0, ON 1)}.

The LDC500 implements an automatic tuning algorithm, based on an “open loop” step-response method. If an autotune cycle is initiated (by sending the TUNE ON command), the LDC500 will first wait until the temperature reading is stable, and then generate an output step in TEC current corresponding to 10% of the user current range (set by TILM). The temperature response is then monitored for a period of time, and loop gain parameters determined.

If the temperature does not stabilize at the beginning of the cycle, the autotuning fails and the loop parameters remain unchanged. If the step response cannot be interpreted successfully, the autotuning also ends in failure and the loop parameters are unchanged. Finally, if the user cancels an autotune cycle in progress (either by sending TUNE OFF or by pressing the [Clear/Cancel] button while the display focus is at Autotune), then the autotune stops and the loop parameters are unchanged.

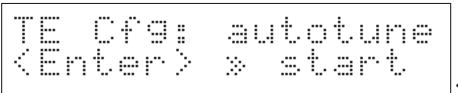
If the TEC module was off upon receipt of the TUNE ON command, it will be turned on for the duration of the tuning cycle, and then returned to off.

Autotuning can be performed regardless of TEC control mode.

Autotuning can be performed when the sensor model is “none” (resistance), or in any of the Celsius models. The tuning algorithm is more robust, however, when using true temperature units instead of resistance units.

When querying TUNE?, the token response is either OFF 0 (tuning has not been started, or was cancelled), ON 1 (tuning is in

progress), UNSTABLE 2 (tuning failed due to initial instability), SUCCESS 3 (tuning succeeded), FAILED 4 (tuning failed to converge), or CHECK_POLARITY 5 (tuning failed due to wrong TEC wiring polarity). All query responses *other than* ON 1 indicate the tuning system is idle.

Front panel:  TE Cfg: autotune
<Enter> > start

Example: TUNE?
SUCCESS

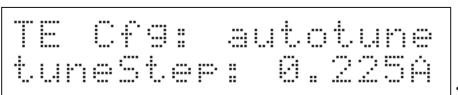
TATS(?) {f}

TEC Autotune Step Size

Set (query) the temperature control autotune step size {to f}, in A.

The default current step used by the TUNE command is 10% of TILM. This step size can be modified with the TATS command, up to a maximum of 25% of TILM.

Increasing TATS may improve autotuning for noisy setups. Decreasing TATS will reduce the temperature excursion during autotuning, which can improve recovery time after tuning, as well as yield slightly improved temperature control.

Front panel:  TE Cfg: autotune
tuneStep: 0.225A

Example: TATS 0.100

TPGN(?) {f}

TEC Control Loop P Gain

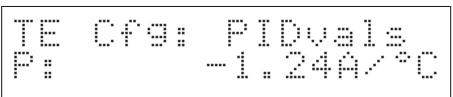
Set (query) the temperature control loop proportional gain {to f}, in A/°C (or A/kΩ).

The temperature control loop of the LDC500 implements a classical PID control law, given by:

$$\text{Output} = P \times \left\{ \epsilon + I \int \epsilon dt + D \frac{d\epsilon}{dt} \right\}$$

where $\epsilon = (T_{\text{set}} - T_{\text{meas}})$ or $\epsilon = (R_{\text{set}} - R_{\text{meas}})$. “Output” is the TEC current, in amps. The TPGN command sets P in the equation. Note that for a properly connected TEC, $P < 0$ whenever the control is in Celsius, or if the sensor has a positive temperature coefficient (for resistance mode).

TPGN is set automatically following a successful autotune cycle.

Front panel:  TE Cfg: PIDvals
P: -1.24A/°C.

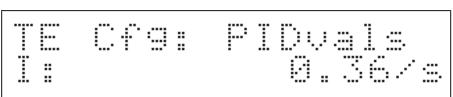
Example: TPGN -1.24

TIGN(?) {f}

TEC Control Loop *I* Gain

Set (query) the temperature control loop integral gain {to *f*}, in 1/s.

See TPGN, above, for a general discussion of the control loop and loop gain parameters. Note that in all cases, $I \geq 0$.

Front panel:  TE Cfg: PIDvals
I: 0.36/s.

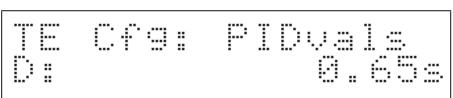
Example: TIGN 0.36

TDGN(?) {f}

TEC Control Loop *D* Gain

Set (query) the temperature control loop derivative gain {to *f*}, in s.

See TPGN, above, for a general discussion of the control loop and loop gain parameters. Note that in all cases, $D \geq 0$.

Front panel:  TE Cfg: PIDvals
D: 0.65s.

Example: TDGN?
6.500000E-01

TPOL(?) {z}

TEC Polarity Reverse Mode

Set (query) the TEC current polarity reverse mode {to *z*=(**NO 0**, YES 1)}.

When TPOL YES is set, the LDC500 will operate with reversed current polarity to the TEC (Peltier) element. This changes the pin assignments to the DB-15 TEC connector to:

pin	description
1, 2	TEC – current terminal (*)
3, 4	TEC + current terminal (*)
5–15	unmodified from section 1.5.4

(*): assignment shown with TPOL YES

This command is for setups in which the TEC wiring is inadvertently reversed. See section 2.2.3 (page 2 – 8) for further discussion.

TPOL cannot be set while the TEC is on.

TE Cfg: Polarity
reversed: *N.

Front panel:

Example: TPOL?
NO

4.5.13 TEC sensor commands

TSNR(?) {z}

Thermometer Type

Set (query) the temperature sensor type {to z=(NTC10UA 0, NTC100UA 1, NTC1MA 2, **NTCAUTO** 3, RTD 4, LM335 5, AD590 6)}.

Four types of temperature sensors are supported by the LDC500: thermistors (generally, NTC thermistors), RTDs (typically Pt-100 or other PTC sensors), LM335 and compatible temperature-to-voltage transducers, and AD590 and compatible temperature-to-current transducers. RTDs and LM335s are biased with a 1 mA excitation current, while the AD590 is biased with 5 V.

The user has several options in biasing the NTC thermistors. Typically, by selecting TSNR NTCAUTO, the LDC500 will auto-range the excitation current to the thermistor between 10 μ A and 1 mA. Alternately, the user can specify a fixed excitation current of 10 μ A (NTC10UA), 100 μ A (NTC100UA), or 1 mA (NTC1MA). The sensor type cannot be changed while the TEC is on and in CT control mode.

TE Cfg: Sensor
*3) NTC auto.

Front panel:

Example: TSNR 3

TIEX(?) {z}

Thermometer Excitation Current

Set (query) the thermometer excitation current {to z=(0, 1, 2)}.

Typically, the temperature sensor excitation current is left at its default setting. In certain applications, however, a user may wish to override the default, and force the excitation current to 10 μ A (TIEX 0), 100 μ A (TIEX 1), or 1 mA (TIEX 2). Note that, if the sensor is set to TSNR NTCAUTO, the current autoranging will override any manual setting provided by TIEX. Changing the TIEX setting for AD590 or LM335 sensors will always result in a sensor fault.

The query form TIEX? can always be used to determine the sensor excitation current in use.

There is no front panel equivalent to TIEX.

Example: TIEX 1

TMDN(?) {z}

NTC Calibration Model

Set (query) the NTC sensor model {to z=(**BETA** 0, SHH 1, NONE 2)}.Two temperature models for NTC thermistors are supported by the LDC500. The default, TMDN **BETA**, models $R(T)$ as:

$$R(T) = R_0 e^{\beta(1/T - 1/T_0)}$$

where T is temperature in kelvin (note, however, that the LDC500 always receives and displays temperature in degrees Celsius), R_0 is the thermistor resistance at reference temperature T_0 , and β is a constant of the thermistor. The second model supported, TMDN **SHH**, is due to Steinhart and Hart:

$$1/T = A + B \ln R + C (\ln R)^3$$

where T is again in kelvin, R is in ohms, and A , B , and C are the so-called Steinhart-Hart coefficients. Finally, if no calibration coefficients are known, or the user desires to operate in resistance control mode, the model can be set to TMDN **NONE**.

Note that TMDN cannot be changed if the TEC is on and in CT mode. TMDN can only be set if the sensor type is NTC.

TE Cfg:	Model
*E0 RTD R/R0=1+αT	B, R(t), t

Front panel: [REDACTED]

Example: TMDN?
BETA

TMDR(?) {z}

RTD Calibration Model

Set (query) the RTD sensor model {to z=(**ALPHA** 0, NONE 1)}.

RTDs use a simple linear resistance model, given by

$$R/R_0 = 1 + \alpha T$$

where T is temperature (in Celsius), R_0 is the resistance at $T = 0^\circ\text{C}$, and α is the sensitivity. If the calibration coefficients are unknown, or the user desires to operate in resistance control mode, the model can be set to TMDR **NONE**.

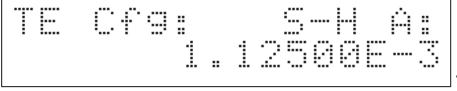
Note that TMDR cannot be changed if the TEC is on and in CT mode. TMDR can only be set if the sensor type is RTD.

TE Cfg:	Model
*E0 RTD R/R0=1+αT	B, R(t), t

Front panel: [REDACTED]

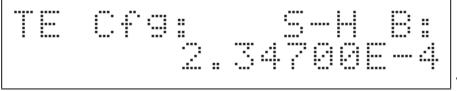
Example: TMDR ALPHA

TSHA(?) {f} Steinhart-Hart Coefficient *A*
Set (query) the *A* coefficient for the Steinhart-Hart model {to *f*}.
See TMDN for formula details.

Front panel: 

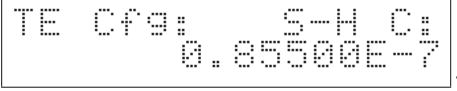
Example: TSHA 1.1250E-3

TSHB(?) {f} Steinhart-Hart Coefficient *B*
Set (query) the *B* coefficient for the Steinhart-Hart model {to *f*}.
See TMDN for formula details.

Front panel: 

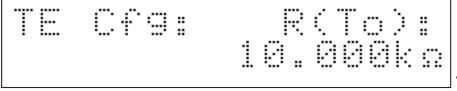
Example: TSHB 2.347E-4

TSHC(?) {f} Steinhart-Hart Coefficient *C*
Set (query) the *C* coefficient for the Steinhart-Hart model {to *f*}.
See TMDN for formula details.

Front panel: 

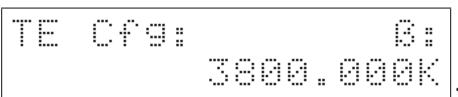
Example: TSHC 8.55E-8

TNTR(?) {f} NTC β -model R_0 Parameter
Set (query) the R_0 parameter for the NTC β -model {to *f*}, in k Ω .
See TMDN for formula details.

Front panel: 

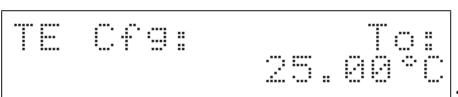
Example: TNTR 10.0

TNTB(?) {f} NTC β -model β Parameter
Set (query) the β parameter for the NTC β -model {to f}, in °C.
See TMDN for formula details.

Front panel: .

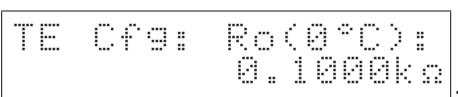
Example: TNTB 3800.

TNTT(?) {f} NTC β -model T_0 Parameter
Set (query) the T_0 parameter for the NTC β -model {to f}, in °C.
See TMDN for formula details.

Front panel: .

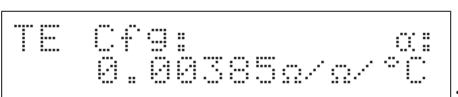
Example: TNTB 25.0

TRTR(?) {f} RTD Linear Model R_0 Parameter
Set (query) the R_0 parameter for the RTD α -model {to f}, in kΩ.
See TMDR for formula details.

Front panel: .

Example: TRTR 0.100

TRTA(?) {f} RTD Linear Model α Parameter
Set (query) the α parameter for the RTD α -model {to f}, in Ω/Ω/°C.
See TMDR for formula details.

Front panel: .

Example: TRTR 0.00385

TLMS(?) {f}

LM335 Slope Parameter

Set (query) the slope parameter for LM335 calibration {to f}, in °C/V.

The LM335 calibration model follows $T = s \cdot V + c$, where V is the raw sensor voltage. TLMS sets the s coefficient in the calibration.

Front panel: 

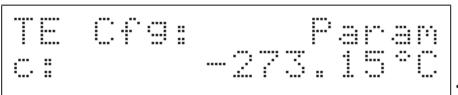
Example: TLMS?
1.000000E+02

TLMY(?) {f}

LM335 Offset Parameter

Set (query) the offset parameter for LM335 calibration {to f}, in °C.

The LM335 calibration model follows $T = s \cdot V + c$, where V is the raw sensor voltage. TLMY sets the c coefficient in the calibration.

Front panel: 

Example: TLMY?
-2.731500E+02

TADS(?) {f}

AD590 Slope Parameter

Set (query) the slope parameter for AD590 calibration {to f}, in °C/µA.

The AD590 calibration model follows $T = s \cdot I + c$, where I is the raw sensor current. TADS sets the s coefficient in the calibration.

Front panel: 

Example: TADS?
1.000000E+0

TADY(?) {f}

AD590 Offset Parameter

Set (query) the offset parameter for AD590 calibration {to f}, in °C.

The AD590 calibration model follows $T = s \cdot I + c$, where I is the raw sensor current. TADY sets the c coefficient in the calibration.

Front panel: 

Example: TADY -273.15

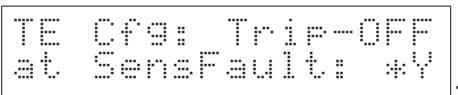
4.5.14 TEC trip-off commands

TTSF(?) {z}

TEC Trip-off on Thermometer Fault

Set (query) the TEC to trip off upon thermometer fault {to z=(NO 0, YES 1)}.

Note that the TEC will always turn off upon a thermometer fault while operating in CT mode; this configuration command only effects operation in TEC-CC mode.

Front panel:  TE Cfg: Trip-OFF
at SensFault: *Y.

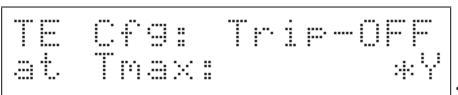
Example: TTSF?
1

TTMX(?) {z}

TEC Trip-off on Max Temperature

Set (query) the TEC to trip off upon exceeding the maximum temperature {to z=(NO 0, YES 1)}.

Note that if the LDC500 is operating with the sensor model set to “none” (resistance units), then arming TTMX will cause the TEC to shut-down if the sensor TRAW? value is greater than TRMX, in kΩ. If the sensor has a negative temperature coefficient, this will correspond to the *lowest* temperature of the operating band, *not* the greatest.

Front panel:  TE Cfg: Trip-OFF
at Tmax: *Y.

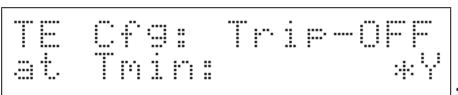
Example: TTMX YES

TTMN(?) {z}

TEC Trip-off on Min Temperature

Set (query) the TEC to trip off upon exceeding the minimum temperature {to z=(NO 0, YES 1)}.

Note that if the LDC500 is operating with the sensor model set to “none” (resistance units), then arming TTmn will cause the TEC to shut-down if the sensor TRAW? value is less than TRMN, in kΩ. If the sensor has a negative temperature coefficient, this will correspond to the *greatest* temperature of the operating band, *not* the lowest.

Front panel:  TE Cfg: Trip-OFF
at Tmin: *Y.

Example: TTmn YES

TTVL(?) {z}

TEC Trip-off on Voltage Limit

Set (query) the TEC to trip off upon exceeding the voltage limit {to z=(NO 0, YES 1)}.

The TEC current source has an intrinsic compliance voltage of ± 8.5 V. If the user needs to assure that the TEC voltage cannot reach that hardware limit, then TTVL, *together with* the TVLM command, can configure the TEC to turn off when the voltage exceeds the TVLM value.

Front panel: .

Example: TTVL?
YES

TTIL(?) {z}

TEC Trip-off on Current Limit

Set (query) the TEC to trip off upon reaching the current limit {to z=(NO 0, YES 1)}.

The TEC current source always limits its magnitude of the output current to the value set by TILM. This limit can be reached during large temperature transitions (when it essentially imposes a temperature rate limit), or at the ultimate cooling or heating limits of the thermoelectric cooler being used. Ordinarily, this limiting is a normal occurrence during operation. For certain critical situations, however, the user may wish the LDC500 to automatically shut down the TEC if the TEC current limit is reached. The TTIL command enables this.

Front panel: .

Example: TTIL 0

4.5.15 Interface commands

Interface commands do not have any front-panel correspondence.

***IDN?**

Identify

Query the LDC500 identification string.

The response is formatted as:

Stanford_Research_Systems,LDC500,s/n*****,ver#.##
where ***** is the 6-digit serial number, and #.## is the firmware revision level.

Example: *IDN?

Stanford Research Systems, LDC501, s/n098023, ver2.00

TOKN(?) {z}

Token Mode

Set (query) the token response mode {to z=(OFF 0, ON 1)}.

Token response mode controls the formatting of response messages generated by the LDC500 to remote queries of token-type values. When TOKN OFF, the LDC500 responds with the numeric version of the token quantity. When TOKN ON, the text version is returned.

Example: TOKN?

ON

TERM(?) {z}

Response Termination

Set (query) the token response mode {to z=(NONE 0, CR 1, LF 2, CRLF 3, LFCR 4)}.

Response messages generated by the LDC500 will be terminated by the 0-, 1- or 2-character termination sequence specified by TERM. Note that the TERM command is *interface specific*. In other words, if TERM LF is received on the RS-232 interface, and then TERM CRLF is received on the ethernet interface, then queries received on the RS-232 interface shall generate response messages terminated with the LF character, while queries received on the ethernet interface shall generate response messages terminated by the CR and LF characters.

TERM settings are saved when the LDC500 is powered off, and restored at power on. They are not affected by *RST or GPAR.

Example: TERM LF

*OPC(?)

Operation Complete

The set form, *OPC, will set the OPC bit in the Standard Event Status register; the query form, *OPC?, will return the value 1.

*OPC is useful for pacing streams of remote commands; the *OPC command will not be processed by the command execution of the LDC500 until all preceding commands have been executed. Note, however, that commands are considered completed once the hardware settings they require are made; analog settling times are *not* part of the normal “execution” process. As a result, *OPC should not be used to indicate that new instrument settings have settled; rather, the usefulness of *OPC is in assuring that the remote interface does not overflow or lose synchronization with a user’s application program.

Example: *OPC?

1

ULOC(?) {i}

Unlock Ethernet

Set (query) the ethernet command lockout {to i}.

Upon power-up, the LDC500 defaults to ULOC 0, which *locks out* all remote commanding over the ethernet port. To enable ethernet control, send the command ULOC 1.

When first connecting to the ethernet command port (port 8888), the user's application program should begin by sending ULOC 1. The ULOC command is the only command that can be processed over ethernet while ULOC 0.

Example: ULOC 1

SPAR {z}

Save User Parameters

Save user settings to record z=(USER0 0,...,USER8 8).

The SPAR command stores all user instrument settings *except* remote interface settings (such as TCP/IP address or baud rate). There are 9 user records available for saving instrument setups, numbered 0–8.

Util: Save cfg:
Front panel: Overwrite: Usr3]

Example: SPAR USER3

GPAR {z}

Restore User Parameters

Restore user settings from record z=(USER0 0,...,USER8 8, DEFAULT 9).

The GPAR command restores all user instrument settings *except* remote interface settings (such as TCP/IP address or baud rate). There are 9 user records available for saving instrument setups, numbered 0–8. Additionally, the default settings for the LDC500 can be restored by GPAR DEFAULT. See (*RST, 4 – 51) for instrument settings after GPAR DEFAULT .

Note that GPAR will not operate if either the TEC or LD is on.

Util: Recall cfg
Front panel: Read from: Usr2]

Example: GPAR 2

LOCK(?) {z} Local Lockout
Set (query) the local lockout {to z=(**LOCAL 0**, **REMOTE 1**, **LOCKOUT 2**)}.
The **LOCK** command provides control over user access to front-panel control of the LDC500. When **LOCK REMOTE** or **LOCK LOCKOUT**, the **REM** indicator will be lit; in this state, the user cannot control any instrument functions from the front panel.

When in **LOCK REMOTE**, the [Utility/Local] button acts as the “local” function, bringing the LDC500 back to the **LOCK LOCAL** state with full front-panel control. Note, however, that in **LOCK LOCKOUT**, even the [Utility/Local] button is disabled: only a remote command returning the instrument to **LOCK LOCAL**, or a power cycle, will restore front-panel control.

Note that any GPIB access to the LDC500 always places the instrument into the **LOCK REMOTE** state.

Example: **LOCK LOCKOUT**

BLVL(?) {z} Display Brightness Level
Set (query) the alphanumeric display brightness level {to z=(**B12 0**, **B25 1**, **B37 2**, **B50 3**, **B62 4**, **B75 5**, **B87 6**, **B100 7**)}.
The brightness of the alphanumeric display on the LDC500 can be adjusted in 12.5% steps with the **BLVL** command.

Front panel: **Util: Brightness**
Level: *3) 50.0%.

Example: **BLVL?**
B50

BAUD(?) {z} Serial Baud Rate
Set (query) the RS-232 baud rate {to z=(**BD1200 0**, **BD2400 1**, **BD4800 2**, **BD9600 3**, **BD14400 4**, **BD19200 5**, **BD38400 6**, **BD57600 7**, **BD115200 8**, **BD230400 9**)}.

Front panel: **Util: RS-232**
Baud: *7) 57600.

Example: **BAUD7**

IPAD(?) i {, j}	IP Address
	Set (query) byte <i>i</i> of the internet address {to <i>j</i> }.
	Note that byte 0 is the left-most byte of the address.
	Util: IP Address Front panel: 169.254.46.27.
	<i>Example:</i> IPAD?0; IPAD?1; IPAD? 2; IPAD?3 169;254;46;27
NMSK(?) i {, j}	Netmask
	Set (query) byte <i>i</i> of the internet network mask {to <i>j</i> }.
	Note that byte 0 is the left-most byte of the mask.
	Util: IP Netmask Front panel: 255.255.0.0.
	<i>Example:</i> NMSK 1, 255; NMSK?0; NMSK?1; NMSK?2; NMSK3 255;255;0;0
GWAY(?) i {, j}	Default Gateway
	Set (query) byte <i>i</i> of the internet default gateway {to <i>j</i> }.
	Note that byte 0 is the left-most byte of the address.
	Util: Gateway Front panel: 0.0.0.0.
	<i>Example:</i> GWAY 0, 172
MACA?	Ethernet hardware address
	Query the low-level ethernet hardware address (MAC address). This is not the same as the IP address, and cannot be changed by the user.
	<i>Example:</i> MACA? 0019:b303:ffff

ENET(?) {z}	Ethernet speed Set (query) the ethernet speed{to $z=(\text{AUTO } 0, \text{M10 } 1, \text{M100 } 2)$ }.
	The ethernet speed can be set to 100Base-T ($z = \text{M100}$), 10Base-T ($z = \text{M10}$), or autonegotiate between the two speeds ($z = \text{AUTO}$).

Example: ENET?
2

*RST	Reset Reset the LDC500 to its default configuration. The following commands are internally executed upon receipt of the *RST command:
------	---

- LDON OFF
- TEON OFF
- SVLM 5.0
- SILM 20.0 (LDC500); SILM 100.0 (LDC501)
- PILM 5000.0
- SILD 0.0
- SIPD 0.0
- SYND 5.0
- RNGE HIGH
- MODU OFF
- SMOD CC
- SIBW HIGH
- PDMW NO
- BIAS 2.5
- RESP 1.000
- SMLK NO
- AILM NO
- APLP NO
- APLC NO
- ATOF NO
- ATMX NO
- ATMN NO
- TSNR NTCAUTO
- TMDN BETA
- TMOD CT
- TCUR 0.0
- TILM 2.25
- TMIN 0.0

- TMAX 50.0
- TVLM 8.0
- TEMP 25.0
- TATS 0.225
- TPGN -0.5
- TIGN 0.36
- TDGN 0.65
- TNTB 3800.0
- TNTR 10.0
- TNTT 25.0
- TMLK NO
- TTSD YES
- TTMX YES
- TTMN YES
- TTVL YES
- TTIL NO
- TPOL NO

4.5.16 Status commands

*STB? [i]	Status Byte Reads the Status Byte register [bit <i>i</i>].
Example:	*STB? 0
*SRE(?) [i,] {j}	Service Request Enable Set (query) the Service Request Enable register [bit <i>i</i>] {to <i>j</i> }.
Example:	*SRE 0,1
*ESR? [i]	Standard Event Status Reads the Standard Event Status Register [bit <i>i</i>].
	Upon executing *ESR?, the returned bit(s) of the ESR register are cleared.
Example:	*ESR? 64

*ESE(?) [i,] {j} Standard Event Status Enable
Set (query) the Standard Event Status Enable Register [bit i] {to j}.

Example: *ESE 6,1
ESE?
64

*CLS Clear Status
*CLS immediately clears the ESR, LDEV, and TEEV registers.

Example: *CLS

LEXE? Last Execution Error
Query the last execution error code. A query of LEXE? always clears the error code, so a subsequent LEXE? will return 0. Valid codes are:

Value	Definition
0	No execution error since last LEXE?
1	Illegal value
2	Wrong token
3	Invalid bit
4	Queue full
5	Not compatible

Example: SILD 12345; LEXE?; LEXE?
1;0

The error (1, “Illegal value,”) is because the parameter value (12345) is too large for SILD. The second read of LEXE? returns 0.

LCME?**Last Command Error**

Query the last command error code. A query of LCME? always clears the error code, so a subsequent LCME? will return 0. Valid codes are:

Value	Definition
0	No execution error since last LCME?
1	Illegal command
2	Undefined command
3	Illegal query
4	Illegal set
5	Missing parameter(s)
6	Extra parameter(s)
7	Null parameter(s)
8	Parameter buffer overflow
9	Bad floating-point
10	Bad integer
11	Bad integer token
12	Bad token value
13	Bad hex block
14	Unknown token

Example: *IDN

LCME?

4

The error (4, “Illegal set”) is due to the missing “?”.

LDCR? [i]**Laser Diode Condition**

Read the Laser Diode Condition Register [bit i].

LDPT(?) [i,] {j}**Laser Diode Positive-Transition**

Set (query) the Laser Diode Positive Transition Register [bit i] {to j}.

Example: LDPT 4,1

LDNT(?) [i,] {j}**Laser Diode Negative-Transition**

Set (query) the Laser Diode Negative Transition Register [bit i] {to j}.

Example: LDNT?

16

LDEV? [i]	Laser Diode Event Query the Laser Diode Event Register [bit i]. Upon executing an LDEV? query, the returned bit(s) of the LDEV register are cleared.
	<i>Example:</i> LDEV? 16
LDEN(?) {i,} {j}	Laser Diode Event Enable Set (query) the Laser Diode Status Enable Register [bit i] {to j}.
	<i>Example:</i> LDEN 4,1
TECR? [i]	TEC Condition Read the TEC Controller Condition Register [bit i].
	<i>Example:</i> TECR? 0 1
TEPT(?) [i,] {j}	TEC Positive-Transition Set (query) the TEC Controller Positive Transition Register [bit i] {to j}.
	<i>Example:</i> TEPT 4,1
TENT(?) [i,] {j}	TEC Negative-Transition Set (query) the TEC Controller Negative Transition Register [bit i] {to j}.
	<i>Example:</i> TENT? 16
TEEV? [i]	TEC Event Query the TEC Controller Event Register [bit i]. Upon executing an TEEV? query, the returned bit(s) of the TEEV register are cleared.
	<i>Example:</i> TEEV? 16

TEEN(?) [i,] {j} TEC Event Enable
Set (query) the TEC Controller Status Enable Register [bit *i*] {to *j*}.

Example: TEEN 4,1

4.6 Status Model

status registers The LDC500 status registers follow the hierarchical IEEE-488.2 format. A block diagram of the status register array is given in Figure 4.1.

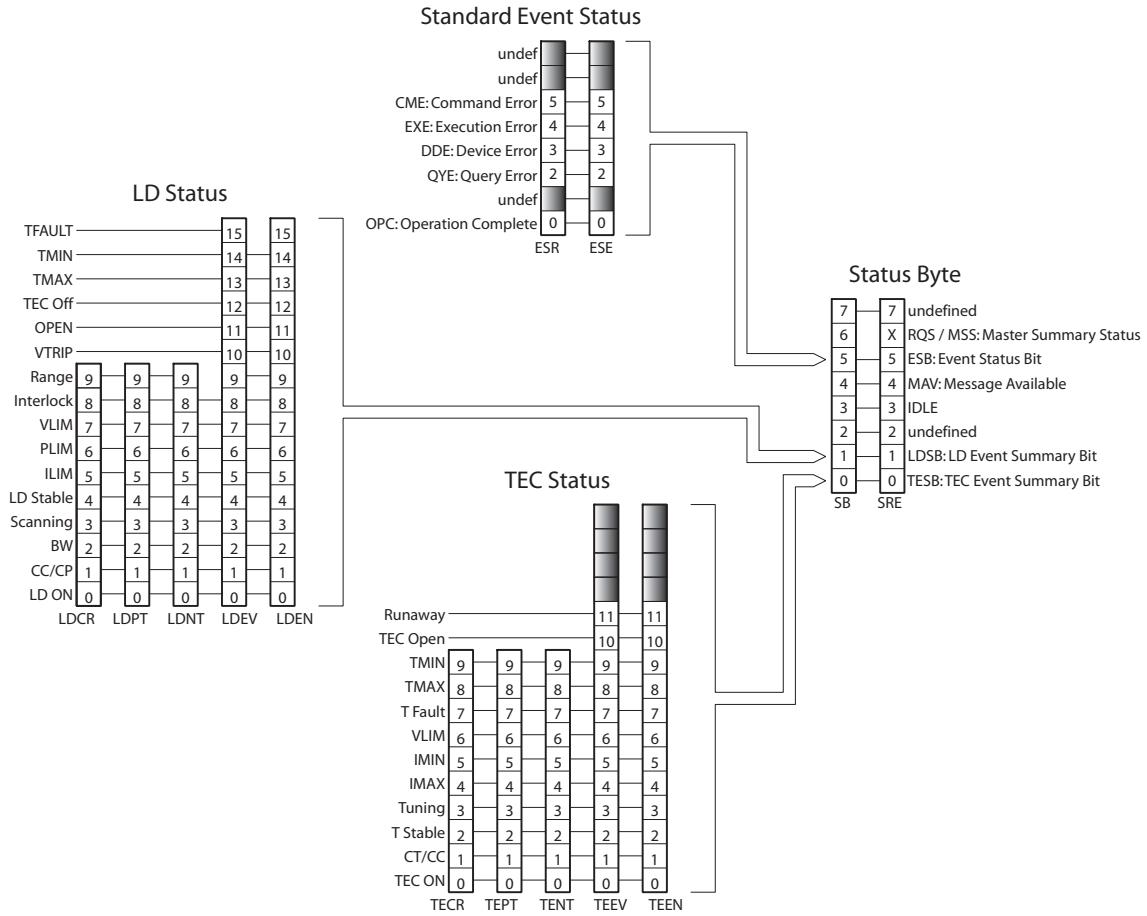


Figure 4.1: Status Model for the LDC500 Series Laser Diode Controllers.

There are five categories of registers in the status model of the controller:

Condition Registers : These read-only registers correspond to the real-time condition of some underlying physical property being monitored. Queries return the latest value of the property, and have no further side effects. Condition register names end with CR.

Transition Selection Registers : These read/write registers define specific transition events ($0 \rightarrow 1$ or $1 \rightarrow 0$). The event is then defined by the selected transition

in the value of the underlying condition register. Transition register names end with PT or NT.

Event Registers : These read-only registers record the occurrence of defined events within the controller. If the event occurs, the corresponding bit is set to 1. Upon querying an event register, any set bits within it are cleared. These are sometimes known as “sticky bits,” since once set, a bit can only be cleared by reading its value. Event register names end with SR or EV.

Enable Registers : These read/write registers define a bitwise mask for their corresponding event register. If any bit position is set in an event register while the same bit position is also set in the enable register, then the corresponding summary bit message is set in the Status Byte. Enable register names end with SE or EN.

Status Byte : This read-only register represents the top of the status model, and is populated with summary bit messages and interface condition bits. Enabled bits within the Status Byte generate the IEEE-488 Request Service event over GPIB.

At power-on, all status registers are cleared.

4.6.1 Status byte (SB)

The Status Byte is the top-level summary of the LDC500 status model. When masked by the Service Request Enable register, a bit set in the Status Byte causes a GPIB Request Service event.

Weight	Bit	Flag
1	0	TESB
2	1	LDSB
4	2	undef (0)
8	3	IDLE
16	4	MAV
32	5	ESB
64	6	MSS
128	7	undef (0)

TESB : TEC Controller Event Summary Bit. Indicates whether one or more of the enabled flags in the TEC Controller Event Register (TEEV) has become true.

LDSB : Laser Diode Event Summary Bit. Indicates whether one or more of the enabled flags in the Laser Diode Event Register (LDEV) has become true.

IDLE : Indicates that the input buffer is empty and the command parser is idle. Can be used to help synchronize LDC500 query responses.

MAV : Indicates that the GPIB Output queue is *not* empty and the LDC500 has a response message available for the host to read. Can be used to help synchronize query responses.

ESB : Event Status Bit. Indicates whether one or more of the enabled events in the Standard Event Status Register is true.

MSS : Master Summary Status. Indicates whether one or more of the enabled status messages in the Status Byte register is true.

This register is read with the *STB? query.

4.6.2 Service request enable (SRE)

Each bit in the SRE corresponds one-to-one with a bit in the SB register, and acts as a bitwise AND of the SB flags to generate MSS. Bit 6 of the SRE is undefined—setting it has no effect, and reading it always returns 0. This register is set and queried with the *SRE(?) command.

At power-on, this register is cleared.

4.6.3 Standard event status (ESR)

The Standard Event Status Register consists of 8 event flags. These event flags are all “sticky bits” that are set by the corresponding events, and cleared only by reading or with the *CLS command. Reading a single bit (with the *ESR? *i* query) clears only Bit *i*.

Weight	Bit	Flag
1	0	OPC
2	1	undef (0)
4	2	QYE
8	3	DDE
16	4	EXE
32	5	CME
64	6	undef (0)
128	7	undef (0)

OPC : Operation Complete. Set by the *OPC command.

QYE : Query Error. Indicates data in the output queue has been lost.

DDE : Device-Dependent Error. Indicates an internal command queue overflow.

EXE : Execution Error. Indicates the error in a command that was successfully parsed. Out-of-range parameters are an example.

CME : Command Error. Indicates a command parser-detected error.

4.6.3.1 Standard event status enable (ESE)

The ESE acts as a bitwise AND with the ESR register to produce the single-bit ESB message in the Status Byte Register (SB). The register can be set and queried with the *ESE(?) command.

At power-on, this register is cleared.

4.6.4 Laser diode condition (LDCR)

The Laser Diode Condition Register consists of 10 condition flags that reflect the real-time condition of the LD portion of the LDC500. Reading the LDCR has no effect on any values.

Weight	Bit	Flag
1	0	LD ON
2	1	CC/CP
4	2	BW
8	3	SCANNING
16	4	LD STABLE
32	5	ILIM
64	6	PLIM
128	7	VLIM
256	8	INTERLOCK
512	9	RANGE

LD ON : Set when the LD current source is on.

CC/CP : Set when the LD current source is in CP mode.

BW : Set when the LD current source is in high bandwidth mode.

SCANNING : Set when a multi-point scan is in progress (see SCAN).

LD STABLE : Set when laser current is stable.

ILIM : Set when the LD current source is at the current limit (SILM).

PLIM : Set when the photodiode reading is above the limit value (either PILM or PWLM).

VLIM : Set when the LD forward voltage is within 250 mV of the voltage limit (SVLM).

INTERLOCK : Set when the external interlock is open.

RANGE : Set when LD range is high (500 mA).

4.6.4.1 Laser diode positive/negative transition (LDPT/LDNT)

These two 16-bit wide registers control the mapping of transitions in the LDCR to setting flags in the LDEV register. For any particular event, if the corresponding bit is set in LDPT, then a 0→1 transition

in the LDCR causes the bit to be set in the LDEV. Likewise, if a bit is set in LDNT, then a 1→0 transition in the LDCR causes the bit to be set in the LDEV.

All combinations of LDPT and LDNT settings are valid. At power-on, both LDPT and LDNT are cleared.

4.6.4.2 Laser diode event (LDEV)

This 16-bit wide register monitors selected events in the LDCR, based on transitions selected in LDPT and LDNT. When the selected transition(s) occur, the corresponding bit is set. Reading the register clear it (reading a single bit clears only that bit). This register is cleared by the *CLS command.

In addition to monitored events from the LDCR, several discrete events are directly defined in LDEV without corresponding real-time condition bits in the LDCR. These are:

Weight	Bit	Flag
1024	10	VTRIP
2048	11	OPEN
4096	12	TEC OFF
8192	13	TMAX
16384	14	TMIN
32768	15	TFAULT

VTRIP : Indicates the LD tripped off due to overvoltage.

OPEN : Indicates the LD tripped due to open circuit.

TEC OFF : Indicates LD tripped off due to the TEC being off (see ATOF).

TMAX : Indicates the LD tripped off due to T_{\max} being exceeded.

TMIN : Indicates the LD tripped off due to T_{\min} being exceeded.

TFAULT : Indicates the LD tripped off due to a temperature sensor fault.

4.6.4.3 Laser diode status enable (LDSE)

This is a 16-bit wide register that masks the LDEV register. The logical OR of the bitwise AND of LDEV and LDEN produces the LDSB message in the Status Byte register (SB).

4.6.5 TEC controller condition (TECR)

The Laser Diode Condition Register consists of 10 condition flags that reflect the real-time condition of the TEC portion of the LDC500. Reading the TECR has no effect on any values.

Weight	Bit	Flag
1	0	TEC ON
2	1	CT/CC
4	2	T STABLE
8	3	TUNING
16	4	IMAX
32	5	IMIN
64	6	VLIM
128	7	T FAULT
256	8	TMAX
512	9	TMIN

TEC ON : Set when the TEC current source is on.

CT/CC : Set when the TEC current source is in CT mode.

T STABLE : Set when the temperature is stable.

TUNING : Set when autotuning is in progress.

IMAX : Set when the output current is at the positive limit.

IMIN : Set when the output current is at the negative limit.

VLIM : Set when the TEC operating voltage is at or above the limit (see TVLM).

T FAULT : Set when the thermal sensor is disconnected/in fault.

TMAX : Set when temperature is above the maximum.

TMIN : Set when temperature is below the minimum.

4.6.5.1 TEC controller positive/negative transition (TEPT/TENT)

These two 16-bit wide registers control the mapping of transitions in the TECR to setting flags in the TEEV register. For any particular event, if the corresponding bit is set in TEPT, then a 0→1 transition in the TECR causes the bit to be set in the TEEV. Likewise, if a bit is set in TENT, then a 1→0 transition in the TECR causes the bit to be set in the TEEV.

All combinations of TEPT and TENT settings are valid. At power-on, both TEPT and TENT are cleared.

4.6.5.2 TEC controller event (TEEV)

This 16-bit wide register monitors selected events in the TECR, based on transitions selected in TEPT and TENT. When the selected transition(s) occur, the corresponding bit is set. Reading the register clear it (reading a single bit clears only that bit). This register is cleared by the *CLS command.

In addition to monitored events from the TECR, several discrete events are directly defined in TEEV without corresponding real-time condition bits in the TECR. These are:

Weight	Bit	Flag
1024	10	TEC OPEN
2048	11	RUNAWAY

TEC OPEN : Indicates the TE tripped off due to open circuit.

OPEN : Indicates the TE tripped due to thermal runaway.

4.6.5.3 TEC controller status enable (TESE)

This is a 16-bit wide register that masks the TEEV register. The logical OR of the bitwise AND of TEEV and TEEN produces the TESB message in the Status Byte register (SB).

5 Error Messages

This chapter describes some of the warning messages that may appear on the alphanumeric display.

In This Chapter

5.1	Laser Diode Driver Messages	5–2
5.1.1	Interlock	5–2
5.1.2	Transitions with high photodiode current . . .	5–2
5.1.3	Transitions with limited laser current	5–2
5.1.4	Transitions locked out	5–2
5.1.5	Responsivity	5–3
5.1.6	Photodiode current overflow	5–3
5.1.7	Responsivity underflow	5–3
5.1.8	Responsivity overflow	5–4
5.1.9	Trip-off from TEC	5–4
5.1.10	Trip-off from temperature	5–4
5.2	TEC Messages	5–4
5.2.1	Autotune	5–4
5.2.2	No loop control	5–5
5.2.3	Transitions locked out	5–5
5.2.4	Temperature faults	5–6
5.2.5	Thermal runaway	5–6
5.2.6	Polarity change locked out	5–6
5.3	Other messages	5–6
5.3.1	Restart	5–6

5.1 Laser Diode Driver Messages

The following warning messages are related to the Laser Diode Driver section of the LDC500.

5.1.1 Interlock

-LD Output OFF-
Interlock open

Pin 1 and Pin 2 on the DB-9 laser connector must be electrically connected to each other for the laser current source to operate. Check the cable or jumper to see if the connection is open.

5.1.2 Transitions with high photodiode current

LD mode locked
PD: $I_{pd} > I_{lim}$

In CC mode, if the photodiode current is greater than the limit, PD I_{lim} , then transitions from CC to CP mode are prohibited. To allow live transitions from CC to CP mode, either reduce the laser operating current or increase the PD I_{lim} value.

5.1.3 Transitions with limited laser current

LD mode locked
LD: $I_{ld} > I_{lim}$

In CP mode, if the laser current is limited by the LD I_{lim} setting, then transitions from CP to CC mode are prohibited. To allow live transitions from CP to CC mode, either reduce the photodiode operating setpoint or increase the LD I_{lim} value.

5.1.4 Transitions locked out

CC/CP lockWhenOn
CMD ignored

Transitions between CC and CP modes can be explicitly locked out during laser operation by setting the CC/CP lock mode to “yes”. To change modes, either change the lock mode to “no” or turn off the laser output. See section 3.2.3.8.

5.1.5 Responsivity

Cant modify RESP
when mW control

The photodiode responsivity cannot be modified or calibrated when the laser is ON and operating in CP milliwatt control mode. See sections 3.2.3.6 and 3.2.3.7.

5.1.6 Photodiode current overflow

Too large: keep
 $Pwlm \times Resp < 5000\mu A$

Any time a new photodiode responsivity is set (either by CALP or RESP), the LDC500 will check that the implied value of PD Ilim, based on the present value of PD Plim, does not exceed the maximum photodiode current of $5000\mu A$ ($10,000\mu A$. for LDC502). If this warning occurs, either the responsivity is too high, or the photodiode power limit (PWLM) needs to be reduced.

LD Settings:
 $Pwlm \times Resp > 5000\mu A$

Similarly, any time a new photodiode power limit (PWLM) is set, the instrument checks that the physical photodiode current limit still remains less than $5000\mu A$ ($10,000\mu A$. for LDC502). Again, if this occurs, either the responsivity is too high, or the photodiode power limit is too high.

Resulting Plim
exceeds $5000\mu A$

Finally, when mW units are selected, the derived photodiode current limit (using responsivity) may exceed $5000\mu A$ ($10,000\mu A$. for LDC502). Again, reduce the power limit or the responsivity value to resolve the problem.

5.1.7 Responsivity underflow

Resulting Resp
below MINRESP

When calibrating responsivity (see section 3.2.3.6), a large value for measured power might result in the responsivity value less than the minimum, $0.051\mu A/mW$. If this occurs, either the power measurement is mistaken, or the photodiode circuit is open (too low a photodiode current).

5.1.8 Responsivity overflow

Resulting Resp
exceeds MAX_RESP

When calibrating responsivity (see section 3.2.3.6), a small value for measured power might result in the responsivity value greater than the maximum, 999,999 μ A/mW. If this occurs, the power measurement is mistaken.

5.1.9 Trip-off from TEC

-LD Tripped OFF-
TE Off

This message indicates the laser diode driver has tripped off because the TEC controller is off. This condition (armed by ATOF, see section 3.2.3.9) shuts down the laser current source if the TEC turns off for any reason.

5.1.10 Trip-off from temperature

-LD Tripped OFF-
Tmax exceeded

-LD Tripped OFF-
Tmin exceeded

-LD Tripped OFF-
T sensor fault

Any of these messages indicate the laser diode driver has tripped off because of a temperature limit setting. Note that these conditions can operate even when the TEC is off, as long as a valid temperature sensor is connected.

5.2 TEC Messages

The following warning messages are related to the TEC Controller section of the LDC500.

5.2.1 Autotune

TE Cfg: Autotune
Failed

If the thermal stage being controlled has an unusually long thermal time constant (greater than around 50 seconds), the default autotuning function may fail to converge because of the very slow temper-

ature response. Often increasing the step size for autotuning will help. See section 3.3.3.6

TE Cfg: Autotune
T not stable

The autotune function requires a stable initial temperature for proper operation. If the TEC controller is on, and set to CT (constant temperature) control mode, and the temperature is not stable, this warning message will appear. Clear the message (by pressing [Clear/Cancel]), and try again later. If the temperature is oscillating, try turning off the TEC, allow the stage to come to room temperature, and then initiate autotuning with the TEC stage initially off.

TE Cfg: Autotune
Check Polarity

The autotune function will fail if the TEC stage temperature responds with the wrong polarity in response to the step change in applied current. If this is detected, the autotune function will halt with the above message. Verify the TEC wiring polarity, and if reversed either correct the problem in hardware, or with the TPOL command (pagerefcmd:TPOL).

A manual procedure to verify the TEC wiring polarity is described in section 2.2.3.

5.2.2 No loop control

Warning: PID P=0
=> no T control

Whenever the sensor model is changed between Constant Resistance (no temperature calibration model used) and Constant Temperature (either β -model or Steinhart-Hart model), the PID proportional gain (TPGN) will be cleared to 0 (zero) for safety. Any time TPGN is zero, the TEC controller can only operate in Constant Current mode. To enable temperature/resistance control, perform an autotune cycle or manually set TPGN to a non-zero value. See section 3.3.3.7.

5.2.3 Transitions locked out

CT/CC lockWhenOn
cmd ignored

Transitions between CT and CC modes can be explicitly locked out during TEC operation by setting the CT/CC lock mode to “yes”. To change modes, either change the lock mode to “no” or turn off the laser output. See section 3.3.3.8.

5.2.4 Temperature faults

-TE Tripped OFF-
T sensor fault

This message indicates a faulty result from the sensor measurement. The sensor type may be wrong, or the model parameters may be incorrect, or the circuit may be open or shorted.

calc. T anomaly:
check model vals

This message indicates the derived value of temperature (from resistance) is outside the range -150°C to $+250^{\circ}\text{C}$. Verify the sensor model parameters.

5.2.5 Thermal runaway

-TE Tripped OFF-
Thermal Runaway

Thermal runaway occurs when the TEC current is positive (attempting to cool the stage), but the measured temperature persistently increases. See section 2.2.6 for a more detailed discussion of thermal runaway.

5.2.6 Polarity change locked out

Turn off TEC to
change Polarity

The TEC wiring polarity can be changed using the TPOL command (page 4 – 39). However, changes to the TEC polarity can only be made when the TEC is off. Turn off the TEC with the [TEC On/Off] button before attempting to change the TEC wiring polarity.

5.3 Other messages

5.3.1 Restart

Unexpected reset
LDC restart 3

If the AC power supply encounters a brief interruption in line current (even as short as 1/2 cycle of the AC line), then fast protection circuits initiate a shutdown of the laser driver, and the entire instrument, to assure protection of the laser diode itself. If AC line power resumes before the power supply completely shuts down, however, the LDC500 detects that a power anomaly occurred and displays the

message shown above. Under certain circumstances, it is also possible for this rapid protection-based shutdown to occur in response to an ESD (electrostatic discharge) event.

If this occurs multiple times, investigate whether there are significant ESD problems in the area where the LDC500 is operated. If the AC line power is known to be unreliable, an uninterruptable power supply may be helpful.

6 Cables and Accessories

This chapter describes cables and accessories that are available for use with the LDC500 Series Laser Diode Controllers.

In This Chapter

6.1 Cables	6-2
6.1.1 Laser diode cables	6-2
6.1.2 TEC cables	6-4

6.1 Cables

Factory cables, for connecting to laser diodes and thermoelectric coolers, are available from SRS for use with LDC500.

6.1.1 Laser diode cables

Two styles of cable are available to connect the LDC500 Series Laser Diode Controllers to a laser diode—a flying-lead cable and a double terminated cable. Both styles have a male DB-9 connector to mate with the controller. All SRS laser diode cables are specially constructed for high flexibility and high bandwidth, and optimized for use with the LDC500 Series Laser Diode Controllers.

The terminated version of the cable (see Figure 6.1) is available in two lengths (6 ft and 12ft).

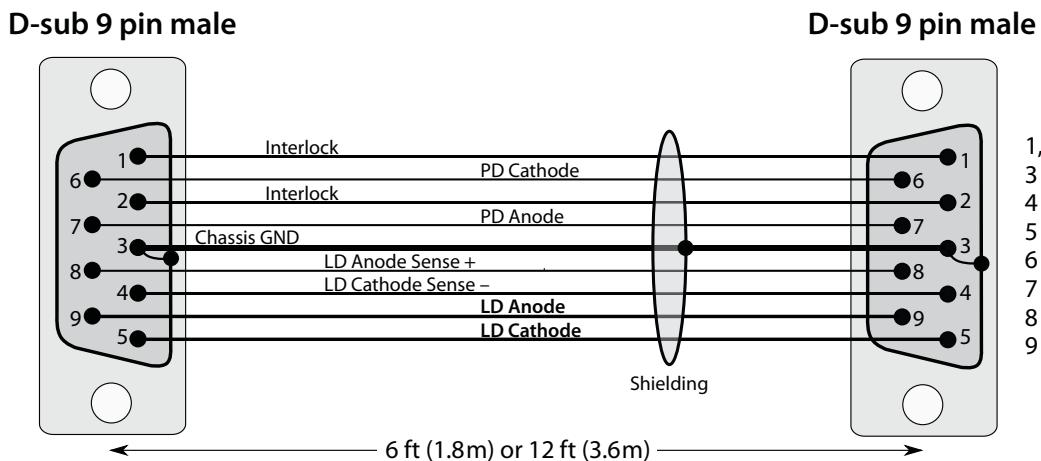


Figure 6.1: Laser diode cable with mating connector. SRS part number O500C3 (6 ft) or O500C5 (12 ft).

This cable can be used with customer-built laser mounts with a female DB-9 connector. Alternatively, these can be used with some commercially-available mounts:

- ILX: Most ILX laser mounts can be directly used, mating the SRS cable to the 9-pin female socket on the mount. Be certain the “Interlock” function is satisfied by connecting pins 1 & 2 internally in the laser diode mount.
- Newport: Mounts from Newport follow a compatible pin assignment, but have the reverse gender—the mount has a 9-pin

male connector. A gender-changer (with two female 9-pin connectors, wired “pin-to-pin”) can be used, but be careful to not use an RS-232 null modem part. The interlock will require connecting pins 1 & 2 internally in the mount.

- Thorlabs: Not compatible. Because of the grounding scheme used in Thor mounts, the cable must be customized for each laser configuration. See the discussion for the flying-lead cable.

The flying-lead version (see Figure 6.2) is available in one length (6 ft), and provides users with the greatest flexibility for interfacing to a range of laser mounts.

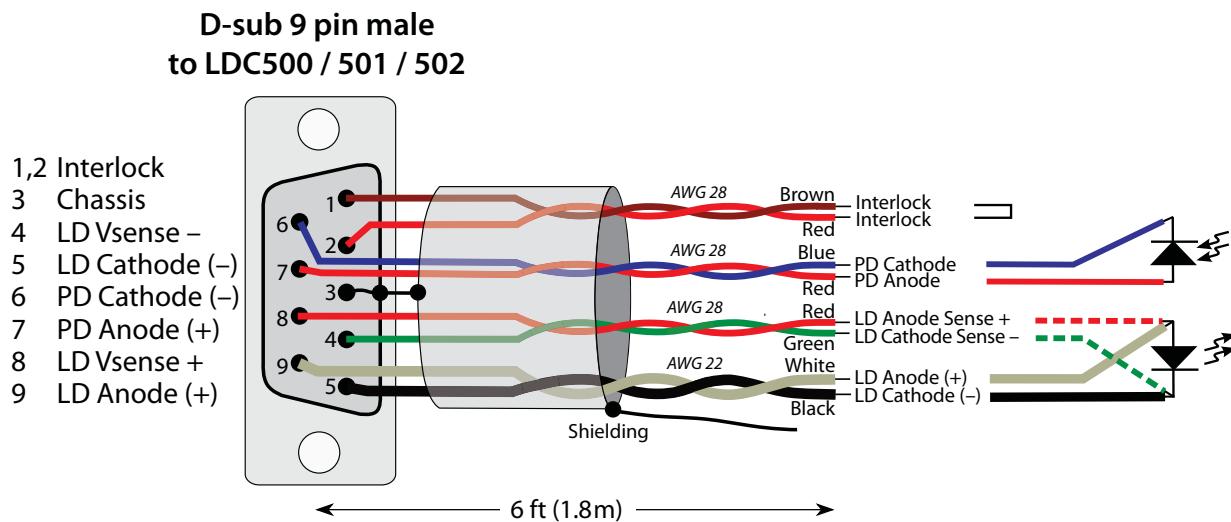


Figure 6.2: Laser diode cable with flying leads. SRS part number O500C1.

6.1.1.1 special note for Thorlabs mounts

Laser diode mounts from Thorlabs are switch-configured, based on the grounding of your specific laser diode and photodiode. These switches connect each terminal (anode or cathode) between either the corresponding pin of the mount connector, and the chassis ground of the mount. The laser diode circuit, and the photodiode circuit, are each completed through the “Laser Ground Pin” of the mount (typically pin 3).

For example, consider a laser diode with Grounded Anode, and photodiode Grounded Cathode. In this case, the black LD Cathode lead and the green LD Cathode Sense lead are both wired to the LD Cathode pin (typically pin 7 on Thorlabs mounts), and the white LD

Anode lead and the red LD Anode Sense lead are both wired to the laser ground pin (typically pin 3). Similarly, the red PD Anode lead is wired to the photodiode Anode pin (typically pin 4), while the blue PD Cathode lead is wired to laser ground (again, pin 3).

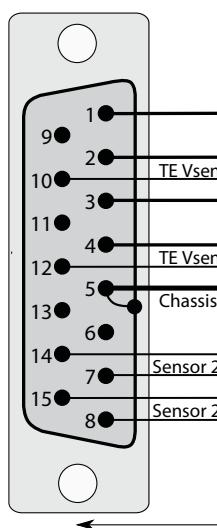
When using these mounts, it is necessary to re-wire the flying-lead end of the cable each time the grounding configuration of the mount is changed.

6.1.2 TEC cables

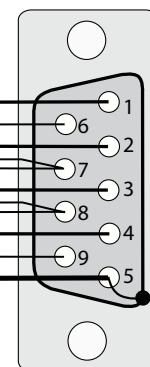
Two styles of cable are also available to connect the LDC500 series controller to a thermoelectric cooler—a flying-lead cable and a double terminated cable. Both styles are built with the male DB-15 connector to mate with the TEC output of the controller. All SRS TEC cables are constructed for high flexibility and high current capacity, and optimized for use with the LDC500 Series Laser Diode Controllers.

The terminated version of the cable (see Figure 6.3) is available in two lengths (6 ft and 12 ft).

**D-sub 15 pin male
to LDC500 / 501 / 502**



**D-sub 9 pin female
to TEC**



- | | |
|-----|------------|
| 1,2 | TE+ |
| 3,4 | TE- |
| 5 | Chassis |
| 6 | TE Vsense+ |
| 7 | Sensor+ |
| 8 | Sensor- |
| 9 | TE Vsense- |

6 ft (1.8m) or 12 ft (3.6m)

Figure 6.3: TEC cable with mating connector. SRS part number O500C4 (6 ft) or O500C6 (12 ft).

This cable can be used with customer-built laser mounts with a male DB-9 connector. Alternatively, these can be used with some

commercially-available mounts:

- ILX: Most ILX laser mounts can be directly used, mating the SRS cable to the male DB-9 plug on the mount. Note that voltage-sensing of the TE element is not implemented in ILX mounts, so the cable resistance contribution to VTEC will appear when measured by the LDC500.
- Newport: Mounts from Newport typically have a male DB-15 plug for the TEC. Users should consider the flying-lead cable.
- Thorlabs: Not compatible. Thorlabs mounts have a male DB-9 plug for their TEC, but the pin assignments are quite different. Users should again consider the flying-lead cable.

The flying-lead version of the cable (see Figure 6.4) is available in one length (6 ft).

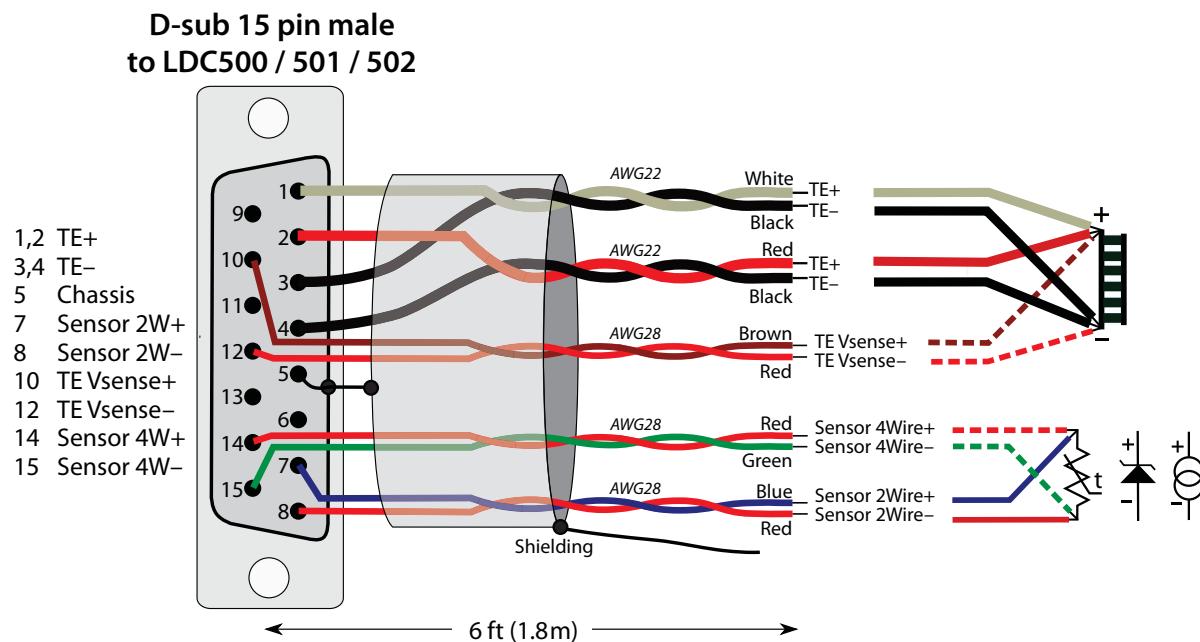


Figure 6.4: TEC cable with flying leads. SRS part number O500C2.

When configuring a TEC system for use with the LDC500 Series Laser Diode Controllers, it is important that the temperature sensor be kept electrically isolated from all other nodes, including chassis ground. For best operation, the TEC (Peltier) element should also be isolated from chassis ground.