

Operation and Service Manual

# Laser Diode Controller

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**LDC501**



Stanford Research Systems

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Revision 1.6 • March 26, 2009

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Printed in U.S.A.

Document number 9-01640-903



*LDC501 Laser Diode Controller*

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## General Information

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### Safety and Preparation for Use



#### WARNING

**Dangerous voltages, capable of causing injury or death, are present in this instrument. Use extreme caution whenever the instrument covers are removed. Do not remove the covers while the unit is plugged into a live outlet.**

### AC line voltage

The LDC501 operates 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 LDC501 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. For 100 V/120 V, use 4 A fuses; for 220 V/240 V, use 2 A fuses.

### Line cord

The LDC501 has 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

Do not attempt to service or adjust this instrument unless another person, capable of providing first aid or resuscitation, is present.

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**

<b>Symbol</b>	<b>Description</b>
	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



### WARNING

The following notation will be used throughout this manual.

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 LDC501 are set as `straight teletype font`, while responses received by the host computer from the LDC501 are set as *slanted teletype font*.

## Specifications

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

### Laser diode current source

		Min	Typ	Max	Units
Output current	Range, high	0		500	mA
	low	0		250	
	Setpoint resolution		10		$\mu$ A
	Accuracy			$\pm 50$	$\mu$ A
	DC output impedance	1.0			M $\Omega$
	Thermal drift			$\pm 10$	ppm/ $^{\circ}$ C
	Short-term stability (1 hr)			$\pm 5$	ppm FS
	Long-term stability (24 hr)			$\pm 20$	ppm FS
	Noise density [1]				nA/ $\sqrt$ Hz
	high range		1.8		
	low range		1.0		
	Wide band noise [2]				$\mu$ A rms
	high range, high BW			3.2	
	high range, low BW			1.6	
	low range, high BW			1.6	
	low range, low BW			1.1	
	Power fail transient [3]			1	mA
Compliance voltage	Range	0		10	V
	Resolution		10		mV
	Accuracy			+0.2	V
Output current limit	Range, high	0		500	mA
	low	0		250	
	Resolution		10		$\mu$ A
	Accuracy			$\pm 100$	$\mu$ A



		Min	Typ	Max	Units
Analog modulation	Input range	-10		+10	V
	Input impedance		2		k $\Omega$
	Transfer function				
	high range, CC mode		50		mA/V
	low range, CC mode		25		
	CP mode		500		$\mu$ A/V
	Modulation bandwidth (-3 dB)				
	high BW, CC mode	DC		1.2	MHz
	low BW, CC mode	DC		10	kHz
	high BW, CP mode	DC		10	kHz
low BW, CP mode	DC		100	Hz	
Photodiode feedback	Bias voltage	0		5	V
	Photodiode current	0		5000	$\mu$ A
	Setpoint resolution [4]		0.1		$\mu$ A
	Accuracy [4]			$\pm 2$	$\mu$ A
Trigger output	TTL pulse width (negative)		10		$\mu$ s
	Delay [5]	4		$10^6$	ms
Measurement & display	LD current resolution		10		$\mu$ A
	accuracy			$\pm 100$	ppm FS
	PD current resolution		0.1		$\mu$ A
	accuracy			$\pm 200$	ppm FS
	LD voltage resolution		1		mV
	accuracy			$\pm 200$	ppm FS

## Conditions:

- [1] Measured electrically at 1 kHz through a 10  $\Omega$  load.
- [2] Measured electrically with an RMS meter through a 10  $\Omega$  load, from 10 Hz to 1 MHz.
- [3] Output current change, measured with an oscilloscope, upon removing AC power cord.
- [4] In CP control mode.
- [5] Delay programmed by the remote SYND command.

**TEC controller**

		Min	Typ	Max	Units	
Temperature control	Control ranges					
		IC sensors	-55		+150	°C
		Resistance sensors	-150		+250	
		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	°C
		Long term (24 hr)			±0.004	
	Control algorithm		digital <i>PID</i>			
	Autotuning		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	
	Noise and ripple [3]	1 A output			0.1	mA rms
		4 A output			0.2	
	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	kΩ	
	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		°C
Thermistor resolution			0.1		Ω	
Accuracy [4]		±0.1 % +0.05 Ω				
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 LDC501 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
Weight	15 lbs
Dimensions	7" W × 5" H × 15" D



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# 1 Operation

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This chapter gives you the necessary information to get started quickly with the LDC501 Laser Diode Controller.

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## 1.1 Introduction to the Instrument

The LDC501 Laser Diode Controller is a combination precision current source and temperature controller. 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 Peltier thermoelectric cooler (TEC) modules to maintain precision thermal control to the laser over a wide range of control and ambient temperatures. Multiple remote interfaces—GPIB, RS-232, and ethernet—give you complete control of the instrument from your computer.

### 1.1.1 Instrument architecture

The LDC501 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.

#### 1.1.1.1 Laser diode driver

The primary function of the LD driver is providing stable, low-noise electrical current to bias the laser into emission. This is delivered by a low-noise current source circuit. The current source has two range settings, with a maximum current of 250 mA or 500 mA. For both ranges, there are two control modes for the magnitude of the current source output: constant current (CC), and constant optical power (CP).

Operating in CC mode, the LDC501 simply programs the desired current magnitude, in milliamps, for the LD current source to maintain. To operate in CP mode, a monitor photodiode must be available to measure the output intensity of the laser diode. In CP mode, the LDC501 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 modulation. When unused, the

modulation input should be left disconnected.

#### 1.1.1.2 TEC controller

The TEC controller section of the LDC501 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,  $\pm 4.5$  A bipolar current source drives the thermoelectric (TE) module of the laser.

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 thermal sensor as a desired temperature. For characterizing TE modules, a second operating mode—constant current (CC)—allows the user to set the TE current at a constant value. Four wire connections to the TE module allow accurate voltage sensing independent of resistive losses in the current leads, allowing for more accurate device characterization.

### 1.1.2 Grounding

For maximum user flexibility, many sections of the LDC501 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 TE module, with a single ground reference each. For the LD circuit, either the laser cathode or anode may be grounded. Note that many laser packages ground one terminal of the laser to the package case—be careful to understand *all* potential ground paths in your system to avoid inadvertant ground loops.

### 1.1.3 Turning on power

Power to the LDC501 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.

### 1.1.4 Hardware reset

To restore the LDC501 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.

## 1.2 Cable Interfaces

Two separate rear-panel subminiature-D connectors provide the interface from the LDC501 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.

### 1.2.1 Modulate

The front-panel BNC input “Modulate” accepts  $\pm 10$  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  $\mu$ A/V, independent of the instrument current range.

Analog modulation is DC-coupled, with a total bandwidth set by the SIBW command (3 – 20).

### 1.2.2 Sync

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 (3 – 16) for more details.

### 1.2.3 Laser diode

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

Be careful that the connection from the LDC501 to your device preserves the wiring polarity, with pins 4 and 5 connecting to the laser diode *cathode*, and pins 8 and 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.



### 1.2.4 TEC

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 + terminal (current)
3, 4	TEC – terminal (current)
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 –

The power current to the TEC module is through pins 1 and 2, returning 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.

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.

## 1.3 Front-Panel Operation

An overview of the front-panel will help users navigate the instrument.

### 1.3.1 Hard controls

Four principal functions of the LDC501 are controlled by dedicated front-panel keys, and are always accessible independent of menu navigation.

#### 1.3.1.1 Laser on/off

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.

#### 1.3.1.2 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.

#### 1.3.1.3 TEC on/off

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.

#### 1.3.1.4 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.

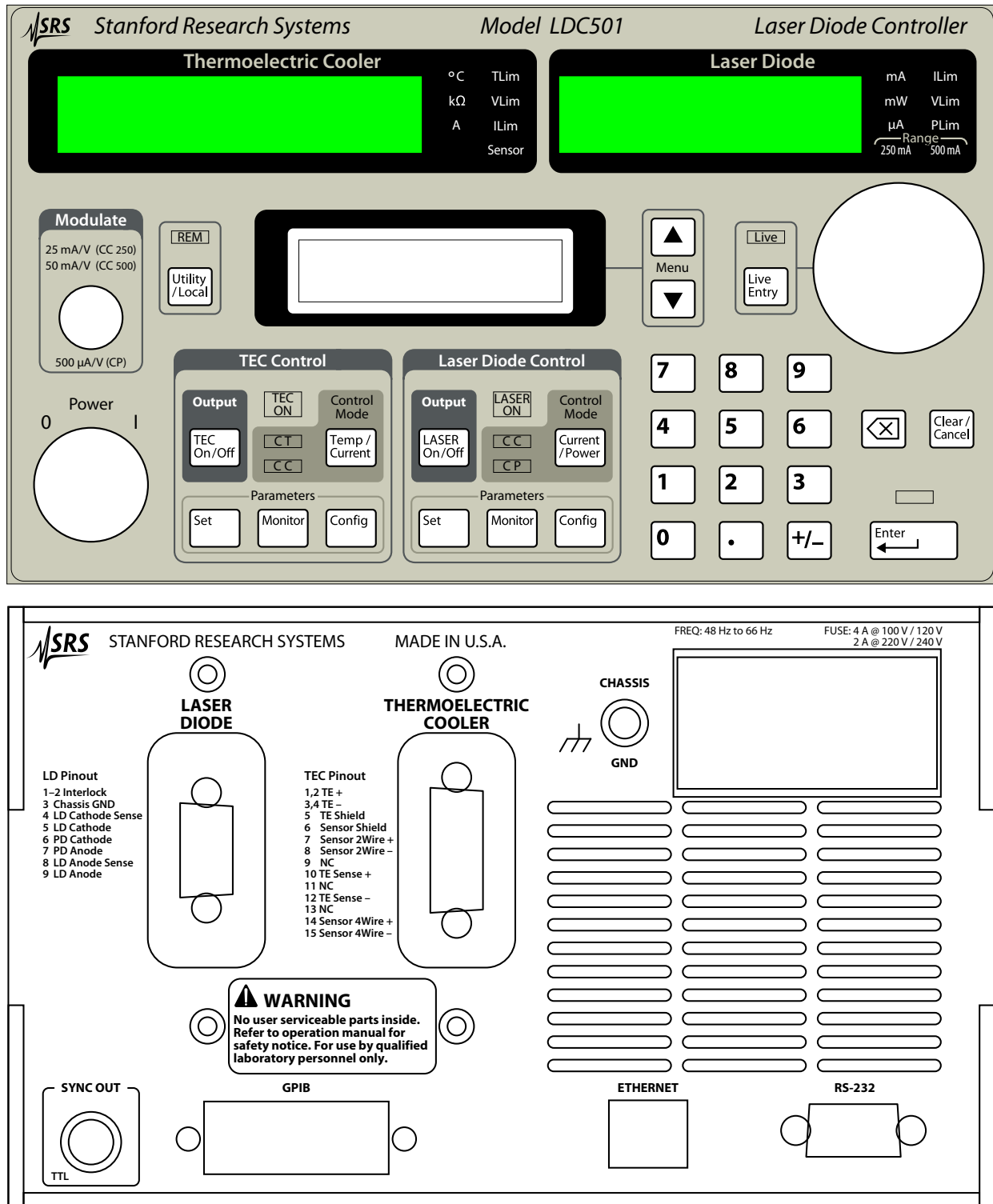


Figure 1.1: The LDC501 front and rear panels.

### 1.3.2 Dedicated displays

The two primary sections of the LDC501, the LD and the TEC, each have a large numeric display dedicated to displaying 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.

### 1.3.3 Alphanumeric display

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.

The LD subsystem has three dedicated menu collections: 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.

A seventh menu collection, Utility, can be selected by pressing the [Utility/Local] button.

#### 1.3.3.1 Menu navigation

Once a menu collection is selected, individual menu selections are navigated by pressing the [A] or [V] 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:  
LD U=      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).

### 1.3.3.2 Numeric entry

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.

### 1.3.3.3 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 “ 3 )”, 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.

### 1.3.3.4 Wheel entry

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.

Parameters with live entry available:

- Laser current setpoint (SILD, 3 – 15 )
- Laser current limit (SILM, 3 – 13 )
- Photodiode current setpoint (SIPD, 3 – 15 )
- Photodiode power setpoint (SWPD, 3 – 16 )
- Photodiode bias (BIAS, 3 – 21 )

- Temperature setpoint (TEMP, 3 – 27 )
- Resistance setpoint (TRTH, 3 – 27 )
- TEC current setpoint (TCUR, 3 – 27 )
- TEC current limit (TILM, 3 – 24 )
- TEC *P* Gain (TPGN, 3 – 31 )
- TEC *I* Gain (TIGN, 3 – 32 )
- TEC *D* Gain (TDGN, 3 – 32 )

## 1.4 Getting Started

This section goes through the steps to configure the LDC501 for operation with a new laser diode. Details on each of the settings are provided later.

### 1.4.1 Laser configuration

Begin with the LDC501 turned on, but both the LD and TEC outputs turned off. Press the Laser [Config] button, and press the [▲] key repeatedly, if necessary, to get to the top of the menu tree. From here, the steps are:

- Set the output current range for the LD driver. Press [0] to select 250 mA, or [1] to select 500 mA. Press [Enter] to accept, and then press [▼] to advance to the next item.
- Choose the laser control mode (CC or CP) by pressing the [Current/Power] button. For this example, we will assume CC.
- If your laser includes a photodiode for optical power monitoring, follow the next two steps:
  - Set the photodiode bias voltage. This reverse bias can be adjusted between 0.0 and 5.0 V. Type your value, and then press [Enter]. Press [▼] to proceed.
  - Set the photodiode responsivity. If you wish to display optical power in mW (rather than photodiode current, in  $\mu\text{A}$ ), enter a non-zero value here, followed by [Enter]. Press [▼] to proceed.
- Select the operating bandwidth. If your application does not require analog modulation above the low-bandwidth cutoff frequency, you will generally obtain lower noise performance leaving the bandwidth on the low setting. Press [0] for low bandwidth, or [1] for high bandwidth, followed by [Enter]. Press [▼] to proceed.
- If you will only operate in CC mode, or CP mode, and do not require “on-the-fly” transfer between control modes, then set “CC/CP lock when on:” to “Y” by pressing [1], followed by [Enter]. Press [▼] to proceed.
- The remaining items under LD config arm various trip-off conditions. Let’s arm the LD to shut down if the maximum temperature is exceeded. Press [▼] 5 more times, to display “Trip-off at Tmax:”. Press [1] followed by [Enter].

### 1.4.2 Laser settings

Now press the Laser [Set] button, and press the [▲] key repeatedly, if necessary, to reach the top of the menu tree. From here, the steps are:

- Press [▼] once to get to “LD Ilim:”. Type in the desired current *limit* for your laser diode, say 150 mA. Press [Enter], and then [▼] twice.
- Enter the maximum voltage for the laser diode, and press [Enter]. Press [▲] repeatedly to return to the “LD I:” menu item.
- Enter the desired operating current for the laser diode, and press [Enter]. Do *not* press [LASER On/Off] yet.

In this example, we armed the Tmax trip-off for the laser. This requires us to configure the TEC section, at least as far as the sensor configuration, prior to turning on the laser.

### 1.4.3 Temperature sensor configuration

Press the TEC [Config] button, and press the [▲] key repeatedly, if necessary, to get to the top of the menu tree.

- Choose the thermal sensor type. Let’s assume our laser diode has an integrated 10 k $\Omega$  NTC thermistor. Press [3] to select “NTC Auto”, followed by [Enter] and [▼].
- Choose the sensor calibration model for the thermistor. If you have Steinhart-Hart coefficients, select [1]; otherwise, for an exponential  $\beta$  model, press [0]. Press [Enter] followed by [▼].
- Enter the sensor model coefficients, pressing [Enter] and [▼] after each one. Stop when you reach the “Autotune” menu.

Now press the TEC [Set] button, and press the [▲] key repeatedly, if necessary, to get to the top of the menu tree. From here:

- Press the [▼] twice, to display “Tmax:”. Enter the maximum operating temperature for the laser, and press [Enter].

### 1.4.4 Operation—no temperature control

At this point, if no temperature stabilization is required, the laser can be turned on by pressing the [Laser On/Off] button. If the laser is to be temperature stabilized, the TEC should be configured and turned on prior to operating the laser.



### 1.4.5 TEC settings

To configure the TEC, we will begin by assuming the temperature sensor was already configured as above. Begin here by pressing the TEC [Set] button, and press the [▲] key repeatedly, if necessary, to get to the top of the menu tree.

- Enter the desired operating temperature, and press [Enter]. Press [▼].
- Enter the maximum operating current for the TEC module, and press [Enter]. Press [▼].
- We previously set the maximum temperature, so press [▼] to advance to “Tmin:” Set the minimum operating temperature (be sure to set this above the dew-point for your operating environment). Press [Enter], and then [▼] again.
- Enter the maximum safe operating voltage for the TEC module. Press [Enter].
- Place the TEC Control system into CT mode by pressing the [Temp/Current] button until the *CT* indicator is lit.

### 1.4.6 TEC operation and tuning

The TEC is nearly ready for operation. Before attempting to operate in temperature control mode, we should allow the LDC501 to autotune its loop parameters.

- With the TEC still OFF, select the TEC [Config] menu, and navigate with [▲] and [▼] to the “Autotune” item.
- Press the [Enter] button to begin autotuning. The TEC module will temporarily turn on, and the thermal step response measured to estimate loop gain and time constants.
- If you need to cancel autotuning, you can press the [Clear/Cancel] button; otherwise, wait until the display indicates that autotuning has completed.

Now the TEC can be turned on. Press the [TEC On/Off] button; the *TEC ON* indicator should illuminate.

Once the temperature has stabilized at the desired operating point, the system may benefit from re-tuning (as the system loop gain can be a strong function of operating temperature for TEC modules). If desired, repeat the autotuning cycle with the TEC already on and settled at the temperature setpoint.

### 1.4.7 Operation—with temperature control

Finally, with the laser module operating under temperature control, you can turn on the laser by pressing [LASER On/Off]. After a 3 s safety delay, the laser will turn on.

### 1.4.8 Thermal runaway

Generally, 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 LDC501 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 LDC501 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 LDC501 will turn off the TEC controller and report a “thermal runaway” fault.

---

## 2 Menus

---

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

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## 2.1 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, 3 – 15).

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

## 2.2 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.

### 2.2.1 LD settings

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

#### 2.2.1.1 Laser current setpoint

```
LD Settings:
LD I:      500.00mA
```

(SILD, 3 – 15)  
Only visible in CC mode.

#### 2.2.1.2 Photodiode current setpoint

```
LD Settings:
PD I:      123.4µA
```

(SIPD, 3 – 15)  
Only visible in CP mode, with RESP = 0

#### 2.2.1.3 Photodiode power setpoint

```
LD Settings:
PD P:      23.10mW
```

(SWPD, 3 – 16)  
Only visible in CP mode, with RESP ≠ 0.

#### 2.2.1.4 Laser current limit

```
LD Settings:
LD Ilim:   123.0mA
```

(SILM, 3 – 13)

## 2.2.1.5 Photodiode current limit

```
LD Settings:
PD Ilin: 5000µA (PILM, 3-14)
```

Only visible with RESP= 0.

## 2.2.1.6 Photodiode power limit

```
LD Settings:
PD Plin: 500mW (PWLM, 3-14)
```

Only visible with RESP≠ 0.

## 2.2.1.7 Laser voltage limit

```
LD Settings:
LD Vlim: 5.25V (SVLM, 3-13)
```

## 2.2.2 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.

## 2.2.2.1 Laser operating current

```
LD Monitor:
LD I= 100.03mA (RILD?, 3-17)
```

## 2.2.2.2 Laser operating voltage

```
LD Monitor:
LD V= 1.302V (RVLD?, 3-18)
```

## 2.2.2.3 Photodiode current

```
LD Monitor:
PD I= 2003.0µA (RIPD?, 3-18)
```

## 2.2.2.4 Photodiode power

```
LD Monitor:
PD P= 307.00mW (RWPD?, 3-18)
```

Only visible with RESP≠ 0.

## 2.2.2.5 Interlock

```
LD Monitor:
Interlock=Closed (ILOCF, 3-19)
```

## 2.2.3 LD configuration

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

## 2.2.3.1 Output range

```
LD Config:
IRange: *1>500mA (RNGE, 3-19)
```

## 2.2.3.2 Photodiode bias

```
LD Config:
PD Bias: 2.5V (BIAS, 3-21)
```

## 2.2.3.3 Photodiode responsivity

```
LD Cfg: PD resp
1.000uA/nW (RESP, 3-21)
```

## 2.2.3.4 Modulation bandwidth

```
LD Config: CC BW
*1>high 1.1MHz (SIBW, 3-20)
```

## 2.2.3.5 Control mode locking

```
LD Config: CC/CP
lock when on: *N (SMLK, 3-21)
```

## 2.2.3.6 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, 3-22)
```

- ```
LD Cfg: Trip-OFF
at CP PLim: *N (APLP, 3-22)
```

- ```
LD Cfg: Trip-OFF
at CC PLim: *N (APLC, 3-22)
```

- |                                   |
|-----------------------------------|
| LD Cfg: Trip-OFF<br>at TE Off: *Y |
|-----------------------------------|

 (ATOF, 3-23)

- |                                 |
|---------------------------------|
| LD Cfg: Trip-OFF<br>at Tmax: *Y |
|---------------------------------|

 (ATMX, 3-23)

- |                                 |
|---------------------------------|
| LD Cfg: Trip-OFF<br>at Tmin: *N |
|---------------------------------|

 (ATMN, 3-24)

## 2.3 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.

### 2.3.1 TEC settings

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

#### 2.3.1.1 Temperature setpoint

|                              |
|------------------------------|
| TEC Settings:<br>T: 22.000°C |
|------------------------------|

 (TEMP, 3-27)

Only displayed in CT mode.

#### 2.3.1.2 Resistance setpoint

|                              |
|------------------------------|
| TEC Settings:<br>R: 10.000kΩ |
|------------------------------|

 (TRTH, 3-27)

Only displayed in CT mode, without a sensor model.

#### 2.3.1.3 TEC current setpoint

|                               |
|-------------------------------|
| TEC Settings:<br>TE I: 1.234A |
|-------------------------------|

 (TCUR, 3-27)

Only displayed in TEC CC mode.

#### 2.3.1.4 TEC current limit

|                                  |
|----------------------------------|
| TEC Settings:<br>TE Ilim: 3.000A |
|----------------------------------|

 (TILM, 3-24)

## 2.3.1.5 Maximum temperature

```
TEC Settings:
Tmax:      65.000°C (TMAX, 3-25)
```

## 2.3.1.6 Minimum temperature

```
TEC Settings:
Tmin:      7.500°C (TMIN, 3-25)
```

## 2.3.1.7 Maximum resistance

```
TEC Settings:
Rmax:     12.500kΩ (TRMX, 3-26)
```

Only displayed without a sensor model.

## 2.3.1.8 Minimum resistance

```
TEC Settings:
Rmin:     9.500kΩ (TRMN, 3-26)
```

Only displayed without a sensor model.

## 2.3.1.9 TEC voltage limit

```
TEC Settings:
TE Vlin:   8.500V (TVLM, 3-25)
```

## 2.3.2 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.

## 2.3.2.1 TEC current

```
TEC Monitor:
Ite=      -1.999A (TIRD?, 3-28)
```

## 2.3.2.2 TEC voltage

```
TEC Monitor:
Ute=      1.609V (TVRD?, 3-28)
```



## 2.3.2.3 Temperature reading

```
TEC Monitor:
T=          22.8910°C (TTRD?, 3-28)
```

## 2.3.2.4 Raw thermometer reading

```
TEC Monitor:
R=          10.967kΩ (TRAW?, 3-28)
```

## 2.3.3 TEC configuration

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

## 2.3.3.1 Thermometer sensor type

```
TE Cfg: Sensor
*3) NTC auto (TSNR, 3-32)
```

## 2.3.3.2 Sensor models

```
TE Cfg: Model
*0) NTC β, R(t), t (TMDN, 3-33)
```

For NTC thermistors

```
TE Cfg: Model
*0) RTD R/R0=1+αT (TMDR, 3-33)
```

For RTDs

2.3.3.3 Model parameters for NTC  $\beta$ 

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

```
TE Cfg: Param
β:          3800.000°C (TNTB, 3-34)
```

```
TE Cfg: Param
R(T0):      10.000kΩ (TNTR, 3-34)
```

```
TE Cfg: Param
T0:         25.00°C (TNTT, 3-35)
```

### 2.3.3.4 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  $3.14 \times 10^{-4}$  for the A coefficient, you would type "0.31400E-3".

- |                 |
|-----------------|
| TE Cfg: Param   |
| SHa: 1.12500E-3 |

 (TSHA, 3-34)

- |                 |
|-----------------|
| TE Cfg: Param   |
| SHb: 2.34700E-4 |

 (TSHB, 3-34)

- |                 |
|-----------------|
| TE Cfg: Param   |
| SHc: 0.85500E-7 |

 (TSHC, 3-34)

### 2.3.3.5 Model parameters for RTD $\alpha$

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

- |                                                   |
|---------------------------------------------------|
| TE Cfg: Param                                     |
| $\alpha$ : 0.00385 $\Omega/\Omega/^\circ\text{C}$ |

 (TRTA, 3-35)

- |                                          |
|------------------------------------------|
| TE Cfg: Param                            |
| $R_0(0^\circ\text{C})$ 0.10000k $\Omega$ |

 (TRTR, 3-35)

### 2.3.3.6 Autotuning

- |                  |
|------------------|
| TE Cfg: autotune |
| <Enter> * start  |

 (TUNE, 3-30)

### 2.3.3.7 PID parameters

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

- |                             |
|-----------------------------|
| TE Cfg: PIDvals             |
| P: -1.24A/ $^\circ\text{C}$ |

 (TPGN, 3-31)

- |                 |
|-----------------|
| TE Cfg: PIDvals |
| I: 0.36/s       |

 (TIGN, 3-32)

- |                 |
|-----------------|
| TE Cfg: PIDvals |
| D: 0.65s        |

 (TDGN, 3-32)

## 2.3.3.8 Control mode locking

```
TE Cfg: CC/CT
lock when on: *N (TMLK, 3-30)
```

## 2.3.3.9 TEC trip-off configuration

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

- ```
TE Cfg: Trip-OFF
at TE Ilim: *N (TTIL, 3-38)
```

- ```
TE Cfg: Trip-OFF
at TE Ulim: *Y (TTVL, 3-37)
```

- ```
TE Cfg: Trip-OFF
at Tmax: *Y (TTMX, 3-37)
```

- ```
TE Cfg: Trip-OFF
at Tmin: *Y (TTMN, 3-37)
```

- ```
TE Cfg: Trip-OFF
at SensFault: *Y (TTSF, 3-36)
```

## 2.4 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.

## 2.4.1 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.

## 2.4.1.1 Save parameters

```
Util: Save Cfg
Overwrite:  Usr3 (SPAR, 3-40)
```

## 2.4.1.2 Restore parameters

```
Util: Recall Cfg
Read from:  Usr2 (GPAR, 3-40)
```

### 2.4.1.3 IP address

The four bytes of the IP address, netmask, and default gateway are each configured with successive menu items (12 in all).

```

Util: IP Address
segment 0: 172 (IPAD, 3 – 41)
  
```

```

Util: IP Netmask
segment 0: 255 (NMSK, 3 – 41)
  
```

```

Util: Gateway
segment 0: 172 (GWAY, 3 – 42)
  
```

### 2.4.1.4 GPIB address

```

Util: GPIB
Address: 2
  
```

### 2.4.1.5 Baud rate

```

Util: RS-232
Baud: *7) 57600 (BAUD, 3 – 41)
  
```

### 2.4.1.6 Display brightness

```

Util: Brightness
Level: *3) 50.0% (BLVL, 3 – 41)
  
```

### 2.4.1.7 Ethernet MAC address

```

Util: MACaddress
0019:b303:ffff (MACA?, 3 – 42)
  
```

## 2.4.2 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.

---

## 3 Remote Operation

---

This chapter describes operating the LDC501 over the remote interfaces.

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### 3.1 Index of Common Commands

Symbol	Definition
$f, g$	Floating-point value
$i, j$	Unsigned integer
$z$	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(?) { $f$ }	3 – 13 Laser Diode Voltage Limit
SILM(?) { $f$ }	3 – 13 Laser Diode Current Limit
PILM(?) { $f$ }	3 – 14 Photodiode Current Limit
PWLM(?) { $f$ }	3 – 14 Photodiode Power Limit

---

#### Laser settings

LDON(?) { $z$ }	3 – 15 Laser Diode Current On/Off
SILD(?) { $f$ }	3 – 15 Laser Diode Current Setpoint
SIPD(?) { $f$ }	3 – 15 Photodiode Current Setpoint
SWPD(?) { $f$ }	3 – 16 Photodiode Power Setpoint
SCAN(?) { $f, i, g$ }	3 – 16 Multi-step Scan of Laser Setpoint
SYND(?) { $g$ }	3 – 17 Sync delay for scans

---

#### Laser monitor

RILD?	3 – 17 Laser Diode Current Reading
RVLD?	3 – 18 Laser Diode Voltage Reading
RIPD?	3 – 18 Photodiode Current Reading
RWPD?	3 – 18 Photodiode Power Reading
ILOC?	3 – 19 Interlock

---

#### Laser configuration

RNGE(?) { $z$ }	3 – 19 Laser Diode Current Range
SMOD(?) { $z$ }	3 – 19 Laser Control Mode
SIBW(?) { $z$ }	3 – 20 Laser Modulation Bandwidth
BIAS(?) { $f$ }	3 – 21 Photodiode Bias Voltage
RESP(?) { $f$ }	3 – 21 Photodiode Responsivity
SMLK(?) { $z$ }	3 – 21 Lock Laser Control Mode When On

---

#### Laser trip-off

AILM(?) { $z$ }	3 – 22 Laser Trip-off on Current Limit
APLP(?) { $z$ }	3 – 22 Laser Trip-off on Photodiode (CP)

---

APLC(?) {z}	3-22 Laser Trip-off on Photodiode (CC)
ATOF(?) {z}	3-23 Laser Trip-off on TEC Off
ATMX(?) {z}	3-23 Laser Trip-off on Max Temperature
ATMN(?) {z}	3-24 Laser Trip-off on Min Temperature

---

**TEC limits**

TILM(?) {f}	3-24 TEC Current Limit
TVLM(?) {f}	3-25 TEC Voltage Limit
TMIN(?) {f}	3-25 Lower Temperature Limit
TMAX(?) {f}	3-25 Upper Temperature Limit
TRMN(?) {f}	3-26 Lower Resistance Limit
TRMX(?) {f}	3-26 Upper Resistance Limit

---

**TEC settings**

TEON(?) {z}	3-27 TEC Current On/Off
TCUR(?) {f}	3-27 TEC Current Setpoint
TEMP(?) {f}	3-27 TEC Temperature Setpoint
TRTH(?) {f}	3-27 TEC Resistance Setpoint

---

**TEC monitor**

TIRD?	3-28 TEC Current Reading
TVRD?	3-28 TEC Voltage Reading
TRAW?	3-28 Raw Thermometer Reading
TTRD?	3-28 Celsius Thermometer Reading
TSNS?	3-29 Temperature Sensor Status

---

**TEC configuration**

TMOD(?) {z}	3-29 TEC Control Mode
TIEX(?) {z}	3-30 Thermometer Excitation Current
TMLK(?) {z}	3-30 Lock TEC Control Mode When On
TUNE(?) {z}	3-30 TEC Autotune
TPGN(?) {f}	3-31 TEC Control Loop <i>P</i> Gain
TIGN(?) {f}	3-32 TEC Control Loop <i>I</i> Gain
TDGN(?) {f}	3-32 TEC Control Loop <i>D</i> Gain
TSNR(?) {z}	3-32 Thermometer Type

---

**TEC sensor**

TMDN(?) {z}	3-33 NTC Calibration Model
TMDR(?) {z}	3-33 RTD Calibration Model
TSHA(?) {f}	3-34 Steinhart-Hart Coefficient <i>A</i>
TSHB(?) {f}	3-34 Steinhart-Hart Coefficient <i>B</i>
TSHC(?) {f}	3-34 Steinhart-Hart Coefficient <i>C</i>
TNTR(?) {f}	3-34 NTC $\beta$ -model $R_0$ Parameter
TNTB(?) {f}	3-34 NTC $\beta$ -model $\beta$ Parameter
TNTT(?) {f}	3-35 NTC $\beta$ -model $T_0$ Parameter

---

---

TRTR(?) {f}	3 – 35 RTD Linear Model $R_0$ Parameter
TRTA(?) {f}	3 – 35 RTD Linear Model $\alpha$ Parameter
TLMS(?) {f}	3 – 35 LM335 Slope Parameter
TLMY(?) {f}	3 – 36 LM335 Offset Parameter
TADS(?) {f}	3 – 36 AD590 Slope Parameter
TADY(?) {f}	3 – 36 AD590 Offset Parameter

---

**TEC trip-off**

TTSF(?) {z}	3 – 36 TEC Trip-off on Thermometer Fault
TTMX(?) {z}	3 – 37 TEC Trip-off on Max Temperature
TTMN(?) {z}	3 – 37 TEC Trip-off on Min Temperature
TTVL(?) {z}	3 – 37 TEC Trip-off on Voltage Limit
TTIL(?) {z}	3 – 38 TEC Trip-off on Current Limit

---

**Interface**

*IDN?	3 – 38 Identify
TOKN(?) {z}	3 – 38 Token Mode
TERM(?) {z}	3 – 39 Response Termination
*OPC(?)	3 – 39 Operation Complete
ULOC(?) {i}	3 – 39 Unlock Ethernet
SPAR {z}	3 – 40 Save User Parameters
GPAR {z}	3 – 40 Restore User Parameters
LOCK(?) {z}	3 – 40 Local Lockout
BLVL(?) {z}	3 – 41 Display Brightness Level
BAUD(?) {z}	3 – 41 Serial Baud Rate
IPAD(?) i {, j}	3 – 41 IP Address
NMSK(?) i {, j}	3 – 41 Netmask
GWAY(?) i {, j}	3 – 42 Default Gateway
MACA?	3 – 42 Ethernet hardware address
*RST	3 – 42 Reset

---

**Status**

*STB? [i]	3 – 43 Status Byte
*SRE(?) [i, j]	3 – 43 Service Request Enable
*ESR? [i]	3 – 43 Standard Event Status
*ESE(?) [i, j]	3 – 44 Standard Event Status Enable
*CLS	3 – 44 Clear Status
LEXE?	3 – 44 Last Execution Error
LCME?	3 – 45 Last Command Error
LDCR? [i]	3 – 45 Laser Diode Condition
LDPT(?) [i, j]	3 – 45 Laser Diode Positive-Transition
LDNT(?) [i, j]	3 – 45 Laser Diode Negative-Transition
LDEV? [i]	3 – 46 Laser Diode Event
LDEN(?) [i, j]	3 – 46 Laser Diode Event Enable
TECR? [i]	3 – 46 TEC Condition

---



---

TEPT(?) [i] {j}	3-46	TEC Positive-Transition
TENT(?) [i] {j}	3-46	TEC Negative-Transition
TEEV? [i]	3-46	TEC Event
TEEN(?) [i] {j}	3-47	TEC Event Enable

## 3.2 Alphabetic List of Commands

---

### ★

*CLS	3 – 44 Clear Status
*ESE(?) [i,] {j}	3 – 44 Standard Event Status Enable
*ESR? [i]	3 – 43 Standard Event Status
*IDN?	3 – 38 Identify
*OPC(?)	3 – 39 Operation Complete
*RST	3 – 42 Reset
*SRE(?) [i,] {j}	3 – 43 Service Request Enable
*STB? [i]	3 – 43 Status Byte

---

### A

AILM(?) {z}	3 – 22 Laser Trip-off on Current Limit
APLC(?) {z}	3 – 22 Laser Trip-off on Photodiode (CC)
APLP(?) {z}	3 – 22 Laser Trip-off on Photodiode (CP)
ATMN(?) {z}	3 – 24 Laser Trip-off on Min Temperature
ATMX(?) {z}	3 – 23 Laser Trip-off on Max Temperature
ATOF(?) {z}	3 – 23 Laser Trip-off on TEC Off

---

### B

BAUD(?) {z}	3 – 41 Serial Baud Rate
BIAS(?) {f}	3 – 21 Photodiode Bias Voltage
BLVL(?) {z}	3 – 41 Display Brightness Level

---

### G

GPAR {z}	3 – 40 Restore User Parameters
GWAY(?) i {, j}	3 – 42 Default Gateway

---

### I

ILOC?	3 – 19 Interlock
IPAD(?) i {, j}	3 – 41 IP Address

---

### L

LCME?	3 – 45 Last Command Error
LDCR? [i]	3 – 45 Laser Diode Condition
LDEN(?) [i,] {j}	3 – 46 Laser Diode Event Enable
LDEV? [i]	3 – 46 Laser Diode Event
LDNT(?) [i,] {j}	3 – 45 Laser Diode Negative-Transition
LDON(?) {z}	3 – 15 Laser Diode Current On/Off
LDPT(?) [i,] {j}	3 – 45 Laser Diode Positive-Transition
LEXE?	3 – 44 Last Execution Error
LOCK(?) {z}	3 – 40 Local Lockout

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<b>M</b>	
MACA?	3 – 42 Ethernet hardware address
<b>N</b>	
NMSK(?) <i>i</i> { <i>j</i> }	3 – 41 Netmask
<b>P</b>	
PILM(?) { <i>f</i> }	3 – 14 Photodiode Current Limit
PWLM(?) { <i>f</i> }	3 – 14 Photodiode Power Limit
<b>R</b>	
RESP(?) { <i>f</i> }	3 – 21 Photodiode Responsivity
RILD?	3 – 17 Laser Diode Current Reading
RIPD?	3 – 18 Photodiode Current Reading
RNGE(?) { <i>z</i> }	3 – 19 Laser Diode Current Range
RVLD?	3 – 18 Laser Diode Voltage Reading
RWPD?	3 – 18 Photodiode Power Reading
<b>S</b>	
SCAN(?) { <i>f, i, g</i> }	3 – 16 Multi-step Scan of Laser Setpoint
SIBW(?) { <i>z</i> }	3 – 20 Laser Modulation Bandwidth
SILD(?) { <i>f</i> }	3 – 15 Laser Diode Current Setpoint
SILM(?) { <i>f</i> }	3 – 13 Laser Diode Current Limit
SIPD(?) { <i>f</i> }	3 – 15 Photodiode Current Setpoint
SMLK(?) { <i>z</i> }	3 – 21 Lock Laser Control Mode When On
SMOD(?) { <i>z</i> }	3 – 19 Laser Control Mode
SPAR { <i>z</i> }	3 – 40 Save User Parameters
SVLM(?) { <i>f</i> }	3 – 13 Laser Diode Voltage Limit
SWPD(?) { <i>f</i> }	3 – 16 Photodiode Power Setpoint
SYND(?) { <i>g</i> }	3 – 17 Sync delay for scans
<b>T</b>	
TADS(?) { <i>f</i> }	3 – 36 AD590 Slope Parameter
TADY(?) { <i>f</i> }	3 – 36 AD590 Offset Parameter
TCUR(?) { <i>f</i> }	3 – 27 TEC Current Setpoint
TDGN(?) { <i>f</i> }	3 – 32 TEC Control Loop <i>D</i> Gain
TECR? [ <i>i</i> ]	3 – 46 TEC Condition
TEEN(?) [ <i>i, j</i> ]	3 – 47 TEC Event Enable
TEEV? [ <i>i</i> ]	3 – 46 TEC Event
TEMP(?) { <i>f</i> }	3 – 27 TEC Temperature Setpoint
TENT(?) [ <i>i, j</i> ]	3 – 46 TEC Negative-Transition
TEON(?) { <i>z</i> }	3 – 27 TEC Current On/Off
TEPT(?) [ <i>i, j</i> ]	3 – 46 TEC Positive-Transition

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TERM(?) {z}	3 – 39 Response Termination
TIEX(?) {z}	3 – 30 Thermometer Excitation Current
TIGN(?) {f}	3 – 32 TEC Control Loop <i>I</i> Gain
TILM(?) {f}	3 – 24 TEC Current Limit
TIRD?	3 – 28 TEC Current Reading
TLMS(?) {f}	3 – 35 LM335 Slope Parameter
TLMY(?) {f}	3 – 36 LM335 Offset Parameter
TMAX(?) {f}	3 – 25 Upper Temperature Limit
TMDN(?) {z}	3 – 33 NTC Calibration Model
TMDR(?) {z}	3 – 33 RTD Calibration Model
TMIN(?) {f}	3 – 25 Lower Temperature Limit
TMLK(?) {z}	3 – 30 Lock TEC Control Mode When On
TMOD(?) {z}	3 – 29 TEC Control Mode
TNTB(?) {f}	3 – 34 NTC $\beta$ -model $\beta$ Parameter
TNTR(?) {f}	3 – 34 NTC $\beta$ -model $R_0$ Parameter
TNTT(?) {f}	3 – 35 NTC $\beta$ -model $T_0$ Parameter
TOKN(?) {z}	3 – 38 Token Mode
TPGN(?) {f}	3 – 31 TEC Control Loop <i>P</i> Gain
TRAW?	3 – 28 Raw Thermometer Reading
TRMN(?) {f}	3 – 26 Lower Resistance Limit
TRMX(?) {f}	3 – 26 Upper Resistance Limit
TRTA(?) {f}	3 – 35 RTD Linear Model $\alpha$ Parameter
TRTH(?) {f}	3 – 27 TEC Resistance Setpoint
TRTR(?) {f}	3 – 35 RTD Linear Model $R_0$ Parameter
TSHA(?) {f}	3 – 34 Steinhart-Hart Coefficient <i>A</i>
TSHB(?) {f}	3 – 34 Steinhart-Hart Coefficient <i>B</i>
TSHC(?) {f}	3 – 34 Steinhart-Hart Coefficient <i>C</i>
TSNR(?) {z}	3 – 32 Thermometer Type
TSNS?	3 – 29 Temperature Sensor Status
TTIL(?) {z}	3 – 38 TEC Trip-off on Current Limit
TTMN(?) {z}	3 – 37 TEC Trip-off on Min Temperature
TTMX(?) {z}	3 – 37 TEC Trip-off on Max Temperature
TTRD?	3 – 28 Celsius Thermometer Reading
TTSF(?) {z}	3 – 36 TEC Trip-off on Thermometer Fault
TTVL(?) {z}	3 – 37 TEC Trip-off on Voltage Limit
TUNE(?) {z}	3 – 30 TEC Autotune
TVLM(?) {f}	3 – 25 TEC Voltage Limit
TVRD?	3 – 28 TEC Voltage Reading

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## U

ULOC(?) {i}	3 – 39 Unlock Ethernet
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### 3.3 Introduction

Remote operation of the LDC501 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.

#### 3.3.1 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.

#### 3.3.2 Buffers

The LDC501 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 LDC501 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.

### 3.4 Ethernet

To connect to the LDC501 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 3 – 39 ). Next, the \*IDN? query should be sent. The LDC501 should reply with the response string described on page 3 – 38 .

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 LDC501 over GPIB, RS-232, or the ethernet port.

## 3.5 Commands

This section provides syntax and operational descriptions for remote commands.

### 3.5.1 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.

### 3.5.2 Notation

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

Symbol	Definition
<i>f, g</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

### 3.5.3 Examples

Each command is provided with a simple example illustrating its usage. In these examples, all data sent by the host computer to the LDC501 are set as *straight teletype font*, while responses received by the host computer from the LDC501 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.



### 3.5.4 Laser limit commands

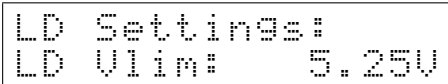
SVLM(?) {f}

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.

Front panel: 

Example: SVLM 5.25

SILM(?) {f}

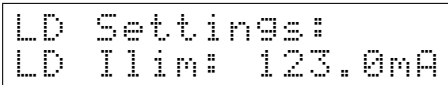
Laser Diode Current Limit

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 and the SILM value is greater than 250 mA, SILM will be lowered to 250.

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.

Front panel: 

Example: SILM 123;SILM?  
123.000

---

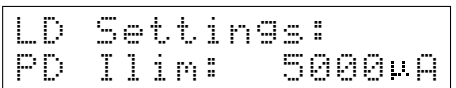
**PILM(?) {f}****Photodiode Current Limit**

Set (query) the monitor photodiode current limit {to *f*}, in  $\mu\text{A}$ .

The photodiode is used to control the laser output in CP control mode. When the photodiode responsivity value, *RESP*, is zero, this control is programmed in microamps of photodiode current. When in this raw photodiode current mode, the *PILM* value limits the operating setpoint *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. Issuing the *PILM* command when *RESP* is non-zero will cause an execution error.

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: 

*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 the photodiode responsivity value, *RESP*, is non-zero, this control is programmed in milliwatts of optical power (as measured by the photodiode). 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. Issuing the *PWLM* command when *RESP* is zero will cause an execution error.

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: 

*Example:* PWLM500.0

### 3.5.5 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.

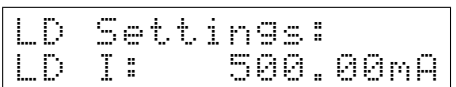
*Example:* LDON ON

---

**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.

Front panel: 

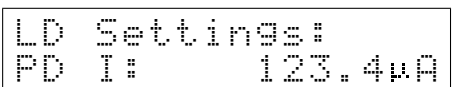
*Example:* SILD?  
500.000

---

**SIPD(?) {f}** Photodiode Current Setpoint

Set (query) the monitor photodiode current setpoint {to f}, in  $\mu$ A.

When the laser is operating in CP mode, and the photodiode responsivity is zero, the laser current is controlled to maintain a constant photodiode current at the level set by SIPD.

Front panel: 


*Example:* 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 the photodiode responsivity is non-zero, the laser current is controlled to maintain a constant optical power, as measured by the photodiode, at the level set by SWPD.

Front panel: 

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 either an optical power step (in mW) or photodiode current (in  $\mu\text{A}$ ), depending on whether RESP= 0 or RESP $\neq$  0. 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  $S + i \cdot f > S_{\text{max}}$  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  $g_{\text{sync}}$ , which is set by the SYND command. Note that the total time between setpoint steps is simply *g*.

Following a time  $g_{\text{sync}}$  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(?) {g}

Sync delay for scans

Set (query) the sync-pulse delay for multi-step scans {to f}, in ms.

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 LDC501 generates the output sync pulse (on the rear-panel “SYNC OUT” connector). The minimum setting is SYND 4.

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

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

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

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

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

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

*Example:* SYND 18

### 3.5.6 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:
LD I=      100.03mA.
```

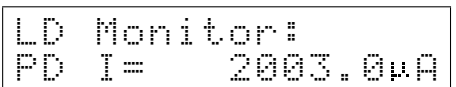
*Example:* RILD?  
100.0309

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

Front panel: 

*Example:* RVLD?  
1.302183

**RIPD?** Photodiode Current Reading  
Query the monitor photodiode current reading, in  $\mu\text{A}$ .  
RIPD? always returns the measured photodiode current, in  $\mu\text{A}$ , regardless of control mode (CC or CP), optical power units (responsivity zero or non-zero), or even laser current source on/off.

Front panel: 

*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, as long as a non-zero value for responsivity has been set. If the responsivity is set to zero, RWPD? generates an execution error.

Front panel: 

*Example:* RWPD?  
307.001

---

ILOC?	<p>Interlock</p> <p>Query the state of the external laser interlock.</p> <p>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.</p>
Front panel:	<pre>LD Monitor: Interlock=Closed.</pre>
<i>Example:</i>	<pre>ILOC? CLOSED</pre>

### 3.5.7 Laser configuration commands

---

RNGE(?) {z}	<p>Laser Diode Current Range</p> <p>Set (query) the laser diode current source range {to z=(LOW 0, HIGH 1)}.</p> <p>The controller has two operating ranges for the laser diode current source. Setting RNGE LOW sets the maximum output current to 250 mA, while RNGE HIGH sets it to 500 mA. The RNGE command cannot be executed while the laser is on.</p>
Front panel:	<pre>LD Config: IRange: *1)500mA.</pre>
<i>Example:</i>	<pre>RNGE HIGH</pre>

---

SMOD(?) {z}	<p>Laser Control Mode</p> <p>Set (query) the laser diode control mode {to z=(CC 0, CP 1)}.</p> <p>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.</p> <p>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</p>
-------------	--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

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	10 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 LDC501 should be left set to SIBW LOW.

Front panel: LD Config: CC BW  
\*1)high 1.1MHz.

*Example:* SIBW?  
HIGH



---

**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.

Front panel: 

*Example:* BIAS 2.5

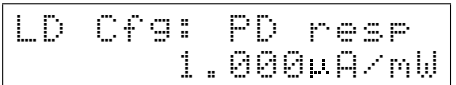
---

**RESP(?) {f}** Photodiode Responsivity

Set (query) the monitor photodiode responsivity {to f}, in  $\mu\text{A}/\text{mW}$ .

The responsivity determines the conversion from photodiode current (in  $\mu\text{A}$ ) to optical power (in mW). Setting RESP to a non-zero value causes the controller to switch to power units when operating in CP mode; a zero value leads to  $\mu\text{A}$  units.

Note that the responsivity cannot be changed while the laser is on and in CP control mode. Also, changing the value of RESP from zero to non-zero, or from non-zero to zero, will cause the photodiode limits PILM and PWLM to reset to zero.

Front panel: 

*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 LDC501 will prevent the SMOD command from operating if the laser is on. The front-panel [CC/CP] key is similarly inhibited.

Front panel: 

*Example:* SMLK?  
NO

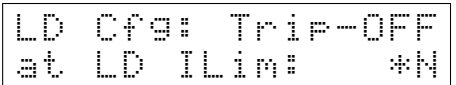
### 3.5.8 Laser trip-off commands

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 LDC501 to automatically turn off the laser current if the laser current reaches the limit current, set AILM YES.

Front panel: 

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 whether RESP is zero or non-zero, 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.

Front panel: 

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 whether RESP is zero or non-zero, but only for CC control mode. If the measured photodiode current (or optical power) exceeds the corresponding 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.

Front panel: 

LD Cfg: Trip-OFF
at CC PLin: *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 LDC501 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.

Front panel: 

LD Cfg: Trip-OFF
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 LDC501 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 LDC501 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.

Front panel: 

LD Cfg: Trip-OFF
at Tmax: *Y

.

*Example:* ATMX YES

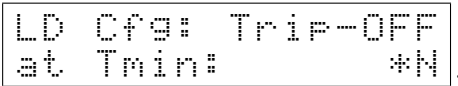
ATMN(?) {z}

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 LDC501 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 LDC501 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: . The screenshot shows a monospaced font display with two lines: 'LD Cfg: Trip-OFF' and 'at Tmin: \*N'.

*Example:* ATMN NO

### 3.5.9 TEC limit commands

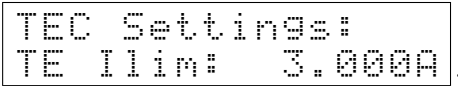
TILM(?) {f}

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: . The screenshot shows a monospaced font display with two lines: 'TEC Settings:' and 'TE Ilin: 3.0000A'.

*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  $\pm 8.5$  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 LDC501.

Front panel: 

*Example:* TVLM?  
8.500000E+00

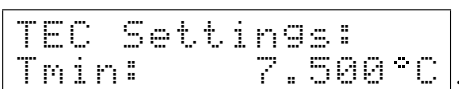
---

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

Set (query) the lower temperature limit {to f}, in °C.

The LDC501 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: 

*Example:* TMIN 7.5

---

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

Set (query) the upper temperature limit {to f}, in °C.

The LDC501 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: . The display shows 'TEC Settings:' on the first line and 'Tmax: 65.000°C' on the second line.

*Example:* TMAX 65.0


### TRMN(?) {f}

#### Lower Resistance Limit

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

When the LDC501 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 TTMN 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: . The display shows 'TEC Settings:' on the first line and 'Rmin: 9.500kΩ' on the second line.

*Example:* TRMN 9.50

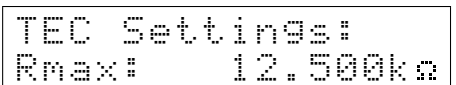
### TRMX(?) {f}

#### Upper Resistance Limit

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

When the LDC501 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 TTMX 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: . The display shows 'TEC Settings:' on the first line and 'Rmax: 12.500kΩ' on the second line.

*Example:* TRMX 12.50

## 3.5.10 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.

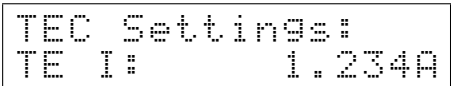
*Example:* TEON?  
 ON

---

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, *not* 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: .


*Example:* 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, *not* the measured operating temperature.

Front panel: .


*Example:* 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, *and* 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: .

*Example:* TRTH 10.000

---

### 3.5.11 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).

Front panel: 

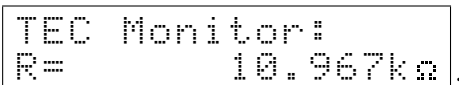
*Example:* TIRD?  
 -1.999976E+00

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

Front panel: 

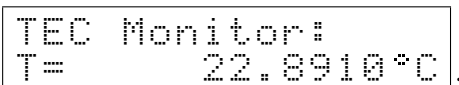
*Example:* TVRD?  
 1.608900E+00

**TRAW?** Raw Thermometer Reading  
 Query the raw sensor value, in k $\Omega$ , V, or  $\mu$ A (depending on the sensor type).

Front panel: 

*Example:* TRAW?  
 1.096738E+01

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

Front panel: 

*Example:* TTRD?  
 2.289103E+01



---

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

### 3.5.12 TEC configuration commands

---

TMOD(?) {z}	TEC Control Mode Set (query) the TEC control mode {to z=(CC 0, CT 1)}. 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. 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 ~3 s timeout, the command expires if not confirmed. The remote form of the command TMOD does <i>not</i> impose any delay or confirmation request; the control mode is changed immediately. Regardless of the source of the request, changing control mode while the TEC is on can be inhibited with the TMLK command.  <i>Example:</i> TMOD CT
-------------	------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

---

**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  $\mu$ A (TIEX 0), 100  $\mu$ 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

---

**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 LDC501 will prevent the TMOD command from operating if the laser is on. The front-panel [CT/CC] key is similarly inhibited.

Front panel: 

*Example:* TMLK?  
NO

---

**TUNE(?) {z}**                      TEC Autotune

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

The LDC501 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 LDC501 will first wait until the temperature reading is stable, and then generate an output step in TEC current corresponding to 12.5% 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,

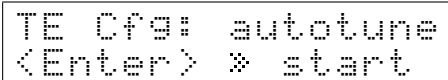
if the user cancels an autotune cycle in progress (either by sending TUNE OFF or by pressing the [Clear/Cancel] button while the display focus is at Autotune), then the autotune stops and the loop parameters are unchanged.

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), or FAILED 4 (tuning failed to converge). All query responses *other than* ON 1 indicate the tuning system is idle.

Front panel: 

Example: TUNE?  
SUCCESS

---

### TPGN(?) {f}

TEC Control Loop *P* Gain

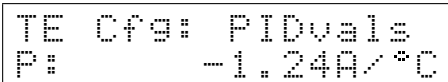
Set (query) the temperature control loop proportional gain {to *f*}, in A/°C (or A/kΩ).

The temperature control loop of the LDC501 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: 

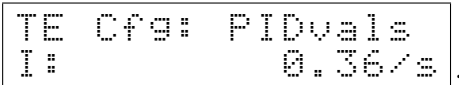
*Example:* TPGN -1.24

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,  $I > 0$ .

Front panel: 

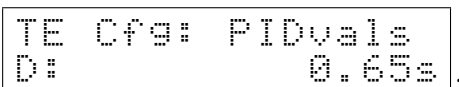
*Example:* TIGN 0.36

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,  $D > 0$ .

Front panel: 

*Example:* TDGN?  
6.500000E-01

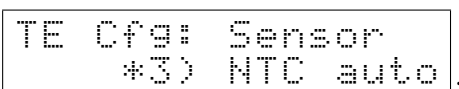
TSNR(?) {z}

Thermometer Type

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

Four types of temperature sensors are supported by the LDC501: 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 LDC501 will auto-range the excitation current to the thermistor between 10  $\mu\text{A}$  and 1 mA. Alternately, the user can specify a fixed excitation current of 10  $\mu\text{A}$  (NTC10UA), 100  $\mu\text{A}$  (NTC100UA), or 1 mA (NTC1MA). The sensor type cannot be changed while the TEC is on and in CT control mode.

Front panel: 

*Example:* TSNR 3

### 3.5.13 TEC sensor commands

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 LDC501. 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 LDC501 always receives and displays temperature in degrees Celsius),  $R_0$  is the thermistor resistance at reference temperature  $T_0$ , and  $\beta$  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.

Front panel: 

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  $\alpha$  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.

Front panel: 

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: 

TE Cfg:          Param
SHa:          1.12500E-3

.

*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: 

TE Cfg:          Param
SHb:          2.34700E-4

.

*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: 

TE Cfg:          Param
SHc:          0.85500E-7

.

*Example:* TSHC 8.55E-8

---

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

Front panel: 

TE Cfg:          Param
R(T0):          10.000k $\Omega$

.

*Example:* TNTR 10.0

---

TNTB(?) {f}                      NTC  $\beta$ -model  $\beta$  Parameter  
 Set (query) the  $\beta$  parameter for the NTC  $\beta$ -model {to *f*}, in  $^{\circ}\text{C}$ .  
 See TMDN for formula details.

Front panel: 

TE Cfg:          Param
$\beta$ :          3800.000 $^{\circ}\text{C}$

.

*Example:* TNTB 3800.

---

---

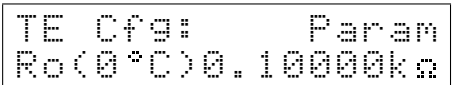
TNTT(?) {f}                      NTC  $\beta$ -model  $T_0$  Parameter  
 Set (query) the  $T_0$  parameter for the NTC  $\beta$ -model {to f}, in  $^{\circ}\text{C}$ .  
 See TMDN for formula details.

Front panel: 

Example: TNTB 25.0

---

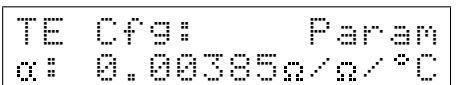
TRTR(?) {f}                      RTD Linear Model  $R_0$  Parameter  
 Set (query) the  $R_0$  parameter for the RTD  $\alpha$ -model {to f}, in  $\text{k}\Omega$ .  
 See TMDR for formula details.

Front panel: 

Example: TRTR 0.100

---

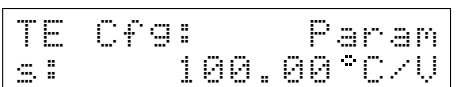
TRTA(?) {f}                      RTD Linear Model  $\alpha$  Parameter  
 Set (query) the  $\alpha$  parameter for the RTD  $\alpha$ -model {to f}, in  $\Omega/\Omega/^{\circ}\text{C}$ .  
 See TMDR for formula details.

Front panel: 

Example: TRTR 0.00385

---

TLMS(?) {f}                      LM335 Slope Parameter  
 Set (query) the slope parameter for LM335 calibration {to f}, in  $^{\circ}\text{C}/\text{V}$ .  
 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: 

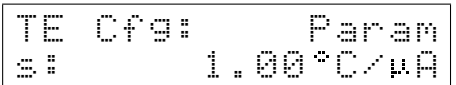
*Example:* TLMY?  
-2.731500E+02

---

**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: 

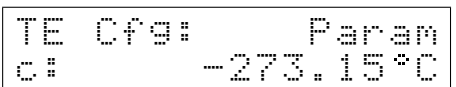
*Example:* TADS?  
1.000000E+0

---

**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

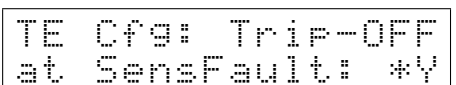
### 3.5.14 TEC trip-off commands

---

**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: 



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 LDC501 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 k $\Omega$ . If the sensor has a negative temperature coefficient, this will correspond to the *lowest* temperature of the operating band, *not* the greatest.

Front panel: 

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 LDC501 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 k $\Omega$ . 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: 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  $\pm 8.5$  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

---

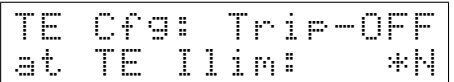
TTIL(?) {z}

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 LDC501 to automatically shut down the TEC if the TEC current limit is reached. The TTIL command enables this.

Front panel:



```
TE Cfs: Trip-OFF
at TE Ilim: *N
```

Example: TTIL 0

### 3.5.15 Interface commands

Interface commands do not have any front-panel correspondence.

---

\*IDN?

Identify

Query the LDC501 identification string.

The response is formatted as:

Stanford\_Research\_Systems,LDC501,s/n\*\*\*\*\*,ver#.##

where \*\*\*\*\* is the 6-digit serial number, and #.## is the firmware revision level.

Example: \*IDN?

Stanford\_Research\_Systems,LDC501,s/n098023,ver1.08

---

TOKEN(?) {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 LDC501 to remote queries of token-type values. When TOKEN OFF, the LDC501 responds with the numeric version of the token quantity. When TOKEN ON, the text version is returned.

Example: TOKEN?

ON

---

---

TERM(?) {z}	<p>Response Termination</p> <p>Set (query) the token response mode {to z=(NONE 0, CR 1, LF 2, CRLF 3, LFCR 4)}.</p> <p>Response messages generated by the LDC501 will be terminated by the 0-, 1- or 2-character termination sequence specified by TERM. Note that the TERM command is <i>interface specific</i>. 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.</p> <p>TERM settings are saved when the LDC501 is powered off, and restored at power on. They are not affected by *RST or GPAR.</p> <p><i>Example:</i> TERM LF</p>
*OPC(?)	<p>Operation Complete</p> <p>The set form, *OPC, will set the OPC bit in the Standard Event Status register; the query form, *OPC?, will return the value 1.</p> <p>*OPC is useful for pacing streams of remote commands; the *OPC command will not be processed by the command execution of the LDC501 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 <i>not</i> 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.</p> <p><i>Example:</i> *OPC? 1</p>
ULOC(?) {i}	<p>Unlock Ethernet</p> <p>Set (query) the ethernet command lockout {to i}.</p> <p>Upon power-up, the LDC501 defaults to ULOC 0, which <i>locks out</i> all remote commanding over the ethernet port. To enable ethernet control, send the command ULOC 1.</p> <p>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.</p>

---

*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.

Front panel: .

*Example:* SPAR USER3

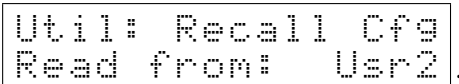
GPAR {z}

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 LDC501 can be restored by GPAR DEFAULT.

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

Front panel: .

*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 LDC501. 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 LDC501 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 LDC501 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 LDC501 can be adjusted in 12.5% steps with the BLVL command.

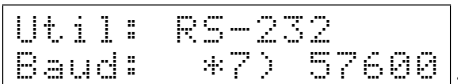
Front panel: 

*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: 


*Example:* BAUD7

IPAD(?) i {, j}

IP Address

Set (query) byte *i* of the internet address {to *j*}.

Note that byte 0 is the left-most byte of the address.

Front panel: 

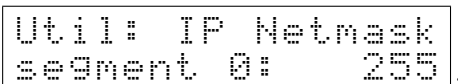
*Example:* IPAD?0; IPAD?1; IPAD? 2; IPAD?3  
172;168;0;3

NMSK(?) i {, j}

Netmask

Set (query) byte *i* of the internet network mask {to *j*}.

Note that byte 0 is the left-most byte of the mask.

Front panel: 

*Example:* NMSK 1, 255; NMSK?0; NMSK?1; NMSK?2; NMSK3  
255;255;0;0

---

 GWAY(?) i {, j}

Default Gateway

Set (query) byte *i* of the internet default gateway {to *j*}.

Note that byte 0 is the left-most byte of the address.

Front panel: Util: Gateway  
segment 0: 172.

*Example:* 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.

*Example:* MACA?  
0019:b303:ffff

---

 \*RST

Reset

Reset the LDC501 to its default configuration.

The following commands are internally executed upon receipt of the \*RST command:

- LDON OFF
- TEON OFF
- SVLM 5.0
- SILM 100.0
- PILM 5000.0
- SILD 0.0
- SIPD 0.0
- SYND 5.0
- RNGE HIGH
- SMOD CC
- SIBW HIGH
- BIAS 2.5
- RESP 0.0
- SMLK NO
- AILM NO
- APLP NO
- APLC NO
- ATOF NO
- ATMX NO
- ATMN NO
- TSNR NTCAUTO

- TMDN BETA
- TMOD CT
- TILM 2.25
- TMIN 0.0
- TMAX 50.0
- TVLM 8.0
- TEMP 25.0
- TPGN -0.5
- TIGN 0.36
- TDGN 0.65
- TNTB 3800.0
- TNTR 10.0
- TNTT 25.0
- TMLK NO
- TTSF YES
- TTMX YES
- TTMN YES
- TTVL YES
- TTIL NO

### 3.5.16 Status commands

---

*STB? [i]	<p>Status Byte</p> <p>Reads the Status Byte register [bit i].</p> <p><i>Example:</i> *STB? 0</p>
-----------	------------------------------------------------------------------------------------------------------

---

*SRE(?) [i,] {j}	<p>Service Request Enable</p> <p>Set (query) the Service Request Enable register [bit i] (to j).</p> <p><i>Example:</i> *SRE 0,1</p>
------------------	--------------------------------------------------------------------------------------------------------------------------------------

---

*ESR? [i]	<p>Standard Event Status</p> <p>Reads the Standard Event Status Register [bit i].</p> <p>Upon executing *ESR?, the returned bit(s) of the ESR register are cleared.</p> <p><i>Example:</i> *ESR? 64</p>
-----------	-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

---

---

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

---

---

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

*Example:* TEEN 4,1

### 3.6 Status Model

status registers The LDC501 status registers follow the hierarchical IEEE–488.2 format. A block diagram of the status register array is given in Figure 3.1.

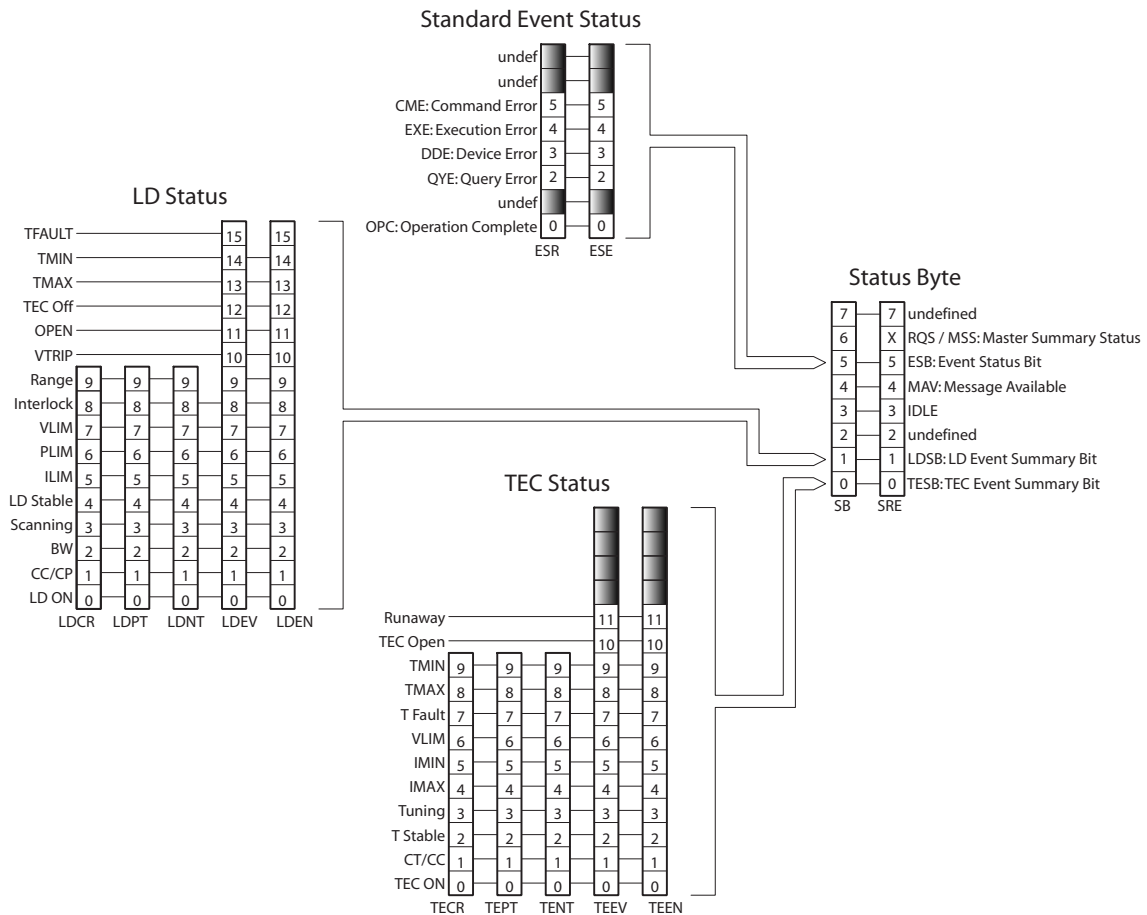


Figure 3.1: Status Model for the LDC501 Laser Diode Controller.

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 → 1 or 1 → 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.

### 3.6.1 Status byte (SB)

The Status Byte is the top-level summary of the LDC501 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 LDC501 query responses.

MAV : Indicates that the GPIB Output queue is *not* empty and the LDC501 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.

### 3.6.2 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.

### 3.6.3 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.

### 3.6.3.1 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.

### 3.6.4 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 LDC501. 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).

#### 3.6.4.1 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.

### 3.6.4.2 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 clears 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.

### 3.6.4.3 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).

## 3.6.5 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 LDC501. 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.

#### 3.6.5.1 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.

#### 3.6.5.2 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.

### 3.6.5.3 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).