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User's Guide

LDT-5900 Series Temperature Controllers

High Power Temperature Controller
LDT-5980
Precision Temperature Controller
LDT-5948



ILX Lightwave®
A Newport Corporation Brand

ILX Lightwave Corporation · 31950 Frontage Road · Bozeman, MT, U.S.A. 59715 · U.S. & Canada: 1-800-459-9459 · International Inquiries: 406-556-2481 · Fax 406-586-9405

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SAFETY AND WARRANTY INFORMATION

The Safety and Warranty Information section provides details about cautionary symbols used in the manual, safety markings used on the instrument, and information about the Warranty including Customer Service contact information.

Safety Information and the Manual

Throughout this manual, you will see the words *Caution* and *Warning* indicating potentially dangerous or hazardous situations which, if not avoided, could result in death, serious or minor injury, or damage to the product. Specifically:



Caution indicates a potentially hazardous situation which can result in minor or moderate injury or damage to the product or equipment.



Warning indicates a potentially dangerous situation which can result in serious injury or death.



Visible and/or invisible laser radiation. Avoid direct exposure to the beam.

General Safety Considerations

If any of the following conditions exist, or are even suspected, do not use the instrument until safe operation can be verified by trained service personnel:

- Visible damage
- Severe transport stress
- Prolonged storage under adverse conditions
- Failure to perform intended measurements or functions

If necessary, return the instrument to ILX Lightwave, or authorized local ILX Lightwave distributor, for service or repair to ensure that safety features are maintained (see the contact information on page x).

All instruments returned to ILX Lightwave are required to have a Return Authorization Number assigned by an official representative of ILX Lightwave Corporation. See Returning an Instrument on page ix for more information.

SAFETY SYMBOLS

This section describes the safety symbols and classifications.

Technical specifications including electrical ratings and weight are included within the manual. See the Table of Contents to locate the specifications and other product information. The following classifications are standard across all ILX Lightwave products:

- Indoor use only
- Ordinary Protection: This product is NOT protected against the harmful ingress of moisture.
- Class I Equipment (grounded type)
- Pollution Degree II
- Installation (overvoltage) Category II for transient overvoltages
- Maximum Relative Humidity: <80% RH, non-condensing
- Operating temperature range of 0 ^{o}C to 40 ^{o}C
- Storage and transportation temperature of -40 ^{o}C to 70 ^{o}C
- Maximum altitude: 3000 m (9843 ft)
- This equipment is suitable for continuous operation.

Safety Marking Symbols

This section provides a description of the safety marking symbols that appear on the instrument. These symbols provide information about potentially dangerous situations which can result in death, injury, or damage to the instrument and other components.

 Caution, refer to manual	 Earth ground Terminal	 Alternating current	 Visible and/or invisible laser radiation
 Caution, risk of electric shock	 Protective Conductor Terminal	 Caution, hot surface	 Frame or chassis Terminal
 or (I) On: In position of a bistable push control. The slash (I) only denotes that mains are on.		 or (O) Off: Out position of a bistable push control. The circle (O) only denotes that mains are off.	

WARRANTY

ILX LIGHTWAVE CORPORATION warrants this instrument to be free from defects in material and workmanship for a period of one year from date of shipment. During the warranty period, ILX will repair or replace the unit, at our option, without charge.

Limitations

This warranty does not apply to fuses, lamps, defects caused by abuse, modifications, or to use of the product for which it was not intended**.**

This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty of merchantability or fitness for any particular purpose. ILX Lightwave Corporation shall not be liable for any incidental, special, or consequential damages**.**

If a problem occurs, please contact ILX Lightwave Corporation with the instrument's serial number, and thoroughly describe the nature of the problem.

Returning an Instrument

If an instrument is to be shipped to ILX Lightwave for repair or service, be sure to:

1. Obtain a Return Authorization number (RA) from ILX Customer Service.
2. Attach a tag to the instrument identifying the owner and indicating the required service or repair. Include the instrument serial number from the rear panel of the instrument.
3. Attach the anti-static protective caps that were shipped with the instrument and place the instrument in a protective anti-static bag.
4. Place the instrument in the original packing container with at least 3 inches (7. 5 cm) of compressible packaging material. **Shipping damage is not covered by this warranty.**
5. Secure the packing box with fiber reinforced strapping tape or metal bands.
6. Send the instrument, transportation pre-paid, to ILX Lightwave. Clearly write the return authorization number on the outside of the box and on the shipping paperwork. ILX Lightwave recommends you insure the shipment.

If the original shipping container is not available, place your instrument in a container with at least 3 inches (7.5 cm) of compressible packaging material on all sides.

Repairs are made and the instrument returned transportation pre-paid. Repairs are warranted for the remainder of the original warranty or for 90 days, whichever is greater.

Claims for Shipping Damage

When you receive the instrument, inspect it immediately for any damage or shortages on the packing list. If the instrument is damaged, file a claim with the carrier. The factory will supply you with a quotation for estimated costs of repair. You must negotiate and settle with the carrier for the amount of damage.

Comments, Suggestions, and Problems

To ensure that you get the most out of your ILX Lightwave product, we ask that you direct any product operation or service related questions or comments to ILX Lightwave Customer Support. You may contact us in whatever way is most convenient.

In the United States:

Phone . . . . . (800) 459-9459 or (406) 586-1244

Fax . . . . . (406) 586-9405

Online: . . . . . http://ilx.custhelp.com

Email: . . . . . support@ilxlightwave.com

Or mail to:

ILX Lightwave Corporation
P. O. Box 6310
Bozeman, Montana, U.S.A 59771
www.ilxlightwave.com

In Europe:

Optical Test and Calibration Ltd.
Listerhills Science Park
Bradford, BD7 1HR United Kingdom
Phone: (44) 1274 393857
Fax: (44) 1274 393336
Online: www.otc.co.uk
Email: sales@otc.co.uk

In Japan:

Kyosai Technos
424, Shimo-Ongata-Machi
Hachioji-Shi
Tokyo, 192-0154 Japan
Phone: (81) 426 521 388
Fax: (81) 426 513 270

In China:

ETSC Technologies Co.
9/F Building 1
SBI Street
Dongxin Road
East Lake High-Tech Development Zone
Wuhan, Hubei, 430074 PRC China
Phone: (86) 27 8717 0152; (86) 27 8741 2681; (86) 27 8780 7925
Fax: (86) 27 8780 7133
Online: www.etsc-tech.com
Email: sales@etsc-tech.com

In China:

Kyosai Technos
3F Bldg G, No.21 Changjiang Road, Wuxi
National Hi-Tech Development Zone
Jiangsu, P.R. China
Phone: (86) 510 522 1707
Fax: (86) 510 522 1679
Email: ilx-service-china@kyosaitec.co.jp

When you contact us, please have the following information:

Model Number: _____

Serial Number: _____

End-user Name: _____

Company: _____

Phone: _____

Fax: _____

Description of what is connected to the ILX Lightwave instrument: _____

Description of the problem: _____

If ILX Lightwave determines that a return to the factory is necessary, you are issued a Return Authorization (RA) number. Please mark this number on the outside of the shipping box.

You or your shipping service are responsible for any shipping damage when returning the instrument to ILX Lightwave; ILX recommends you insure the shipment. If the original shipping container is not available, place your instrument in a container with at least 3 inches (7.5 cm) of compressible packaging material on all sides.

We look forward to serving you even better in the future!

CHAPTER 1

INTRODUCTION AND SPECIFICATIONS

This manual contains operation and maintenance information for the LDT-5900 Series Temperature Controllers. If you want to get started right away, read Chapter 2, which covers Operations, first.

Our goal is to make the best laser diode instrumentation available anywhere. To achieve this, we need your ideas and comments on ways we can improve our products. We invite you to contact us at any time with your suggestions.

WARNING

If any of the following symptoms exist, or are even suspected, remove the LDT-5900 Series Temperature Controller from service. Do not use until trained service personnel can verify safe operation.

Visible damage

Severe transport stress

Prolonged storage under adverse conditions

Failure to perform intended measurements or functions

If necessary, return the LDT-5900 Series Temperature Controller to ILX Lightwave for service and repair to ensure that safety features are maintained. Follow the "Returning an Instrument" process described on page xi.

Potentially lethal voltages exist within the LDT-5900 Series Temperature Controllers. To avoid electric shock, do not perform any maintenance on the instrument unless you are qualified to do so. Qualified service personnel are required to wear protective eye wear and anti-static wristbands while working on the LDT-5900 Series circuit boards. High voltages and high currents are present on and around the printed circuit boards.

Product Overview

The LDT-5900 Series Temperature Controllers consists of two family members, the LDT-5948 60W Precision Temperature Controller and the LDT-5980 120W High Power Temperature Controller. These instruments are bi-directional current sources with precision measurement circuits to monitor and control the temperature of the device under test. They have the following operating characteristics:

- PWM (pulse width modulated) output power of 60 W for the LDT-5948;(5A @ 12V DC) and 120 W for the LDT-5980 (10A @ 12V DC)
- 0.001 ^{o}C set point resolution
- 0.005 ^{o}C stability
- Constant temperature, constant current, constant resistance and constant voltage control modes
- Compatible with thermistors, IC and RTD temperature sensors
- Four-wire sensor measurements
- Four-wire TEC voltage measurement
- AC resistance measurement
- Heating and cooling temperature and current limits
- Software controlled PID feedback loop control
- PID Autotune mode
- IEEE GPIB and RS-232 remote interfaces
- Programmable triggers
- Closed case calibration

Installing the LDT-5900

This section provides information about the necessary requirements to install a LDT-5900 Series Temperature Controller and how to begin operating the instrument.

Initial Inspection

Verify that the following items were shipped with the instrument:

- LDT-5900 User's Guide
- Power Cord

When unpacking the instrument, make sure to save the packaging and protective Electrostatic Discharge (ESD) cap on the rear of the instrument, in case you have to return the instrument to ILX Lightwave. Shipping damage is not covered under the standard instrument warranty.

Grounding Requirements

The LDT-5900 Series Temperature Controller comes with a three-conductor AC power cable. The power cable must be plugged into an approved three-contact electrical outlet or used with a three-contact to two-contact adaptor with the grounding wire connected to an electrical ground (safety ground). ILX Lightwave recommends connecting the instrument only to properly earth-grounded receptacles. The power cord connector and power cable meet IEC safety standards.

AC Line Power Requirements

This instrument operates from a single-phase power source delivering line voltages of 100-240 VAC (all values RMS), from 50-60 Hz.

Tilt-Foot Adjustment

The LDT-5900 Series comes standard with folding front legs and two rear feet for use as a benchtop instrument. Extend the front legs to tilt the front panel upward, making it easier to read the display.

Rack Mounting

The LDT-5900 Series Temperature Controllers conform to international standards for a 2U height 1/2 width rack mounting. Rack mount accessory kits contain detailed mounting instructions.

Available Options and Accessories

Description	Model Number
Single Rack Mount Kit (enables installation into a standard 19 inch rack)	RM-139
Dual Rack Mount Kit (enables installation of two LDT-5900 instruments into a standard 19 inch rack)	RM-140
Temperature Controlled Laser Diode Mount	498X
High Power Laser Diode Mount	4442
5900 TE Controller / Unterminated 10A Interconnect Cable (6 feet)	CC591H*
5900 TE Controller / Laser Diode Mount 5A Interconnect Cable (6 feet)	CC595H*
Calibrated 10 Kohm Thermistor	510
Uncalibrated 10 Kohm Thermistor	520
Uncalibrated AD590LH IC Temperature Sensor	530
Uncalibrated LM335 IC Temperature Sensor	540

* To prevent fire hazard, ILX recommends using only the CC59XH Series cables with the 5900 Series Temperature Controllers. Unless properly configured, use of other cables may lead to fire hazard and may limit the controller's maximum output current. See Chapter 2 for more details.

Other laser diode mounts, sensors and accessories are available. Please contact ILX Lightwave for information on additional options for your applications.

Specifications

TEMPERATURE CONTROL OUTPUT[1]	LDT-5948	LDT-5980
Temperature Control Range[2]		
Thermistor Sensor	-50.000 °C to +250.000 °C	-50.000 °C to +250.000 °C
IC Sensor	-50.000 °C to +150.000 °C	-50.000 °C to +150.000°C
RTD	-50.000 °C to +199.999 °C	-50.000 °C to +199.999 °C
Set Point Accuracy[3]		
T Mode	±0.005 °C	±0.01 °C
I_{TE} Mode	±0.03 A	±0.03 A
V_{TE} Mode[4]	±0.05 V (typical)	±0.05 V (typical)
Set Point Resolution		
T Mode	0.001 °C	0.001 °C
I_{TE} Mode	0.001 A	0.001 A
V_{TE} Mode	0.001 V	0.001 V
Temperature Stability (24 hours)[5]	±0.005 °C	±0.005 °C
Output Type	Bidirectional current source	
Compliance Voltage	12V DC	12V DC
Output Current Range	-5.000 to 5.000 A	-10.000 to 10.000 A
Maximum Output Power	60W	120W
Current Noise and Ripple[6]	15 mA rms (typical)	15 mA rms (typical)
Current Limit Range	-5 to 5 Amps	-10 to 10 Amps
Current Limit Set Accuracy	±0.050 Amps	±0.050 Amps
Control Algorithm[7]	Software PID Loop	Software PID Loop
Proportional Term	0 to 9999.99	0 to 9999.99
Integral Term	0 to 999.999	0 to 999.999
Derivative Term	0 to 999.999	0 to 999.999
TEMPERATURE SENSOR	**LDT-5948**	**LDT-5980**
Types		
Thermistor	NTC (2-wire)	
RTD Sensor	Platinum 100 □ / 1000 □	
IC Sensor		
IC-V (LM-335)	Voltage output, 5 mV/°C to 14mV/°C	
IC-I (AD-590)	Current output, 1□A/°K	

Thermistor Sensing Current	10 A / 100 A / 1 mA	
Useable Thermistor / RTD Range	10 A; 10 k to 600 k 100 A; 1 k to 60 k 1mA; 10 to 6 k	
Sensor Bias	IC-V = 9V, LM335 = 1mA, RTD = 1.0 mA	
User Calibration	Thermistor: Steinhart-Hart, 3 constants IC Sensors offset/slope, RTD = R_0, A, B, C	
TEC MEASUREMENT (DISPLAY)	**LDT-5948**	**LDT-5980**
Thermistor Resistance		
10 A Setting	Range: 10 k to 600 k Resolution: 0.001 k Accuracy: ±0.05% ± 5.0	
100 A Setting	Range: 1 k to 60 k Resolution: 0.001 k Accuracy: ±0.05% ± 0.5	
1 mA Setting	Range: 10 to 6 k Resolution: 0.001 k Accuracy: ±0.08% ± 0.6	
Voltage Measurement		
Range	-12.000 to 12.000 V	-12.000 to 12.000 V
Resolution	1 mV	1 mV
Accuracy	± 10 mV	± 10 mV
AC Resistance Measurement		
Waveform	Pseudo AC	Pseudo AC
Amplitude	±10 mA	±10 mA
Accuracy[9]	± 1% ± 0.01	± 1% ± 0.01
SYNCHRONIZATION	**LDT-5948**	**LDT-5980**
Trigger In		
Type	TTL; rising edge triggered	
Resolution	100 s	
Trigger Out		
Type	TTL; active high	
Jitter	5 ns	
Delay	Programmable 1ms to 60 seconds	
Resolution	1 ms	

GENERAL	LDT-5948	LDT-5980
Output Connectors		
TEC I/O	Female 25 pin, D-sub	
GPIB	IEEE-488	
RS-232	Female 9 pin D-sub	
Trigger In	BNC	
Trigger Out	BNC	
Power Requirements	90 - 260V at 50/60 Hz	
Size	3.5” x 7.3” x 12”	
Weight	10.0 pounds (4.5 kg)	
Ambient Temperature Range	Operating: 10 to 40 ^{o}C Storage: -40 to 70 ^{o}C	
Humidity	< 85%, relative, non-condensing	
Warm-up	Five (5) minutes to rated accuracy	
EMC	EN 61326-1:2000 (CE Requirements)	
Safety	EN 61010-1:2001; 73/23/EEC, 93/68/EEC	

1. All values relate to a five minute warm up period.
2. Software limits of range. Actual range possible depends on the physical load, thermistor type and TEC module used.
3. Accuracy figures are set point referenced and represent the uncertainty that the 5948/5980 adds to the measurement. This figure does not include the sensor uncertainties which can add up to 2 ^{o}C. Accuracy figures are quoted for a typical 10 k□ thermistor and 100 □A current setting for -5 ^{o}C to 50 ^{o}C. Both resolution and accuracy are dependent upon the user-defined configuration of the instrument.
4. Into a 0.1 to 2.5 □load.
5. Temperature stability measurements made at 25 ^{o}C with a 10 kohm thermistor on the 100 □A setting. The number is derived from the avg P-P value over the measurement period.
6. Measured over the full DC current range into a 1□□load.
7. P=Proportional, I=Integral, D=Derivative. Software programmable terms through the front panel or GPIB.
8. Thermistor sensing current range software selectable through the front panel or GPIB.
9. Resistance range 0.3□ to 10□ with 4-wire voltage sense for rated accuracy.
10. Higher resolution can be obtained through GPIB; less than 0.1 □ with 10 □A thermistor current and <0.01 □ with 100 □A thermistor current.

CHAPTER 2

OPERATIONS

This chapter describes the operation of the LDT-5900 Series Temperature Controller. It is divided into five sections covering front panel overview, rear panel overview, general operations, front panel operations and basic TEC operations.

Front Panel Overview

The LDT-5900 Series Temperature Controller's front panel contains a Vacuum Fluorescent Display (VFD) display, power switch, LED indicators, buttons and adjust knob. Each of the labeled areas on the front panel is described in the Front Panel Operations section.

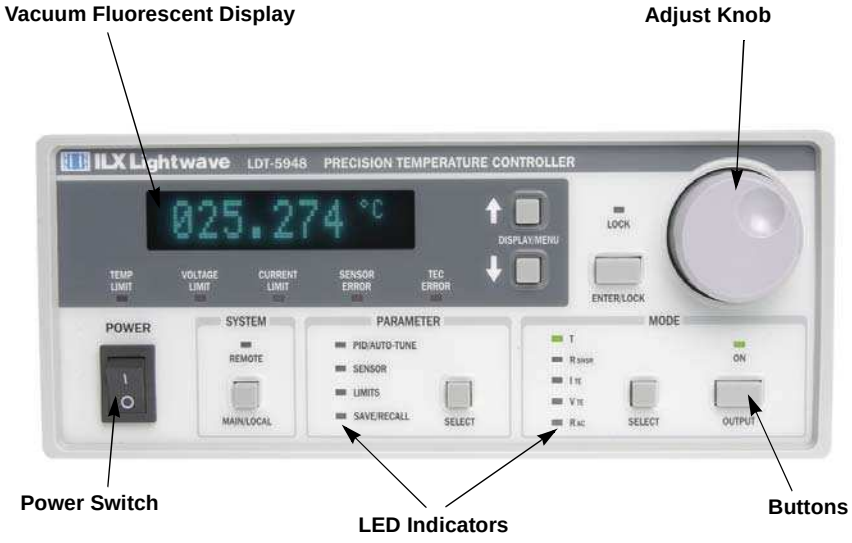


Figure 2.1 Front Panel

Rear Panel Overview

Rear Panel Controls and Connections



Figure 2.2 Rear Panel

AC Power Entry Module

The AC Power Entry Module is located on the lower right side of the rear panel. The LDT-5900 must be connected to a properly rated AC source in order to operate.

Trigger Input Connector

The **TRIGGER IN** connector is located to the right of center on the rear panel. The leading edge input of this signal is used to initiate a programmable temperature setpoint step. The TRIGGER IN is a BNC input connector and can be driven with a TTL signal. For more information on trigger functionality, see “Front Panel Operations” in Chapter 2.

Trigger Output Connector

The **TRIGGER OUT** connector is located next to the Trigger In connector. This output indicates if the measurement for the currently selected control mode (e.g. Temperature) is within the specified setpoint tolerance. This is a TTL signal generated by the instrument with programmable delay. The signal is low when the measurement is out of the tolerance window and high when within the tolerance window. For more details on trigger functionality, see “Front Panel Operations” in this chapter

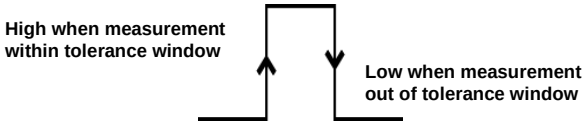


Figure 2.3 Trigger Out

GPIB Connector

The GPIB interface connector is located in the upper left corner of the rear panel. Refer to Figure 2.2. The 24-pin GPIB interface connector is tapered to ensure proper orientation. Finger tighten the two screws on the cable connector.

A total of 15 devices can be connected together on the same GPIB interface bus. The cables have single male/female connectors on each end so that several cables can be stacked. This permits more than one cable to be attached to any one device. The maximum total length of the GPIB cables must not exceed 20 meters (65 feet) or 2 meters (6.5 feet) time the total number of devices on the bus.

The maximum individual cable length must not exceed 4 meters (13 feet).

For more information regarding GPIB communications, see Chapter 3.

RS-232 Connector

The **RS-232** connector is located under the GPIB interface connector. This is a standard female DB-9 connector for RS-232 communications. This connection can be cabled to a computer's serial communication port. ILX recommends a maximum cable length of 3 meters (9.8 feet).

For more information regarding RS-232 communications, see Chapter 3.

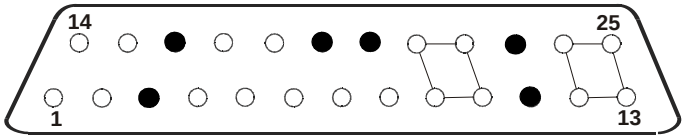
General Operation

The following sections present some guidelines for operation, as well as some common operating procedures. Remote operations are discussed in Chapter 3 and the command reference is discussed in Chapter 4.

Warm Up and Environmental Considerations

Operate the LDT-5900 Series Temperature Controller at an ambient temperature range of 10 ^{o}C to 40 ^{o}C. Storage temperatures should be in the range of -40 ^{o}C to +70 ^{o}C. To achieve the rated stability, let the LDT-5900 warm up for at least five minutes.

Rear Panel Connections



1 RT+_SENSE	6 CHASSIS	11 N/C	16 N/C	21 TEC+
2 RT-_SENSE	7 TEC+_SNS	12 TEC -	17 CABLE ID1	22 TEC+
3 N/C	8 TEC-_SNS	13 TEC -	18 CABLE ID2	23 N/C
4 ID1	9 TEC+	14 RT-	19 N/C	24 TEC-
5 ID2	10 TEC+	15 RT+	20 N/C	25 TEC-

Figure 2.4 Rear Panel TEC Connector

When the LDT-5900 is controlling a thermoelectric (TE) module in cooling mode, current flows from TEC+ (pins 9, 10, 21 and 22 connected internally) to TEC- pins (12, 13, 24 and 25 connected internally). This is referred to as positive current. Sensor current (10 □A, 100 □A or 1 mA) flows through the sensor connected at RT+ (pin 15) and RT- (pin 14). A voltage develops across the temperature sensor connected to these pins and can be accurately measured at the sensor through the 4-wire voltage sense pins (1 and 2), RT+ Sense and RT-Sense. Similarly, the TE voltage can be accurately measured through the 4-wire TE voltage sense pins 7 and 8. The sensor input (pins 14 and 15), as well as the RT sense and TEC sense (pins 1,2,7, and 8) should be floating with respect to ground. Pin 6 is connected to the chassis, which is connected to earth ground via the AC power cord earth conductor.

ILX recommends using either the CC-591H, 5900 TE Controller / unterminated 10A interconnect cable or the CC5955 TE Controller / Laser Diode Mount 5A interconnect cable to connect the module to the load. The CC-59X Series cables are specifically designed to be compatible with the 5900 Series Temperature Controllers. See the ILX Lightwave product catalogue or contact ILX Customer Service (see page xii for contact information) for information about the cable.

Note: If you choose to assemble your own interconnect cables, 18AWG wire is recommended to minimize voltage drop at high current. Note that the DB-25 connector pins are rated for $I_{nominal}$ = 2.5A, and thus all four TEC+ pins (9, 10, 21, 22) must be used if 10A is to be delivered to a load as well as all 4 TEC- pins (12, 13, 24, 25) for the return.

Also, the cable ID pins must be configured as follows or the output current from the LDT-5900 will be limited to 1A.

MAX Output Current	Cable ID1	Cable ID2
	Pin 17 to 4	Pin 18 to 5
10A	Shorted	Shorted
5A	Shorted	Open

TEC Grounding Considerations

The cable ID ground (pins 4 and 5) are isolated from chassis ground (pin 6). The chassis is provided for shielding purposes only.

CAUTION

Do NOT connect the TEC Module pins (9, 10, 12, 13, 21, 22, 24 and 25) to any grounded pins (4, 5 and 6) or damage could occur to the module.

Front Panel Operation

Figure 2.5 shows the front panel of the LDT-5900 Series Temperature Controller. The key operating parameters for the LDT-5900 Series Temperature Controller can be set, adjusted, and displayed through various menus accessible by using the front panel push buttons (keys) and knobs.

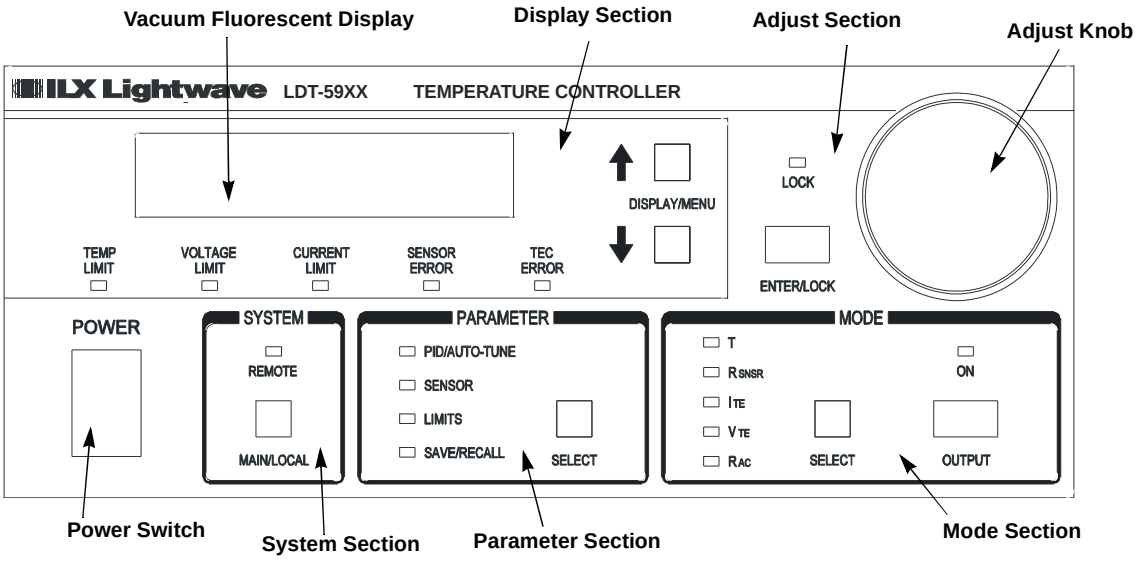
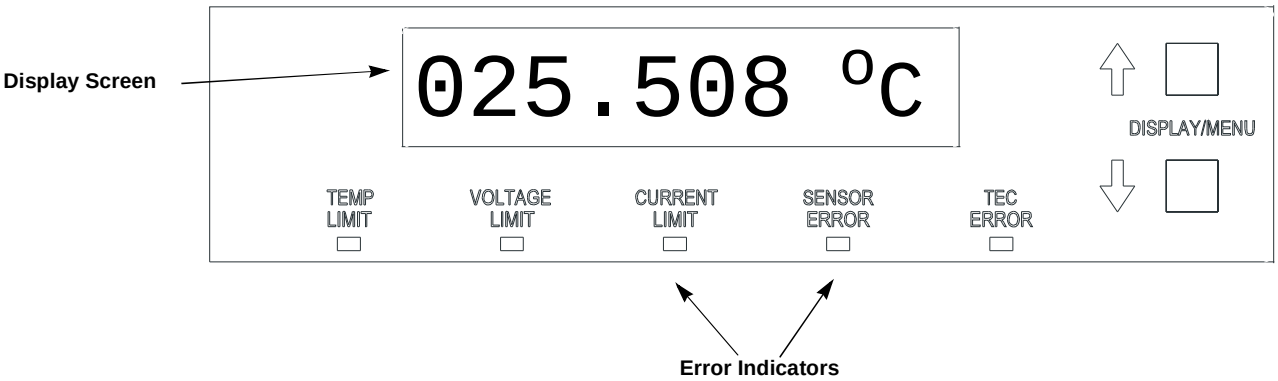


Figure 2.5 Front Panel

Display Section

Three important areas of the front panel display section are the display screen, the DISPLAY / MENU buttons and the error indicators. The display is a vacuum fluorescent display that is continually updated at approximately a 2 Hz rate. The DISPLAY / MENU arrow keys allow the user to select which measurement to display and to select the parameters to adjust in the various menus.



The error indicators (LEDs) in the display section are described as follows:

- TEMP LIMIT - The Temperature Limit LED will be RED when either the Low Temperature or the High Temperature Limit is met or exceeded and the output will be shut off.
- VOLTAGE LIMIT - The Voltage Limit LED will be RED when either high or low TEC voltage limit is reached.
- CURRENT LIMIT - The Current Limit LED will be GREEN when either the high or low current limit is reached and the temperature error signal is decreasing, (e.g. when driving the load to a given setpoint). The Current Limit LED will be RED when either the high or low current limit is reached and the temperature error signal is increasing, (e.g. system is in a thermal run-away condition.)
- SENSOR ERROR - The Sensor Error LED will be RED if the temperature sensor (either a thermistor, IC or RTD) is open, shorted or outside of the nominal measurement range.
- TEC ERROR - The TEC Error LED will be RED if the TEC is either shorted, open or not connected.

For more information on which errors will cause the output to turn off, see “Output Off Registers” in Chapter 3.

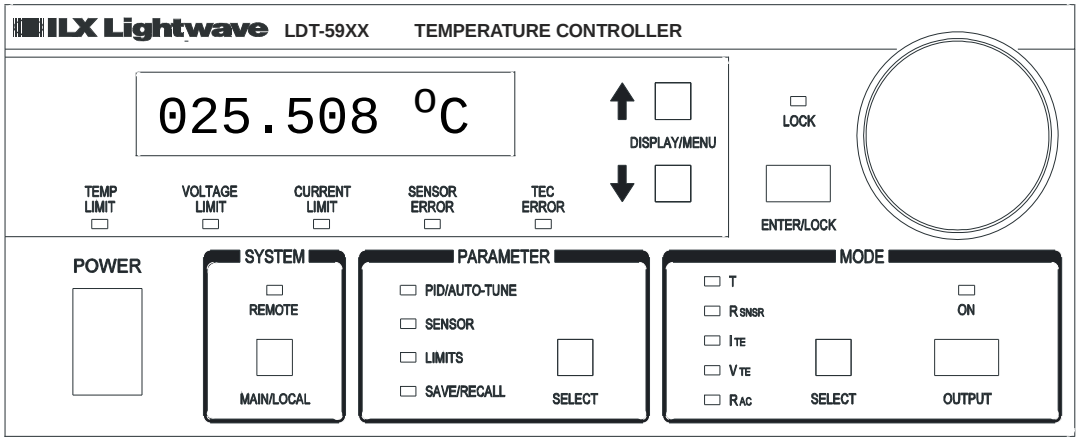
Adjust Section

The Adjust section of the front panel contains the Adjust Knob and the ENTER / LOCK Key. (See Figure 2.5) The adjust knob (digital encoder) allows the user to change the value of a selected menu parameter. The parameter selected is indicated by brackets [123.456]. The ENTER / LOCK key is used in menus to enter and store a parameter that has been modified by the knob. When not in a menu, this key is used to lock (disable) or unlock the adjust knob.

- LOCK - The Lock LED will be GREEN when the adjust knob has been locked and is disabled.

Measurement and Setpoint

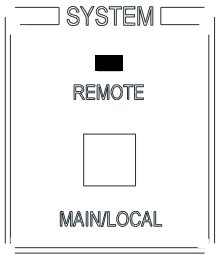
By default, the LDT-5900 Series Temperature Controller displays the temperature measurement from the selected sensor in ^{o}C. Using the DISPLAY / MENU arrow keys, the user can change the displayed temperature conversion units (^{o}C, ^{o}F, K) or the measurement parameter altogether (sensor measurement, TE current, TE voltage, TE power). After exiting any menu, the instrument will always return to the measurement display.



Whilte the measurement display is active, the user can access and change the setpoint for the selected control mode. (See the Mode Section later in this chapter for details on control modes and setpoints.) Turning the adjust knob will cause the screen to switch from displaying the measurement to displaying the setpoint. This is indicated by brackets around the setpoint value. The setpoint value can then be adjusted with the knob and stored by pressing the ENTER / LOCK key. After 10 seconds of inactivity, the screen will switch back to display the measurement, or the user can press either DISPLAY / MENU arrow key to immediately switch back to the measurement display.

System Section

The System section of the front panel contains the MAIN / LOCAL button and the REMOTE indicator. Sending a command over the GPIB or RS-232 interfaces automatically puts the instrument in Remote Mode and illuminates the Remote LED. The MAIN / LOCAL button returns the instrument to local (front panel) control. (See the Remote Communication section of Chapter 3 for more details).

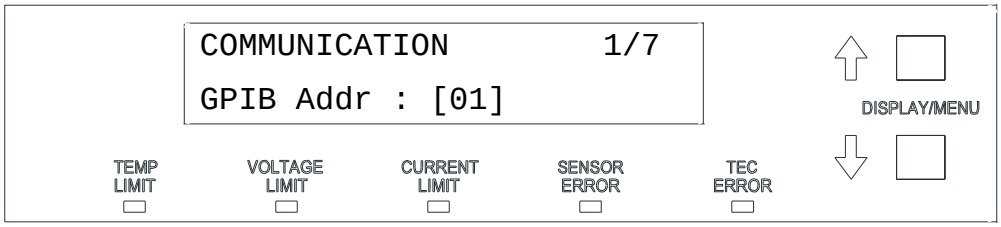


System Menu

Pressing the Main / Local Key cycles through the system menu as described in further detail below. System menu entry will automatically timeout after 10 seconds of no activity and the instrument will return to is default measurement display mode.

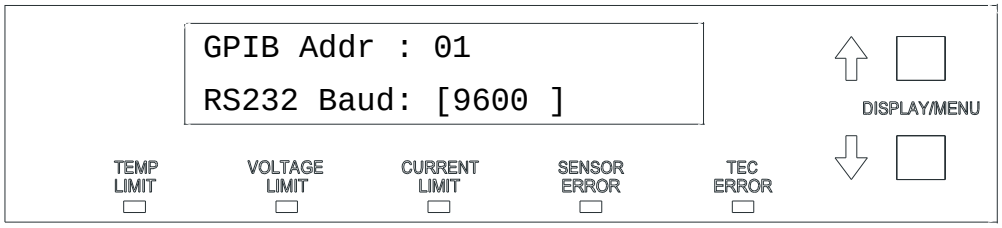
Communication

The first page of the system menu allows the user to select the appropriate remote communications and appears as follows:



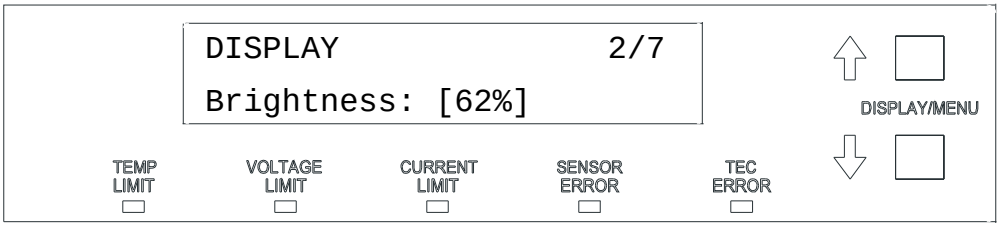
For GPIB communications, the GPIB address can be set between 0 and 30 by using the adjust knob to select the desired value, and then pressing the ENTER / LOCK key to save it. By pressing the down arrow key, the RS-232 baud rate is

selected and can be set between a minimum of 1200 and a maximum of 230400. For more information on remote communications, see Chapter 3.



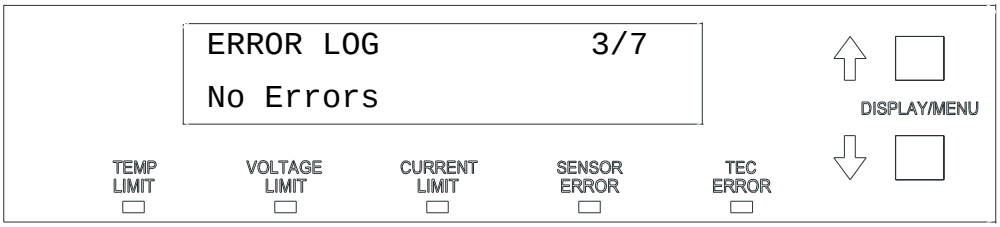
Display

The second page of the system menu allows the user to set the brightness of the display between 25% and 100% by using the adjust knob and then pressing the ENTER / LOCK key.



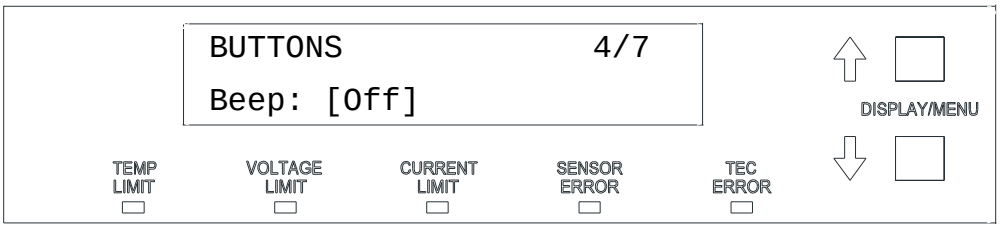
Error Log

The third page of the system menu allows the user to view the error log and appears as follows when no errors are present. Pressing the ENTER / LOCK key clears the error log. The DISPLAY / MENU up and down arrow keys scroll thru the error log, which lists the most recent error at the top. Table 3.7 in Chapter 3 lists the error codes for the LDT-5900 Series Temperature Controllers.



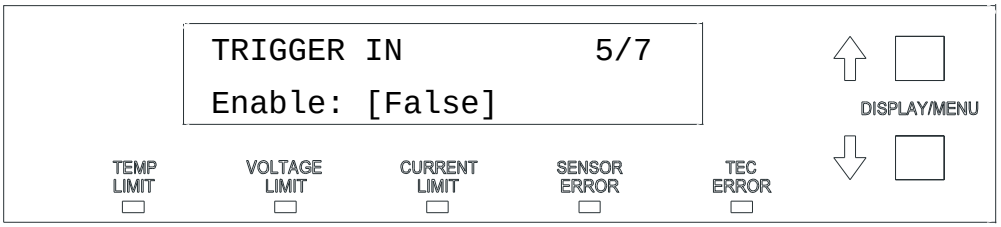
Buttons

The fourth page of the system menu allows the user to set the beep for the buttons either on or off by using the adjust knob and then pressing the ENTER / LOCK key.

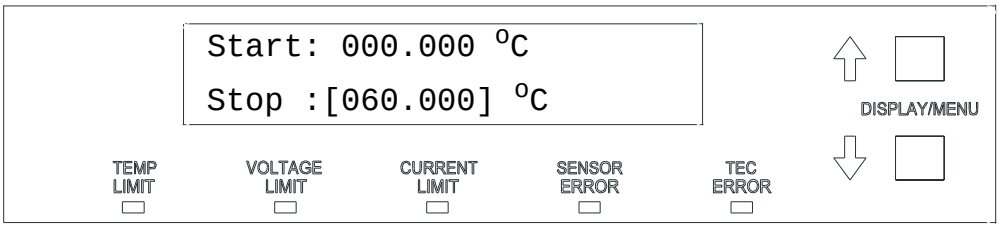


Trigger In

The fifth page of the system menu allows the user to set up all parameters for the trigger in functionality. From this menu, the trigger in can be enabled or disabled.



Pressing the down arrow key scrolls through the various parameters within this menu, allowing the user to then set the start, stop and step temperatures.

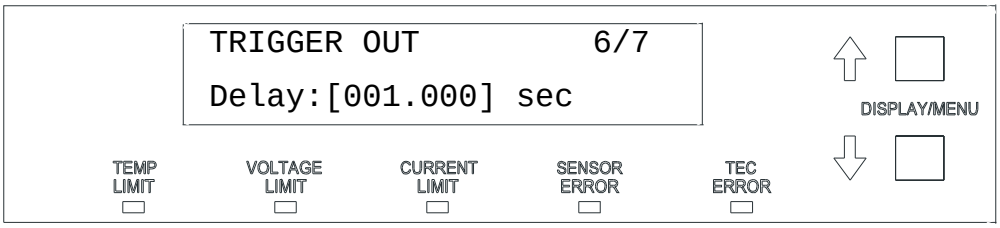


When enabled, the Trigger In feature allows the user to modify the temperature control setpoint by sending a TTL pulse into the TRIG IN BNC connector on the back of the instrument. (See the Rear Panel Overview section earlier in this chapter for connector location.) The first time a Trigger In pulse is received, the temperature setpoint will be set to the Start temperature specified in this menu. Subsequent pulses will increment (or decrement) the setpoint by the Step value.

When the setpoint reaches the specified Stop temperature, the next pulse will reset the setpoint back to the Start temperature. The setpoint cannot exceed the Stop temperature, and any attempt to step beyond the Stop temperature will instead reset the setpoint back to the Start temperature.

Trigger Out

The sixth page of the system menu allows the user to set up the trigger out delay time..

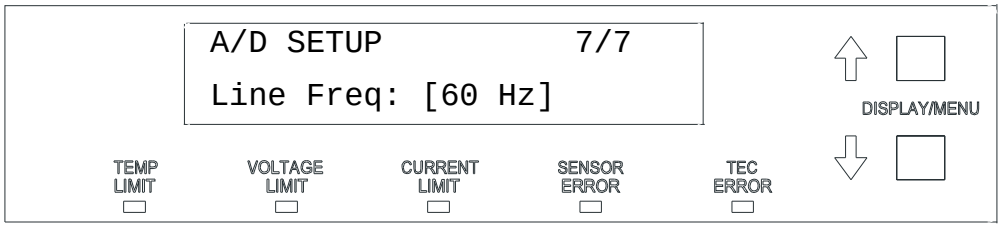


The Trigger Out feature allows the user to determine if the instrument is controlling a TEC within a specific tolerance window. This window is defined by the setpoint +/- a user specified tolerance. (See the Limits portion of the Parameter Section later in this chapter for details on how to set this tolerance value.) If the measurement for the selected control mode (e.g. Temperature) is within this tolerance window, the Trigger Out TTL level will be high, if out of tolerance, the level will be low. The Trigger Out signal is output from the TRIG OUT BNC connector. (See the Rear Panel Overview section earlier in this chapter for connector location.

The delay time determines how long the measurement must remain within the tolerance window before Trigger Out is asserted high. If the measurement goes out of tolerance during this delay period, the delay time interval is restarted when the measurement goes back into tolerance.

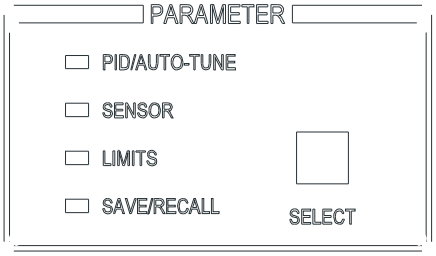
A/D Setup

The last page of the system menu allows the user to set up the A/D filter to reject either 50 Hz or 60 Hz AC line noise. The default frequency for this filter is 60 Hz.



Parameter Section

The Parameter section contains the SELECT key and the parameter indicators. Pressing the SELECT key cycles through each of the available menus. An illuminated green LED next to each of the listed menus indicates which is currently active. The parameter menus are PID / AUTO-TUNE, Sensor, Limits and Save / Recall, all of which are described as follows.



Parameter menu entry will automatically timeout after 10 seconds of no activity and the instrument will return to its default measurement display mode.

PID / AUTO-TUNE

Selecting this parameter allows access to the Auto-Tune feature and to view or modify the PID constants.

The Auto-Tune feature and user modification of the PID constants are only available in constant temperature (T) and constant sensor (R_{SNSR}) control modes. (See the Mode Section later in this chapter for details on selecting the control mode.) The PID constants are not used in any of the other control modes.

Background

Tuning the temperature controller means setting the proportional, integral and derivative terms for the best control for a particular system or process.

The P, I, and D terms are defined as follows:

P = The proportional constant, which controls the loop gain

I = The integral constant, which offsets errors and affects settling time

D = The derivative constant, which affects the damping rate

The range of acceptable PID values are shown in the table below.

Table 2.1 PID Constant Values

Parameter	Range	Default
Proportional	0 - 9999.99	20.0
Integral	0 - 999.999	0.8
Derivative	0 - 999.999	1.0

The LDT-5900 Series Temperature Controllers have an auto-tune algorithm that will help the user determine nominal values for the PID coefficients. While the auto-tuned values typically provide acceptable stability and overshoot for a given thermal system, these values can usually be optimized through further user tuning, as described later in this section.

Auto-Tune Operation

The auto tune algorithm in the LDT-5900 series of temperature controllers will calculate a thermal system's PID coefficients through an iterative PID temperature control process. Figure 2.6 describes the tuning process pictorially.

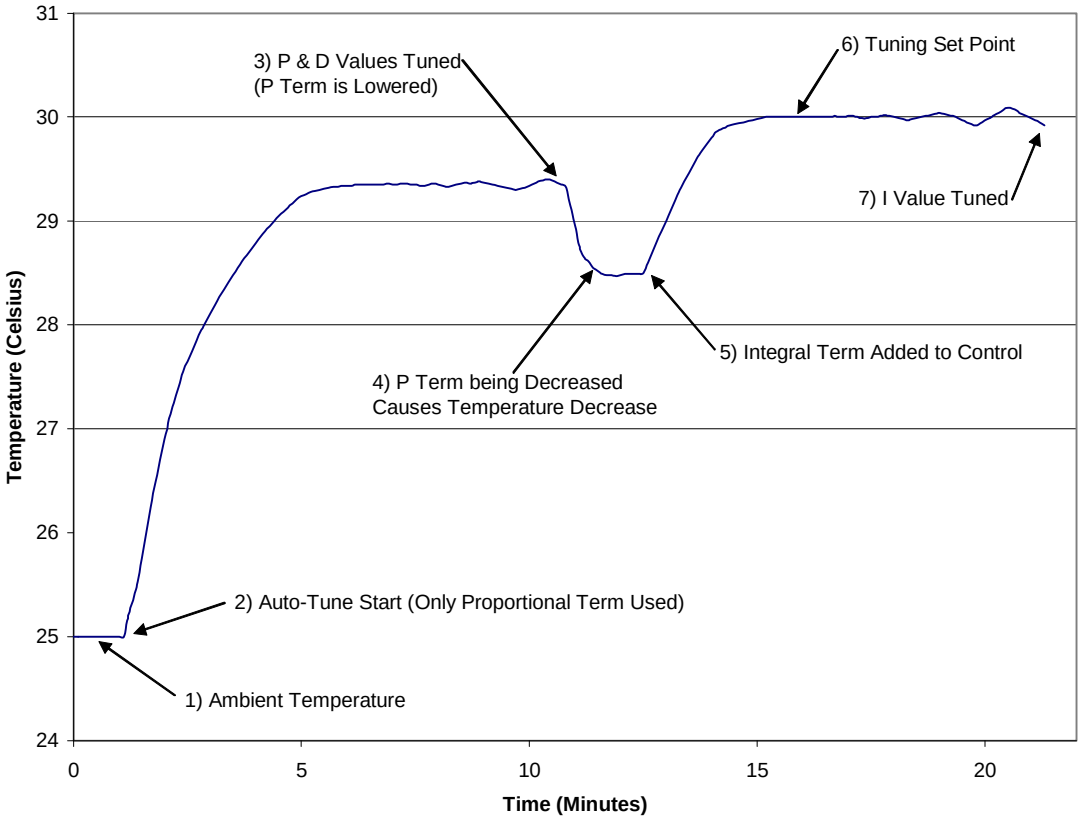


Figure 2.6 Auto Tuning Process

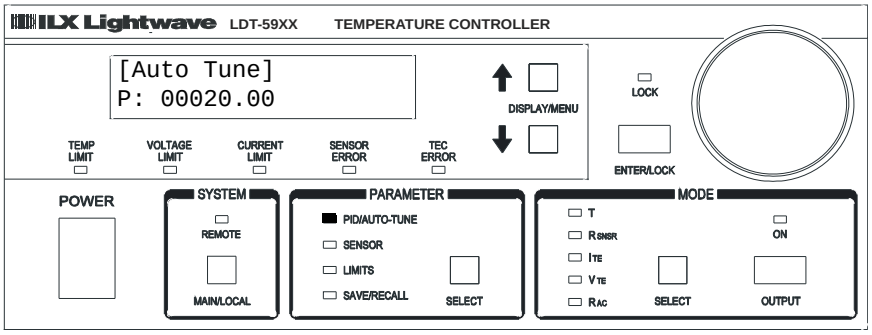
The auto tune algorithm starts controlling temperature (Point 2 on Figure 2.6) with an arbitrary coefficient for the loop gain (P term), and slowly increases it until the temperature begins to oscillate. Once the temperature begins to oscillate, the P term is reduced by 40% and the D term is calculated (Point 3). The derivative term (D term) is calculated from the period of the oscillations that occurred during the tuning of the P term. The control loop is allowed to settle after the P and D terms are calculated and set. If the defined tuning set point is above the ambient temperature, the decrease in the P term will cause a decrease in the control temperature (Point 4).

After the temperature has stabilized, the integral term (I term) is then added to the control loop (Point 5 on Graph). The I term is then increased until it causes the temperature to oscillate around the user defined tuning set point (Point 7 on Graph). The final I term coefficient is set to 33% of the I term value that is found to start oscillations in the temperature control loop.

This tuning method calculates PID coefficients that result in fast settling times and good set point stability. The auto tune algorithm slowly moves towards the oscillation points of the thermal system to consistently find suitable PID coefficients on a wide range of thermal systems, and to ensure that the thermal system will not be damaged. The calculated PID coefficients are dependent upon the user defined current limit and setpoint temperature. If a new setpoint temperature is desired that would require the controller to cool (vs. heat), the Auto-Tune feature can be used to calculate optimal PIDs for the new temperature setpoint. The tuning times of the auto tune process will range from 10 to 45 minutes, or more, depending on the thermal system being tuned. Typical tuning times are around 25 minutes. Thermal systems with higher P, I and D coefficients will take more time to tune than those with lower P, I and D coefficients.

To utilize this feature:

- Connect the temperature controller to the desired thermal load.
- Verify the current limits and temperature set point are set appropriately for the particular TEC.
- Press the Parameter SELECT button to activate the PID / AUTO-TUNE parameter.
- Auto-Tune should be highlighted with brackets.
- If the status from a previous Auto-Tune is shown next to the [Auto-Tune] selection (i.e. “Success” or “Failed”), press the ENTER / LOCK key to clear it.
- Press the ENTER / LOCK key to begin..



While Auto-Tune is in process, the PID/AUTO-TUNE LED will be flashing and the thermal system’s temperature will be displayed. Once an Auto-Tune is complete, the instrument will then beep and disable the output, and the display will read “AutoTune Success”. The instrument will automatically enter the new P, I and D values from a successful Auto-Tune.

If “AutoTune N/A” is displayed, the Auto-Tune feature (and modification of the PID constants) is not available for the currently selected control mode.

To abort an Auto-Tune that is in progress, press the OUTPUT key. The instrument will then disable the output and the display will read “AutoTune Failed”. The P, I and D values will remain unaltered.

There are limitations to the Auto-Tune feature. Any of the following will cause the Auto-Tune algorithm to fail:

- Thermal systems where P < 0.5 or I < 0.1
- Noisy temperature measurements
- Reaching any output off enable condition (such as temperature or voltage limits) during the auto-tune operation, (see “Output Off Registers” in Chapter 3).

If the Auto-Tune algorithm fails for a particular thermal system, it may be necessary to modify the PID coefficients manually, as described in the following section.

Modifying the PID Coefficients

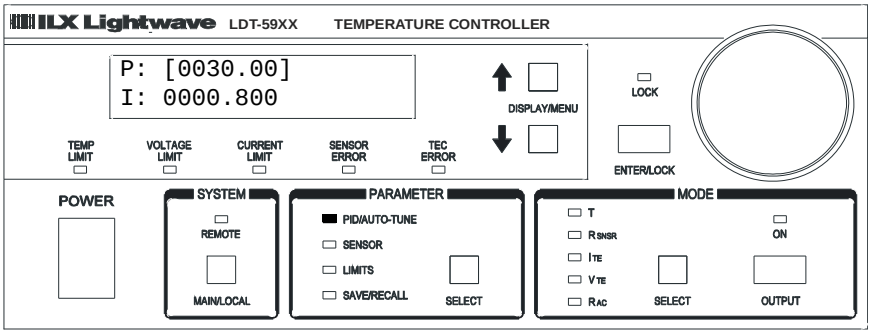
The Auto-Tune algorithm is designed to provide coefficients for optimal performance, but if improvement is required, the nominal coefficients can be further optimized manually to obtain the desired performance using the following guidelines.

P - The proportional gain coefficient essentially pushes the system to its final setpoint. Increasing the P will decrease the response time. Conversely, decreasing P will increase the response time.

I - The integral gain coefficient determines how fast the system will settle to its final setpoint. Large values will settle faster with more overshoot. Possible oscillation could occur if too large. Small values will take longer to settle but with much less overshoot.

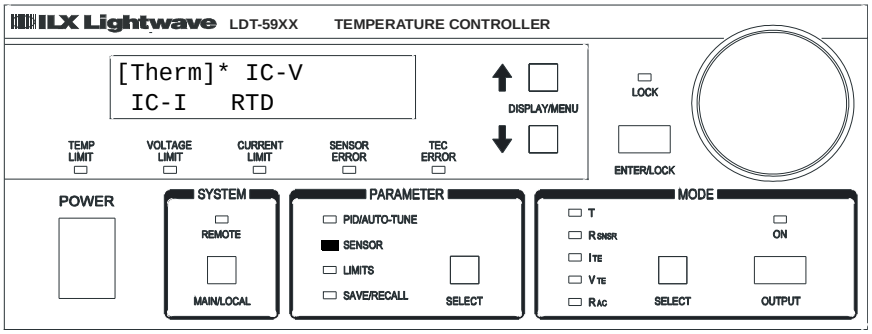
D - The derivative gain coefficient helps to control the output response dynamics. Large values can help the system to settle more quickly, but a D value that is too large can cause the system to be unstable or oscillate. Small values allow the temperature to move as quickly as possible.

When optimizing the system performance, it is recommended that only one coefficient be modified at a time. To modify the PID coefficients, select the PID / AUTO-TUNE menu. Using the up and down arrows, select the appropriate parameter. The one selected will be enclosed in brackets. Use the Adjust Knob to adjust the desired value and then press the ENTER / LOCK key to save it.



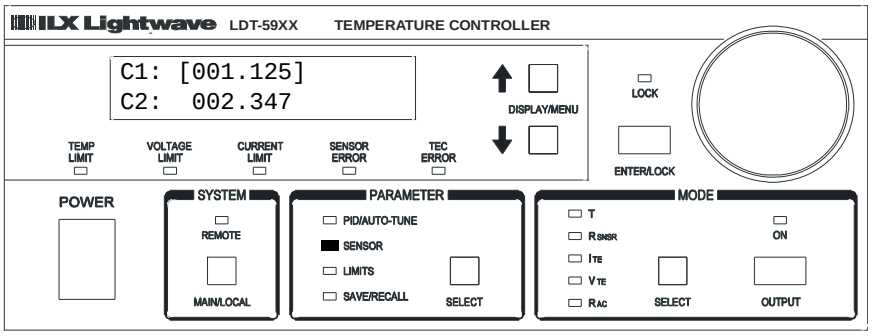
SENSOR

The Sensor parameter allows the user to select the type of sensor for the application: Thermistor, IC-V, IC-I or RTD. The sensor currently selected has an asterisk next to it.



To select a sensor type, press the down arrow key until the proper sensor is highlighted and then press the ENTER / LOCK key.

A menu displaying the coefficients and current setting required for that particular sensor is then accessed. For a thermistor, the Steinhart-Hart coefficients (C1, C2, C3) and sensor current can be modified, as shown below.



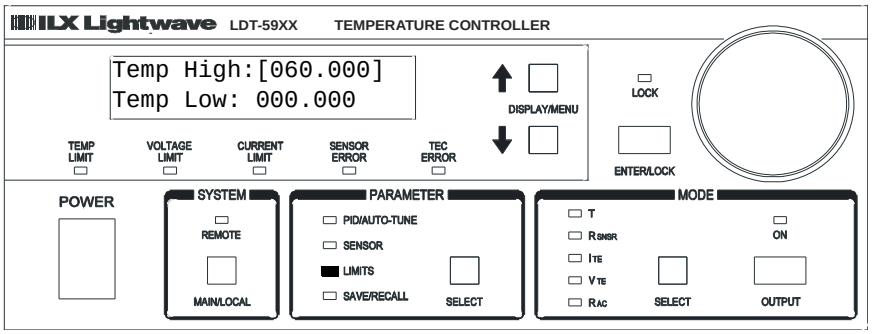
The coefficients can be modified by using the Adjust Knob and then pressing the ENTER / LOCK key. For more details on sensor, see “Sensor Options” later in this chapter.

LIMITS

The Limits menu allows the user to select and modify the setpoint and error limits. The arrow keys and adjust knob can be used to cycle through and select or modify the following parameters:

- Temperature High / Low Limits
- ITE (TE Current) High / Low Limits
- Sensor High / Low Limits
- VTE (TE Voltage) High / Low Limits
- Set Point Tolerance (for Trigger Out)

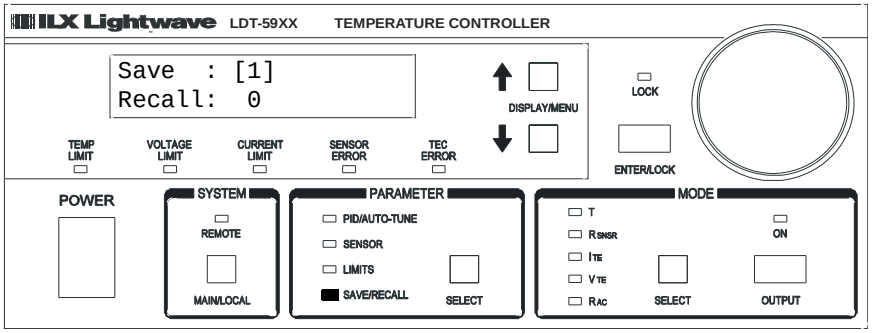
When the limit parameter is selected, the display will look as follows.



When these limits are exceeded, the corresponding LIMIT or ERROR LED in the Display Section is illuminated. Als0, exceeding these limits may cause the controller output to be turned off automatically. (See the Output Off Registers section in Chapter 3).

SAVE / RECALL

The Save / Recall menu functions are used to quickly configure the LDT-5900 Series Temperature Controller's parameters to user-determined pre-set values.

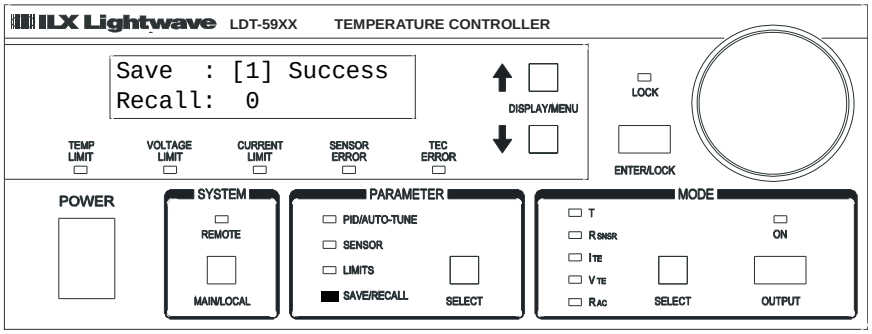


SAVE

The Save function is used to store the current instrument configuration into non-volatile memory. When a configuration is stored, all of the parameter values (PIDs, sensors, limits), trigger settings and setpoint values are saved. There are nine (9) "bins" for user storage. Bin 0 is reserved for the factory default parameters. (See "Default Settings" in Chapter 2) Bins 1-9 can be used to save any desired configuration for later use. This allows fast and easy setup for tests or other high-repeatability needs. The system GPIB address and RS-232 baud rate are not saved in the user bins.

To save a configuration, repeatedly press the SELECT key until the SAVE / RECALL LED is illuminated. Use the adjust knob to select an appropriate storage bin and then press the ENTER / LOCK key.

Once a configuration has been properly saved, the following will be displayed:



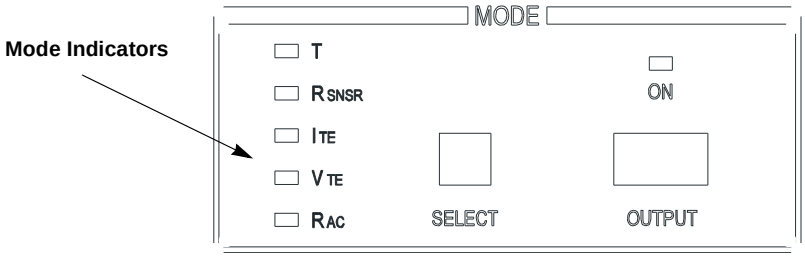
RECALL

The Recall function is used to return the LDT-5900 to a previously defined state or configuration. To recall a saved configuration (or unconfigured bin) of the LDT-5900, select the Recall parameter from the SAVE / RECALL menu. Using the knob, adjust the value to the desired configuration bin number. Press the ENTER / LOCK key to recall the saved user settings. After the recall is completed, the LDT-5900 will immediately be configured to the desired settings. However, the OUTPUT will be turned off.

When the LDT-5900 is manufactured, all of the usable recall bins are initialized to the default values. They will remain that way until the user performs a SAVE operation on a particular bin.

Mode Section

The three important areas of the Mode section are the OUTPUT key, the SELECT key and the mode indicators.

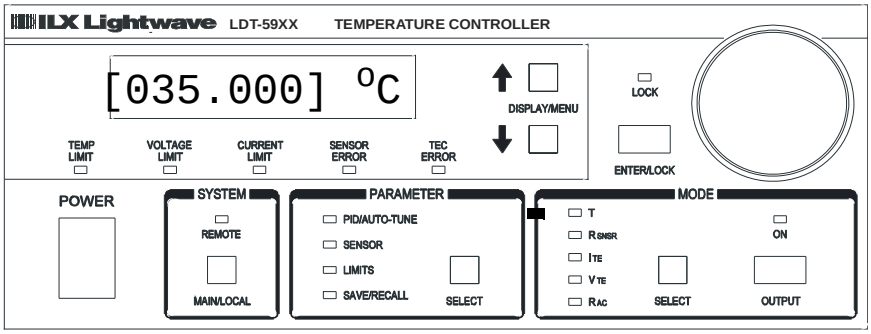


The OUTPUT key is used to turn the controller output current on or off. The OUTPUT is off when the instrument is first powered up. It may also be shut off automatically during operation if certain error or out of limit conditions occur. (See Chapter 3, “Output Off Registers”). Turning OUTPUT on enables temperature (or other mode) control of the TEC.

The SELECT key may be pressed repeatedly to cycle through the various modes. The modes that can be selected here are constant temperature (T), constant resistance (R_{SNSR}), constant current (I_{TE}), constant voltage (V_{TE}) and AC resistance mode (R_{AC}). Once a mode is selected, the setpoint for that mode is displayed for 10 seconds. If the setpoint is already at the desired value, the setpoint entry menu can be exited by pressing either the up or down arrow key. The setpoint for any mode can be modified by using the adjust knob and then pressing the ENTER / LOCK key.

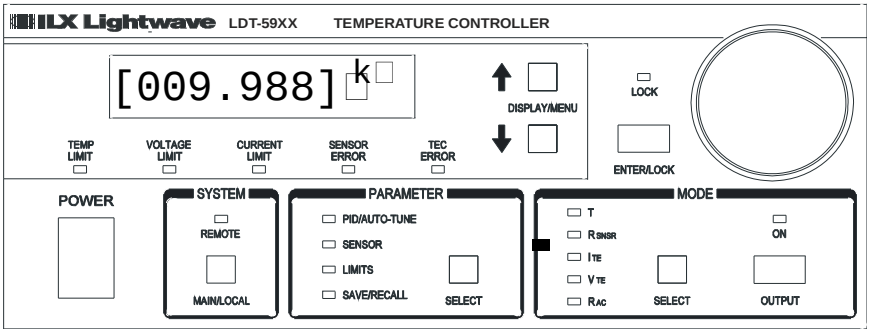
T

Selecting T will enable the instrument to operate in constant temperature mode when OUTPUT is turned on. In T mode, the controller output current to the TEC is continuously adjusted to maintain the setpoint temperature at the sensor. Any of the sensor types (thermistor, RTD, IC-I, IC-V) can be used in this control mode. Auto-Tune and user selectable PID constants are active in this mode.



R_{SNSR}

Selecting R_{SNSR} will enable the instrument to operate in constant sensor mode when OUTPUT is turned on. In R_{SNSR} mode, the controller output current to the TEC is continuously adjusted to maintain the setpoint sensor resistance (thermistor, RTD), current (IC-I) or voltage (IC-V). Auto-Tune and user selectable PID constants are active in this mode.

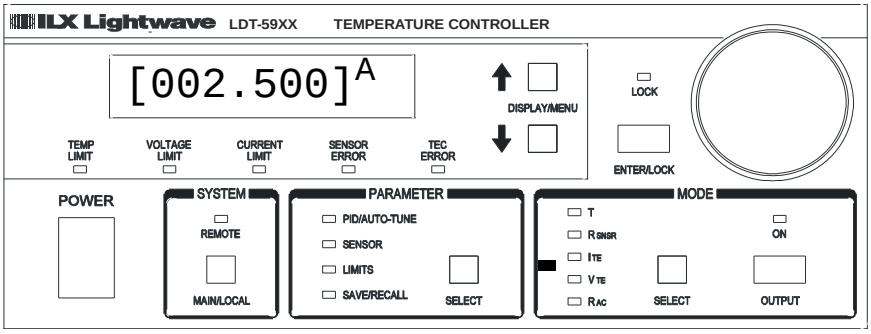


I_{TE} or V_{TE}

Selecting I_{TE} or V_{TE} will enable the instrument to operate in constant TEC current or constant TEC voltage mode when OUTPUT is turned on. In I_{TE} mode, the setpoint current is continuously output to the TEC.

In V_{TE} mode, the controller output current is continuously adjusted to maintain the setpoint voltage across the TEC. VTE mode is intended for applying a constant voltage into a typical TE load (.1□ ≤ R < 2.5□ □

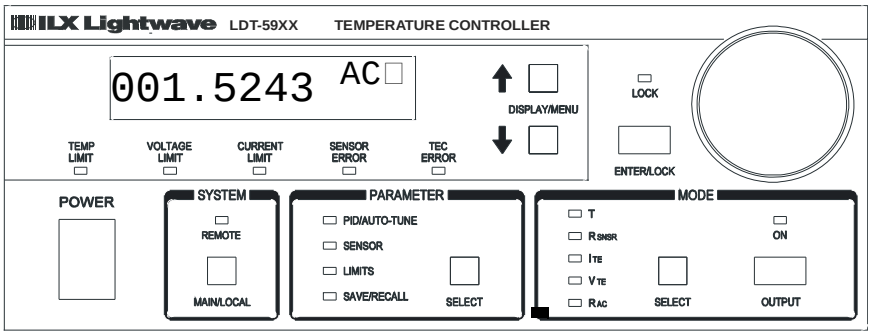
In both I_{TE} and V_{TE} modes, sensor measurements are not used to adjust the output. However, sensor temperature is monitored for the purpose of automatically turning off the output if the user specified limits are exceeded. (See the “Output Off Registers” section in Chapter 3.) Auto-Tune is not available and user selectable PID constants are not used in I_{TE} and V_{TE} modes.



R_{AC}

Selecting R_{AC} mode will enable the instrument to measure the resistance of a TE module. The resistance of the TE module is measured by generation of a pseudo AC current of small amplitude (< 15 mA). A small positive current (Ip) is input to the module for time T and the output voltage (Vpi) across the TE is measured with an ADC. The current is then reversed at the same amplitude (In) for time T, and the output voltage (Vn) across the TE is again sampled by the ADC. The TE resistance R_{AC} is then calculated with the following formula:

$$R_{AC} = .5 * \left[\frac{\sum_{i=10}^{i=1..10} (Vpi / Ip)}{i} - \frac{\sum_{i=10}^{i=1..10} (Vni / In)}{i} \right]$$



To activate this feature, press the OUTPUT key. The instrument will measure and display the resistance of the TE module, and then turn output off.

Basic TEC Operation Instructions

This procedure is for basic setup and operation of the LDT-5900 Series Temperature Controllers. See General Guidelines for Sensor Selection and Safety Limits for detailed information about the specific sensors and control parameters.

1 Connect the appropriate output cable (either the CC595S or the CC591H) to the 25-pin D-sub connector at the back of the LDT-59XX Controller.

2 Connect your thermal load (with TEC and sensor) to output cable, verifying all wiring.

3 Press the SELECT key in the Parameter section until “SENSOR” menu indicator is illuminated

3a Using the up/down arrow keys, select the appropriate sensor and press the ENTER / LOCK key.

3b Using the adjust knob, enter the correct coefficientsand current setting for your sensor and press the ENTER / LOCK key. (The user must press ENTER / LOCK within ten seconds of selecting the value.)

4 Press the SELECT key in the Parameter section until “LIMITS” menu indicator is illuminated.

4a Using the up/down arrow keys, the adjust knob, and ENTER / LOCK key, enter Temperature, Sensor, I_{TE} and V_{TE} limits appropriate for your sensor and application.

5 Verify that no errors are present. If in constant temperature or sensor mode, verify that an appropriate temperature or sensor reading is being measured.

6 Press the SELECT key in the Parameter section until “PID / AUTO-TUNE” indicator is illuminated. Enable the auto-tune function to determine nominal P, I and D coefficients for your thermal load.

7 Press the SELECT key in the Mode section to select constant T, R_{SNSR}, I_{TE} or V_{TE} mode. Using the adjust knob, enter the correct setpoint for your application and press ENTER . LOCK. (The user must press ENTER / LOCK within ten seconds of selecting the value.)

8 Enable OUTPUT on. Actual measured value should move to setpoint value.

General Guidelines for Sensor Selection and Safety Limits

This section presents some guidelines to assist in selecting the optimal settings for your application.

Sensor Options

The LDT-5900 Series Temperature Controllers can measure temperature through a variety of sensor options; thermistors, IC sensors (IC-I, IC-V) or RTDs.

Thermistor - When a thermistor sensor is selected, the LDT-5900 measures temperature based on using a negative temperature coefficient (NTC) thermistor. An NTC thermistor is a device whose resistance decreases as its temperature increases. The controller provides a sense current (100 □A or 10 □A) through the thermistor which results in a voltage across the thermistor. This voltage is used as a feedback signal by the LDT-5900 digital control loop to maintain a constant temperature. The thermistor should be connected across the RT+ and RT- pins, as well as across the RT+_SENSE and RT-SENSE pins.

In constant temperature mode, the quantity that is maintained constant by the module is the sensor resistance. In constant temperature mode (T), the LDT-5900 converts the temperature setpoint to a thermistor resistance setpoint using user defined constants.

The Steinhart-Hart equation is used to convert a temperature to a resistance for thermistor sensors. The equation describes the nonlinear resistance versus temperature characteristics of typical thermistors. Calibrating a thermistor consists of measuring its resistance at various temperatures, and fitting these measured data to the Steinhart-Hart equation. The resulting coefficients C1, C2, and C3 effectively describe the thermistor. More information about the Steinhart-Hart equation is contained in ILX Application Note #4. Contact ILX Customer Service (see page xii for contact information) or go to the ILX website (www.ilxlightwave.com).

To measure the precise temperature of a load, you must use a calibrated sensor. For example, when using a thermistor, enter its Steinhart-Hart coefficients C1, C2, and C3 in the TEC page 3 menu (see Basic TEC Operation Instructions). If the exact temperature is not crucial (within ±1.5 ^{o}C) and you are using a 10 k□□ thermistor, use the default constants provided by the LDT-5900. However, the LDT-5900 temperature accuracy specifications apply only to a calibrated thermistor. For more information about calibrating your thermistor, go to www.ilxlightwave.com/support/index.html and click Technical Solutions.

Thermistor resistance changes with temperature. The LDT-5900 supplies constant current, either 10 □A or 100 □A, through the thermistor so that a temperature change results in a voltage change across the thermistor. This voltage change is sensed by the instrument and fed back to the control loop. The

supply current selection depends on the thermistor operating temperature range and the required temperature resolution. A general rule of thumb for a 10 k□ thermistor is to use the 10 □A range for temperatures between -30 °C and +30 °C, and the 100 □A range for temperatures between 10 °C to 70 °C.

Select the thermistor sense current of 10 □A or 100 □A through the front panel sensor menu. Using 10 □A as the sense current allows you to use a maximum thermistor resistance of 600 k□. The 100 □A setting allows a 60 k□ maximum.

To ensure proper current and thermistor selection, certain principles must be considered:

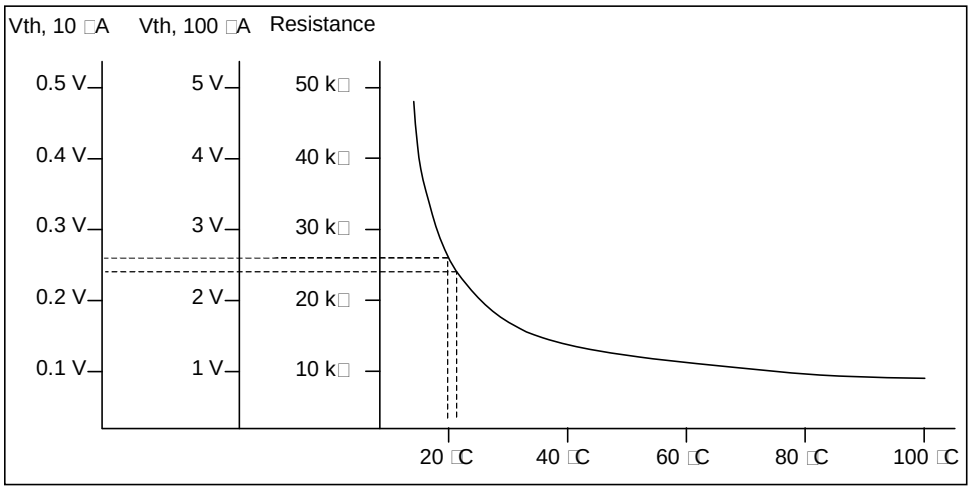
- To ensure measurement accuracy, the voltage across the thermistor must not exceed 6 V.
- To improve control responsiveness and accuracy, the thermistor voltage variations that result when the load temperature deviates from the setpoint must be as large as possible.

  The importance of maximizing voltage variation is shown in Figure 2.7, which shows resistance as a function of temperature for a thermistor. The values shown were selected for simplicity in this example, and may not reflect real thermistor values.

In the example shown in Figure 2.7, the thermistor resistance is 25 k□ at 20 °C. Deviations of 1 °C from 20 °C cause resistance variations of about 2 k□. If using the 10 □A setting, there is 20 mV of feedback to the control circuit. Using the 100 □A setting provides 200 mV of feedback. The larger feedback signal means that the temperature is more precisely controlled.

Notice also that the lower slope of the curve at the higher temperatures results in a smaller feedback signal. It may be necessary, if you are controlling to higher temperatures, to use a thermistor with a different curve.

Figure 2.7 Example Thermistor Resistance vs. Temperature



IC-I Sensors - When an IC-I sensor is selected, the LDT-5900 measures temperature based on the current delivered by the sensor. An example of an IC-I sensor is the Analog Devices AD590. This device delivers 1□A/K or approximately 298 □A at 25°C.

The (+) terminal of the transducer should be connected to the RT+ pin and the (-) terminal should be connected to RT-. The RT+_SENSE and RT-_SENSE pins should NOT be connected when using this device. The nominal slope for the AD590 is 1□A/K and the offset is nominally 0□A but both can be adjusted to calibrate your particular sensor by entering the PARAMETER/SENSOR menu. The sensor will have approximately 9V across it at 25°C but will vary over the temperature range.

In IC-I sensor mode, the LDT-5900 has a sensor current limit of 600 □A (approximately 325 °C).

IC-V Sensors - When an IC-V sensor is selected, the LDT-5900 measures temperature based on the voltage delivered by the sensor. An example of an IC-V sensor is the National Semiconductor LM335A. This device delivers 10mV/K or approximately 2.98V at 25°C.

The (+) terminal of the transducer should be connected to the RT+ pin and the (-) terminal should be connected to RT-. The RT+_SENSE and RT-_SENSE pins should NOT be connected when using this device. The nominal slope for the LM335A is 10mV/K and the offset is nominally 0mV but both can be adjusted to calibrate your particular sensor by entering the PARAMETER/SENSOR menu. The sensor will have approximately 1mA of current through it at all times.

In IC-V sensor mode, the LDT-5900 has a sensor voltage limit of 6V (525.00 °C).

RTD Sensors - When an RTD sensor is selected, the LDT-5900 measures temperature based on the resistance. An example of an RTD sensor is the Xian Diamond USA T2001SDL. This device has a positive slope and a nominal resistance at 0 °C of 100 ohms.

Two wire RTDs should be connected across the RT+ and RT- pins, as well as across the RT+_SENSE and RT-_SENSE pins. Three wire RTDs are connected similarly to the two wire, except that the third wire is specifically dedicated to the RT-_SENSE pin.

The resistance versus temperature function for typical platinum RTDs is accurately modeled by the Callendar-Van Dusen equation, as shown below.

$R_T = R_0 (1 + AT + BT^2 + 100CT^3 + CT^4)$

Where :

R_0 = Resistance (□) at 0°C

R_T = Resistance (□) at temperature T (°C)

T = Temperature in °C

The A, B, and C, are derived from resistance measurements at 0, 100 °C and 260 °C, and are defined as follows:

A = □ + (□ *□)/100

B = (-□ * □)/100^2

$C_{T<0}$ = (-□ * ß)/100^4

where: □ = R_{100} - R_0 / 100 * R_0

ß = Constant for T < 0 C

□= R_0 * (1 + □ * 260) - R_{260} / 4.16 * R_0 * □

For temperatures greater than 0 °C, the 5900 controller derives the temperature by solving the following quadratic equation:

$$T = \frac{-R_0A + w\ (R_0^2A^2 - 4R_0B(R_0 - R_T))}{2R_0B}$$

These sensor coefficients (A, B, C and R_0) are required for the LDT-5900 to accurately report the temperature when utilizing an RTD sensor. Typical RTDs have a nominal resistance (R_0) of 100 or 1000 ohms.

Common Callendar-Van Dusen constants are listed below and are used as default values in the LDT-5900.

- A($^oC^{-1}$) = 3.908 x 10^{-3}
- B($^oC^{-2}$) = -5.775 x 10^{-7}
- C($^oC^{-4}$) = -4.183 x 10^{-12}

For optimal accuracy and stability, the 1mA current source should be selected for RTD sensors with resistance of 1 to 6000 ohms. In general, the change in resistance per change in temperature is much lower for a typical 100 □ RTD than that of a typical 10 k□ thermistor. The proportional and integral terms for the PID loop must be increased appropriately when using an RTD sensor for optimal setting time and stability.

Setting Safety Limits

TEC modules can be damaged by excessive current, and module manufacturers typically specify a maximum safe operating current for their module. The LDT-5900 provides a current limit feature that allows you to set the maximum current

that the controller supplies. See “Limits” under the Parameter section in Chapter 2 to set the appropriate limits for your TE.

It is normal for the controller to operate at the current limit, especially when the load temperature is far from the setpoint. The current limit LED will illuminate green when the controller is in a current-limit condition.

If the heatsink is too small for the application, the heatsink eventually becomes heat saturated condition where heat is being transferred to the heatsink faster than the heatsink can dissipate the heat. When the heatsink becomes saturated, the TEC current increases in an attempt to cool the load; this additional current creates more heat than can be dissipated and subsequently, more TEC current is applied. This situation is sometimes referred to as *thermal runaway*, and can cause a load and TEC to become damaged. The current limit LED will illuminate RED in a thermal runaway condition, (i.e. the current is running at its limit and the temperature is moving away from the setpoint).

To help avoid thermal runaway damage, the LDT-5900 Series Temperature Controller provides a high-temperature limit setting. When the load temperature exceeds the High Temperature setting, the LDT-5900 turns off the TEC current and generates an error. Using GPIB, you can disable the high-temperature limit from turning off the controller. See Chapter 3, Output Off Registers and Chapter 4, Command Reference for more information about disabling or enabling conditions that turn off the controller.

Default Settings

When you select Default from the Recall menu, the LDT-5900 Series Temperature Controller returns to the following settings:

Output:	Off
Mode:	Constant-Temperature
Temperature Setpoint:	25 °C
TEC Current Setpoint:	1.0 A
Current Limit High:	+ 2.5A
Current Limit Low:	- 2.5A
Temperature Limit High:	60 °C
Temperature Limit Low:	0 °C
Resistance Setpoint:	10 k□
P, I, D:	20, 0.8, 1.0
Sensor:	Thermistor
Voltage Limits:	± 12.0 V
Tolerance:	0.005
Sensor Limits:	0.010 k□ □□100.0 k□
Display:	100%
Beep:	On
Trig In:	Disabled, Start: 0 °C; Stop: 60 °C; Step: 1 °C
Trig Out:	Delay 0.0 sec
Sensor Current:	100 □A
C1:	1.125 (x 10-3)
C2:	2.347 (x 10-4)
C3:	0.855 (x 10-7)

Retrieving Default Settings

See Chapter 3, Remote Operations for remote execution of the Save and Recall functions.

1. Select **Sav/Rec** to access the Save/Recall Config. menu.
2. Recall 0 contains the factory default settings.

CHAPTER 3

REMOTE OPERATIONS

Everything you can do from the front panel can also be done remotely, and in some cases, with more flexibility. For instance, in remote mode you have access to commands for functions not found on the front panel. The following sections show you the fundamentals of operating your LDT-5900 module remotely through the General Purpose Interface Bus (GPIB) and RS-232 interfaces.

Remote Configuration

GPIB Configuration

GPIB (General Purpose Interface Bus) is the common name for ANSI/IEEE Standard 488.2 1987, an industry standard for interconnecting test instruments in a system. Before you can operate the LDT 5900 Series Temperature Controller from a remote location with GPIB, you need to know its GPIB address. The following sections describe reading and changing the GPIB address.

Reading the GPIB Address

Press the MAIN/LOCAL key in the system section of the front panel to view the "System Menu". Page 1 of the System Menu is the Communications menu, and GPIB address will be displayed in the GPIB field directly under this menu.

Changing the GPIB Address

Every device on the GPIB bus must have a unique address. The default address from the factory is address "01". If it is necessary to change the address, press the MAIN/LOCAL key in the System section of the front panel. Page 1 displays the Communications menu. The "GPIB Address" can be changed by turning the adjust knob until the desired address value is displayed, and then press the "ENTER/LOCK" key. The new GPIB address will then be stored in non-volatile memory. The allowable address range is 0 - 30.

RS-232 Configuration

Before you can operate the LDT-5900 Series Temperature Controller over RS-232, you need to select the baud rate. The instrument's baud rate setting must match the baud rate used by the host controller serial RS-232 interface, which is typically a serial COMM port on your PC. The following sections describe reading and changing the baud rate.

The LDT-5900 Series Temperature Controller's RS-232 is configured for 8-bit, no parity, no flow control, and one stop bit. This is not adjustable. Only the baud rate may be altered.

Reading the Baud Rate

Press the MAIN/LOCAL key in the system section of the front panel to view the "System Menu". Page 1 of the System Menu is the Communications Menu. Press the down arrow key and the RS-232 baud rate will be displayed.

Changing the Baud Rate

The factory default baud rate is 9600. The allowable baud rates are 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200, and 230400. Refer to the serial port configuration of your PC (if used) for the allowable baud rates. If it is necessary to change the baud rate, press the MAIN/LOCAL key in the System section of the front panel. Page 1 displays the Communications menu. Press the down arrow to select the RS-232 Baud field. The baud rate can be changed by turning the adjust knob until the desired baud rate is displayed and then press the "ENTER/LOCK" key. The baud rate will then be stored in non-volatile memory.

Remote Communication

This section contains information about changing operation from local to remote, GPIB vs RS-232 communication, the command set, command syntax, and error and status registers. Before remote communications are initiated, be sure to configure the GPIB or RS-232 as described above. Refer to Chapter 4, Command Reference, for information about specific commands.

Changing Operation from Local to Remote

Sending a command over the GPIB or RS-232 interface will automatically put the instrument in REMOTE mode. The REMOTE indicator in the SYSTEM section of the front panel will illuminate when the controller is in remote operation mode. When in REMOTE mode, all buttons and the knob are disabled, except for the MAIN/LOCAL button. When the instrument is in REMOTE mode, pressing the MAIN/LOCAL button on the front panel returns the instrument to LOCAL control mode and re-enables front panel input.

GPIB Versus RS-232 Communication

The LDT-5900 Series Temperature Controller should not be run remotely via GPIB and RS-232 at the same time. When using the RS-232 interface, the remote GPIB command set is fully operable. Command syntax does not vary between GPIB and RS-232 usage. However, the commands which affect GPIB hardware operation will not be useful. For example, the user could send the "*SRE" command via RS-232. However, any service request (SRQ) via GPIB would not be visible since RS-232 has no hardware to support it. This is because SRQ is a function of the GPIB interface hardware and is not available via RS-232.

All commands received by the RS-232 interface are acknowledged by the LDT-5900 transmitting "Ready" when the command operation is complete. Queries are acknowledged by the specific query response message. Multiple commands/queries separated by semicolons and issued as one command string are only acknowledged with a "Ready" response if the entire command string contains no queries. (See the Command Separators section later in this chapter for additional details.) The LDT-5900 terminates all RS-232 transmitted responses with <CR><LF> (Carriage Return - Line Feed) characters. The LDT-5900 expects all commands/queries sent via the RS-232 interface to be terminated with any of the following characters: <CR> (Carriage Return), <LF> (Line Feed), or ASCII 250 character (Hex 0xFA).

Command Syntax

This section describes command syntax and structure. You need this information to effectively write GPIB or RS-232 control programs. The syntax of GPIB commands follow the rules defined in the ANSI/IEEE 488.2-1987 standard.

Letters

Any GPIB or RS-232 command or query must contain all of the letters that are shown in upper case in the command definition, though they do not need to be typed in upper case. Some of the device dependent commands include optional letters shown in lower case in the command reference (Chapter 4, Command Reference). Letter case does not matter. Lower case characters are used in this manual to identify optional letters; although, the optional letters must be in the correct sequence. Some examples of what does, and does not, work:

Okay	Not Okay
DISP	DS
Disp	dsp
Displ	dply
Displa	DSPLY
Display	disply

White Space

White space is normally the space character (space bar). A single white space must separate a command from its parameters or data. For example:

Okay	Not Okay
DELAY 500	DELAY500

To enhance readability, you can use one or more white spaces before a comma, semicolon, or terminator. Since a computer normally puts the terminator at the end of each command string (line), an extra space character at the end of the command line does not affect the command string.

A query has no space between the mnemonic and the question mark. For example:

Okay	Not Okay
TIMER?	TIMER ?

Note: Too many consecutive white spaces can overflow the 80-byte data I/O buffer.

Terminators

A program message terminator identifies the end of a command string. These are the valid terminator sequences:

- <NL>
- <^END>
- <NL><^END>

Many computers terminate with <CR><NL><^END> (Carriage Return - New Line - EOI). A carriage return (<CR>) is read as a white space. The LDT-5900 terminates its responses with <NL><^END>.

Command Separators

You can put more than one command on the same line (same command string) if you separate them with a semicolon.

Note: The semicolon can be preceded by one or more spaces. Examples:

```
MEAS:T?; output?
```

Note: White space after a trailing semicolon will result in an error if no command follows it.

```
MODE T; set:T 35.450 ; const:therm 1.125, 2.347, 0.855;
output ON
```

Parameters

Some commands require a parameter. The parameter must be separated from the command by at least one space.

The syntax symbol <`nrf value`> refers to the flexible numeric representation defined by the GPIB standard. It means that you can represent numbers in integer or floating point form, or in engineering/scientific notation. The IEEE-488.2 standard uses the names NR1, NR2, and NR3 respectively to denote "integer", "floating point", and "scientific notation". For example the number "twenty" may be represented by any of the following ASCII strings:

Integer	20	+20	NR1
Floating point	20.0	+20.0	NR2
Scientific notation	2.0E+1 2.0e+1	+2.0E+1 +2.0e+1	NR3

There are no default values for omitted parameters. If a command is expecting a parameter and none is entered, an error is generated.

Resolution

All queries to the LDT-5900 Series Temperature Controllers that return a numerical value will have nine (9) significant degits to the right of the decimal point.

For further clarity in programming, the (Boolean) values of one (1) and zero (0) may be used or their names as indicated in the following table.

Table 3.1 Substitute Parameter Names

SUBSTITUTE NAME	VALUE
ON	1
OFF	0
TRUE	1
FALSE	0
SET	1
RESET	0

If multiple parameters are expected, they must be separated with commas. For example, to set the Steinhart-Hart constants (C1, C2, and C3) for a thermistor, the following command may be sent:

```
CONST:THERM 1.111, 2.004, 0.456
```

Table 4.1 on page 31 lists the LDT-5980/5948 commands, with the full path shown for each command and a brief explanation of its usage.

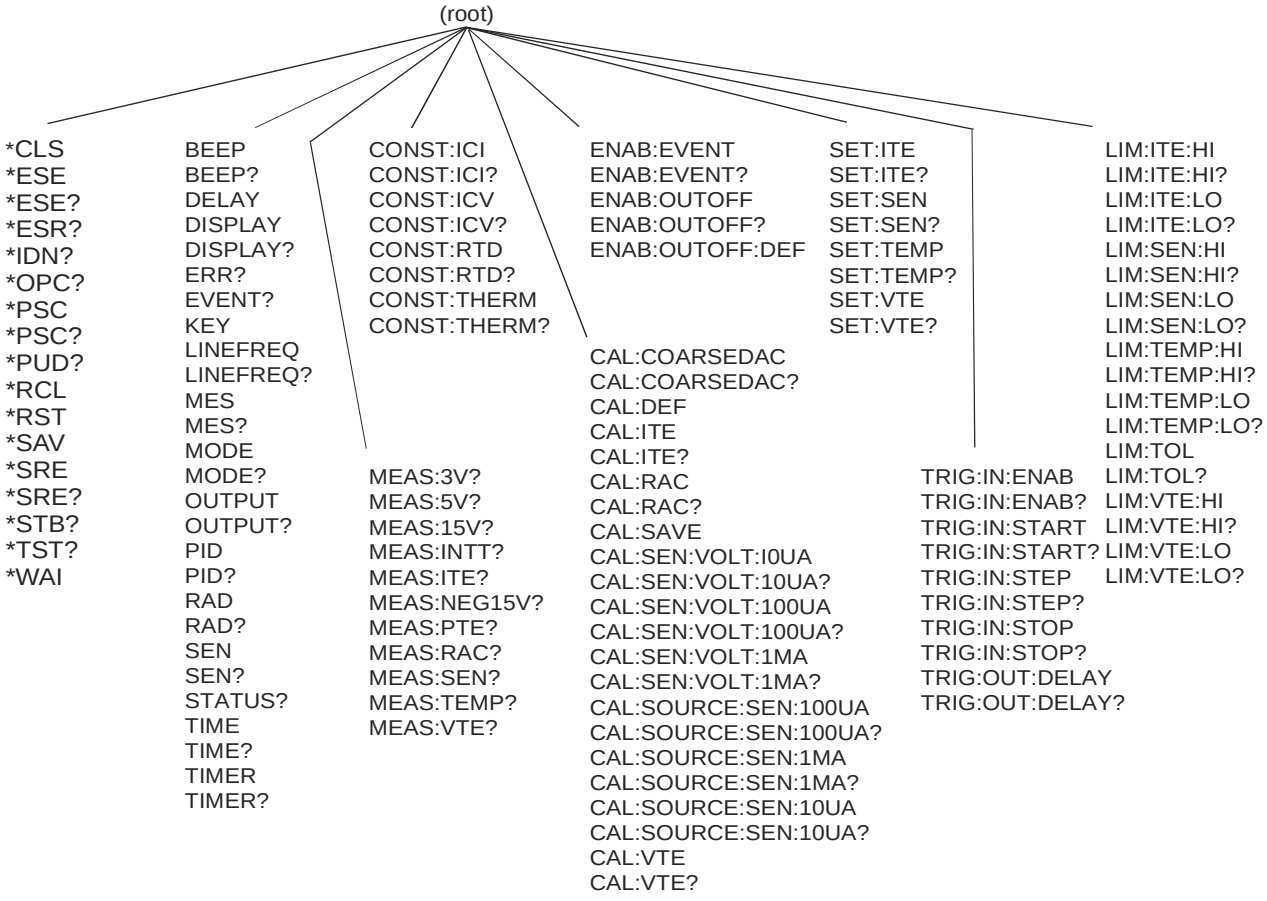


Figure 3.1 LDT-5900 Command Path Structure

Syntax Summary

GPIB or RS-232 commands must contain all of the letters shown in upper case in the command definition. Optional letters shown in lower case for some device dependent commands in the command reference are useful for clarity, but must be in the correct sequence.

A single white space must separate a command from its parameters or data. White space is normally the space character (space bar). Other control characters are also interpreted as white space.

Note: Do not use white space before the question mark in a query command.

If you encounter problems with remote communications, the terminator string can be the cause. The instrument accepts <NL>, or <^END>, or <NL><^END> as a command line terminator. Many computers terminate with <CR> <NL> <^END> (Carriage Return - New Line - EOI). The instrument ignores the <CR> (Carriage Return) and treats it as white space.

You can put more than one command on the same line (same command string) if you separate them with a semicolon.

GPIB uses a flexible representation for numeric parameters: integer, floating point, or engineering/scientific notation. There are no default values for omitted parameters.

Some device-dependent GPIB commands are compound commands, in which the first mnemonic opens a path to a set of commands relating to that path. The second mnemonic then defines the actual command.

Table 3.2 shows examples of invalid syntax command strings that produce errors:

Table 3.2 Invalid Syntax Command Strings

COMMAND	COMMENT
`MODE`	Missing ?, MODE? expected.
`MODE T DEC`	Missing semicolon, DEC command generates an error.
`DISP ?`	Space not allowed before question mark, DISP? command expected.

IEEE 488.2 Common Commands

IEEE 488.2 Common Commands and Queries are distinguished by the "*" which begins each mnemonic. The diagrams below show the syntax structure for common commands, common command queries, and common commands with numeric data required.

Numeric data is required with *PSC (1 = on, 0 = off), *RCL (0 to 9, see Save and Recall on page 15), *SAV (1 to 9, see Save and Recall on page 15), *ESE (0 to 255, see page 34), *SRE (0 to 255, see page 38), and *PUD (used at factory only).

The instrument self-test query *TST? will always return 0 since no self-test routine is incorporated into the unit.

A list of all of the IEEE 488.2 Common Commands supported by the LDT-5900 Series Temperature Controllers follows.

*CLS	*ESE	*ESE?
*ESR?	*IDN?	*OPC
*OPC?	*PSC	*PSC?
*PUD	*PUD?	*RCL
*RST	*SAV	*SRE
*SRE?	*STB?	*TST?
*WAI		

Command Timing

This section describes, for each command, whether the command is performed in an overlapped or sequential manner. Command timing states whether the next command can begin while another command is being executed, or if the next command must wait until this command is completed before its execution begins. See Operation Complete Definition on page 40 for information about the operation complete flag.

Sequential/Overlapped Commands

All common commands for the LDT-5900 Series Temperature Controllers are sequential and most device-dependent commands are executed after the previous command is complete.

The *WAI (common command) is an example of a sequential command which forces the next command to wait until the no-operation-pending flag is true. This is essentially the same as waiting for the OPC flag to become true, because the no-operations-pending flag is used to set the OPC flag (bit 0 of the Standard Event Status Register).

Query Response Timing

Query responses are evaluated at the time the query request is parsed, and not at the time the response message is sent. In most cases this does not create a problem since the time between parsing a query and sending its response is small.

However, due to latency of new measurements being available, we recommend waiting at least one second after changing any sensor parameter or output condition before querying temperature measurements, sensor measurements or status. Likewise wait one second to turn the output on after changing any sensor parameter.

Status Reporting

The following sections discuss the LDT-5900 status reporting, including the “STATUS”, “EVENT”, “ENABLE:EVENT” and “ENABLE:OUTOFF” commands and queries. The Event REgisters are used to report when status bits get set and the Output Off Registers are used to specify the conditions that force the controller output to turn off. Refer to Chapter 4, Command REference, in this guide for more information about issuing these commands.

Status Registers

The Status Registers report the current state of the temperature controller operation and the sensors. A host controller program must poll the LDT-5900, using the "STATUS?" query, to access these registers. The bits of the two 16-bit registers are defined as shown in Table 3.3 and 3.4.

Table 3.3 LDT-5900 Status Registers: Status Register 0

Bit Number	Condition	Decimal Value
0	Upper Temperature Limit	1
1	Lower Temperature Limit	2
2	Sensor Open	4
3	Sensor Shorted	8
4	TEC Current Upper Limit	16
5	TEC Current Lower Limit	32
6	TEC Voltage Upper Limit	64
7	TEC Voltage Lower Limit	128
8	TEC Open	256
9	TEC Shorted	512
10	Auto-Tune in Progress	1024
11	Sensor Upper Limit	2048
12	Sensor Lower Limit	4096
13	3V PCB Supply Out of Tolerance	8192
14	5V PCB Supply Out of Tolerance	16384
15	15V PCB Supply Out of Tolerance	32768

Table 3.4 LDT-5900 Status Registers: Status Register 1

Bit Number	Condition	Decimal Value
0	RAC Measurement Complete	1
1	Reserved	2
2	Output On	4
3	Measurement Within Setpoint Tolerance	8
4	Measurement Out of Setpoint Tolerance	16
5	Reserved	32
6	Reserved	64
7	Reserved	128
8	Reserved	256
9	Internal PCB Temperature Over Limit	512
10	Invalid Calibration Data	1024
11	DSP Reset	2048
12	TEC Temperature Runaway	4096
13	Reserved	8192
14	-15V PCB Supply Out of Tolerance	16384
15	Reserved	32768

Event Registers

The Event Registers report the temperature controller and sensor events that have occurred since power-on, or since the previous read of the Event Registers. A host controller program must use the “EVENT?” query, to access these registers. The EVENT? query will also clear the contents of the Event Registers. The bits of the two 16-bit registers correspond to the bits in the Event Enable Registers shown in Tables 3.5 and 3.6.

In most applications, the Event Registers are used in conjuncion with the Event Enable Registers to alery an instrument controller on the GPIB bus that a certain condition (i.e. Upper Temperature Limit) has occurred. The user should first set the desired event bits in the Event Enable Registers using the “ENABLE:EVENT” command. Then enable GPIB Service Request generation (see the *SRE command in Chapter 4). The instrument will then generate a GPIB Service Request (SRQ) when any of the specified conditions occur. Use the EVENT? query to determine which event(s) caused the SRQ. The user must clear the Event Registers with the EVENT? query to re-enable SRQ generation for the nabled event(s).

The Event Registers bits are set (and, if enabled, the SRQ is generated) only when the enabled event condition transitions from the false state to the true state. For example, if the Upper Temperature Limit event bit is enabled, the SRQ will be generated when the measured temperature goes from in limit to over limit. If the measured temperature stays over limit after the event is acknowledged (by clearing the Event Registers with the EVENT? query) the next SRQ will only be generated after the temperature returns to the in limit state and then again goes over limit.

It is not necessary to enable event bits using the ENABLE:EVENT command to use the Event Registers. The EVENT? query will return the correct state of the event bits regardless of which bits are enabled in the Event ENable REgisters. Only the generation of Service Requests and the state of the summary bit in the *STB Register (see Chapter 4) are affected by the ENABLE:EVENT command.

Table 3.5 LDT-5900 Event Register Contents: Event Register 0

Value = 1 Event is enabled

Value = 0 Event is disabled

Bit Number	Condition	Default Value	Decimal Value
0	Upper Temperature Limit	1	1
1	Lower Temperature Limit	1	2
2	Sensor Open	1	4
3	Sensor Shorted	1	8
4	TEC Current Upper Limit	0	16
5	TEC Current Lower Limit	0	32
6	TEC Voltage Upper Limit	0	64
7	TEC Voltage Lower Limit	0	128
8	TEC Open	0	256
9	TEC Shorted	0	512
10	Auto-Tune in Progress	0	1024
11	Sensor Upper Limit	1	2048
12	Sensor Lower Limit	1	4096
13	3V PCB Supply Out of Tolerance	0	8192
14	5V PCB Supply Out of Tolerance	0	16384
15	15V PCB Supply Out of Tolerance	0	32768

Table 3.6 LDT-5900 Event Register Contents: Event Register 1

Bit Number	Condition	Default Value	Decimal Value
0	RAC Measurement Complete	0	1
1	Reserved	0	2
2	Output On	0	4
3	Measurement Within Setpoint Tolerance	0	8
4	Measurement Out of Setpoint Tolerance	0	16
5	Reserved	0	32
6	Reserved	0	64
7	Reserved	0	128
8	Reserved	0	256
9	Internal PCB Temperature Out of Tolerance	0	512
10	Invalid Calibration Data	0	1024
11	DSP Reset	0	2048
12	TEC Temperature Runaway	0	4096
13	Reserved	0	8192
14	-15V PCB Supply Out of Tolerance	0	16384
15	Reserved	0	32768

Output Off Registers

The Output Off Enable Registers allow the user to specify the conditions which will cause the temperature controller output to automatically turn off. A host controller program must issue the "ENABLE:OUTOFF" command and query, to access these registers. The bits of these two registers correspond to the bits of the Status Registers and are defined in Table 3.7 and Table 3.8. No error is reported if the controller output is turned off due to one of these conditions occurring. However, if the user attempts to turn output on while an Output Off Enable condition presently exists (i.e. temperature over limit) then an error will be reported and the request to turn output on will be aborted. The default (factory) settings for the Output Off Enable Registers are also shown in Table 3.7 and 3.8. These registers are not affected by the *PSC (Power-On Status Clear) command.

Table 3.7 LDT-5900 Output Off Register Contents: Output Off Enable Register 0

Value = 1 Output Off is enabled

Value = 0 Output Off is disabled

Bit Number	Condition	Default Value	Decimal Value
0	Upper Temperature Limit	0	1
1	Lower Temperature Limit	0	2
2	Sensor Open	0	4
3	Sensor Shorted	0	8
4	TEC Current Upper Limit	0	16
5	TEC Current Lower Limit	0	32
6	TEC Voltage Upper Limit	0	64
7	TEC Voltage Lower Limit	0	128
8	TEC Open	1	256
9	TEC Shorted	1	512
10	Auto-Tune in Progress	0	1024
11	Sensor Upper Limit	0	2048
12	Sensor Lower Limit	0	4096
13	3V PCB Supply Out of Tolerance	0	8192
14	5V PCB Supply Out of Tolerance	0	16384
15	15V PCB Supply Out of Tolerance	0	32768

Table 3.8 LDT-5900 Output Off Register Contents: Output Off Enable Register 1

Bit Number	Condition	Default Value	Decimal Value
0	Reserved	0	1
1	Reserved	0	2
2	Reserved	0	4
3	Reserved	0	8
4	Measurement Out of Setpoint Tolerance	0	16
5	Reserved	0	32
6	Reserved	0	64
7	Reserved	0	128
8	Reserved	0	256
9	Internal PCB Temperature Out of Tolerance *	1	512
10	Reserved	0	1024
11	Reserved	0	2048
12	TEC Temperature Runaway	0	4096
13	Reserved	0	8192
14	Reserved	0	16384
15	Reserved	0	32768

* This bit cannot be cleared.

Error Messages

This section contains descriptions of the errors that are specific to the LDT-5900.

Testing for Errors in Remote Operation

For more information about specific GPIB commands, see Chapter 4, Command Reference.

1 Send the query ERR? to read the system errors.

Table 3.9 Error Codes

Range	**Area of Operation**
E-100 to E-199	Command / Parser Errors
E-200 to E-299	Execution Control Errors
E-300 to E-399	Remote Operation Errors
E-400 to E-499	TEC Control Errors
E-700 to E-799	System Errors
E-800 to E-899	Internal Errors
Error Code	**Explanation**
0	No errors found
123	Command not found
124	Look-up failed because query / command match failed
125	Parser syntax error
126	End of data error
127	Invalid parameter for command
130	Query not supported
131	Command not supported
201	Parameter value out of range
202	Error in conversion of parameter type
203	Command is a "secure" command, but secure commands are disabled
214	Response is too long to output
226	Error in arbitrary block specification
228	Delimiter not found
230	Invalid internal response
301	No data found error
302	Not empty error

Table 3.9 Error Codes

Error Code	Explanation
401	Controller output off error
402	Calibration failed
403	DSP reset failed
404	Calibration constant error
405	Invalid sensor error
407	Invalid mode error
408	DSP controller communication failure
410	Upper Temperature Limit caused controller output to turn off
411	Lower Temperature Limit caused controller output to turn off
412	Open sensor caused controller output to turn off
413	Shorted sensor caused controller outputcontroller output to turn off
414	Upper Current Limit caused controller output to turn off
415	Lower Current Limit caused controller output to turn off
416	Upper Voltage limit caused controller output to turn off
417	Lower Voltage Limit caused controller output to turn off
418	Open TEC Module caused controller output to turn off
419	Shorted TEC Module caused controller output to turn off
420	Sensor over resistance caused controller output to turn off
421	Sensor under resistance caused controller output to turn off
422	Plus 3V supply out-of-tolerance condition caused controller output to turn off
423	Plus 5V supply out-of-tolerance condition caused controller output to turn off
424	Plus 15V supply out-of-tolerance condition caused controller output to turn off
425	Measurement out of setpoint tolerance caused controller output to turn off
426	PCB Temperature out-of-tolerance caused controller output to turn off
427	Invalid calibration data caused controller output to turn off
428	DSP reset caused controller output to turn off
429	Current limit and thermal runaway caused controller output to turn off
430	Cable change caused controller output to turn off
431	Neg 15V supply out-of-tolerance condition caused controller output to turn off
432	Setpoint over upper limit caused controller output to turn off
433	Setpoint under lower limit caused controller to turn off
714	Display error
715	Logic error
821	Command handler couldn’t send message
832	UART received bad length byte

Table 3.9 Error Codes

Error Code	Explanation
850	Internal mail list access list failed
851	Unknown TEC ID command
854	Invalid UART ID
855	UART transmit buffer overflow
856	UART receive buffer overflow

CHAPTER 4

COMMAND REFERENCE

This chapter is a reference for all of the remote GPIB and RS-232 commands for the LDT-5900 Series Temperature Controllers. It contains an overview of the commands, shown in Table 4.1, as well as detailed command descriptions, listed in alphabetical order.

GPIB Commands

Table 4.1 GPIB Command Summary Reference List

NAME	Parameters	FUNCTION
BEEP	1	Used to turn beep function on or off
BEEP?	none	Queries the state of the beep function
CAL:COARSEDAC	2	Enters the Coarse DAC calibration coefficients
CAL:COARSEDAC?	none	Queries the Coarse DAC calibration coefficients
CAL:DEFault	none	Resets all calibration coefficients to default (uncalibrated) values
CAL:ITE	2	Enters TE current coefficients
CAL:ITE?	none	Queries the TE current coefficients
CAL:RAC	2	Enters TE AC resistance calibration coefficients
CAL:RAC?	none	Queries the TE AC resistance calibration coefficients
CAL:SAVE	none	Saves all calibration data in non-volatile memory
CAL:SENsor:VOLTage:10UA	2	Enters the temperature sensor voltage calibration coefficients for the 10 □A current setting
CAL:SENsor:VOLTage:10UA?	none	Queries the temperature sensor voltage calibration coefficient for the 10 □A current setting
CAL:SENsor:VOLTage:100UA	2	Enters the temperature sensor voltage calibration coefficients for the 100 □A current setting
CAL:SENsor:VOLTage:100UA?	none	Queries the temperature sensor voltage calibration coefficient for the 100 □A current setting
CAL:SENsor:VOLTage:1MA	2	Enters the temperature sensor voltage calibration coefficients for the 1mA current setting
CAL:SENsor:VOLTage:1MA?	none	Queries the temperature sensor voltage calibration coefficient for the 1 mA current setting
CAL:SOURCE:SENsor:10UA	1	Enters the 10 □A sensor current calibration coefficient
CAL:SOURCE:SENsor:10UA?	none	Queries the 10 □A sensor current calibration coefficient
CAL:SOURCE:SENsor:100UA	1	Enters the 100 □A sensor current calibration coefficient
CAL:SOURCE:SENsor:100UA?	none	Queries the 100 □A sensor current calibration coefficient
CAL:SOURCE:SENsor:1MA	1	Enters the 1 mA sensor current calibration coefficient

Table 4.1 GPIB Command Summary Reference List

NAME	Parameters	FUNCTION
CAL:SOURCE:SENsor:1MA?	none	Queries the 1 mA sensor current calibration coefficient
CAL:VTE	2	Enters the TE voltage calibration coefficients
CAL:VTE?	none	Queries the TE voltage calibration coefficients
*CLS	none	Resets the Standard Event Status Register, Status Byte Register and Error Queue to zero
CONST:ICI	2	Enters the IC-I sensor coefficients
CONST:ICI?	none	Queries the IC-I sensor coefficients
CONST:ICV	2	Enters the IC-V sensor coefficients
CONST:ICV?	none	Queries the IC-V sensor coefficients
CONST:RTD	4	Enters the RTD sensor coefficients
CONST:RTD?	none	Queries the RTD sensor coefficients
CONST:THERMistor	3	Enters the thermistor Steinhart-Hart coefficients
CONST:THERMistor?	none	Queries the thermistor Steinhart-Hart coefficients
DELAY	1	Executes a GPIB delay (in ms)
DISPlay	1	Used to turn front panel display on or off
DISPlay?	none	Queries the status of the front panel display
ENABle:EVENT	2	Enters the values for the Event Enable Registers
ENABle:EVENT?	none	Queries the contents of the Event Enable Registers
ENABle:OUTOFF	2	Enters the value for the Output Off Enable Registers
ENABle:OUTOFF?	none	Queries the contents of the Output Off Enable Registers
ENABle:OUTOFF:DEFault	none	Resets Output Off Enable REgisters to factory default values
ERRors?	none	Queries the error codes in the Error Queue
*ESE	1	Enters the value for the Standard Event Status Enable Register
*ESE?	none	Queries the Standard Event Status Enable Register
*ESR?	none	Queries the Standard Event Status Register
EVENT?	none	Queries the contents of the Event Registers
*IDN?	none	Returns the device identification information
KEY	1	Initiates a front panel key press or knob turn
LIMit:ITE:HIgh	1	Enters the upper TE current limit setting
LIMit:ITE:HIgh?	none	Queries the upper TE current limit setting
LIMit:ITE:LOw	1	Enters the lower TE current limit setting

Table 4.1 GPIB Command Summary Reference List

NAME	Parameters	FUNCTION
LIMit:ITE:LOw?	none	Queries the lower TE current limit setting
LIMit:SENsor:HIgh	1	Enters the upper sensor limit setting
LIMit:SENsor:HIgh?	none	Queries the upper sensor limit setting
LIMit:SENsor:LOw	1	Enters the lower sensor limit setting
LIMit:SENsor:LOw?	none	Queries the lower sensor limit setting
LIMit:Temp:HIgh	1	Enters the upper temperature limit setting
LIMit:Temp:HIgh?	none	Queries the upper temperature limit setting
LIMit:Temp:LOw	1	Enters the lower temperature limit setting
LIMit:Temp:LOw?	none	Queries the lower temperature limit setting
LIMit:TOLerance	none	Enters the setpoint tolerance
LIMit:TOLerance?	none	Queries the setpoint tolerance
LIMit:VTE:HIgh	1	Enters the upper TE voltage limit setting
LIMit:VTE:HIgh?	none	Queries the upper TE voltage limit setting
LIMit:VTE:LOw	1	Enters the lower TE voltage limit setting
LIMit:VTE:LOw?	none	Queries the lower TE voltage limit setting
LINEfreq	1	Enters the line frequency filter (50 or 60 Hz)
LINEfreq?	none	Queries the line frequency filter setting
MEASure:3Volts?	none	Queries the measured 3V PCB supply voltage
MEASure:5Volts?	none	Queries the measured 5V PCB supply voltage
MEASure:15Volts?	none	Queries the measured 15V PCB supply voltage
MEASure:IADC?	none	Queries the internal TE current sensor
MEASure:INTTemp?	none	Queries the measured internal temperature
MEASure:ITE?	none	Queries the measured TE current
MEASure:NEG15Volts?	none	Queries the measured -15V PCB supply voltage
MEASure:PTE?	none	Queries the measured TE power
MEASure:RAC?	none	Queries the measured TE AC resistance
MEASure:SENsor?	none	Queries the measured sensor R, □A or mV
MEASure:Temp?	none	Queries the measured sensor temperature
MEASure:VTE?	none	Queries the measured TE voltage
MESsage	1	Enters an ASCII string into non-volatile memory
MESsage?	none	Queries the ASCII message string
MODE	1	Selects the instrument's control mode
MODE?	none	Queries the instrument's control mode
*OPC	none	Sents the Operation Complete status when all overlapped commands are completed
*OPC?	none	Queries the status of all overlapped commands
OUTPUT	1	Turns the controller output on or off

Table 4.1 GPIB Command Summary Reference List

NAME	Parameters	FUNCTION
OUTPUT?	none	Queries the state of the controller output
PID	3	Enters the P, I and D constants
PID?	none	Queries the P, I and D constants
*PSC	1	Enables power-on status and event clearing
*PSC?	none	Queries the power-on clear status
*PUD	1	Enters the program user data
*PUD?	none	Queries the contents of the user data
RADix	1	Enters the radix of returned integer values
RADix?	none	Queries the radix of returned integer values
*RCL	1	Recall a stored setup configuration
*RST	none	Performs a device reset
*SAV	1	Save the current setup configuration
SENsor	1	Selects the sensor type
SENsor?	none	Queries the sensor type
SET:ITE	1	Enters the constant TE current setpoint
SET:ITE?	none	Queries the constant TEcurrent setpoint
SET:SENsor	1	Enters the constant sensor setpoint
SET:SENsor?	none	Queries the constant sensor setpoint
SET:Temp	1	Enters the constant temperature setpoint
SET:Temp?	none	Queries the constant temperature setpoint
SET:VTE	1	Enters the constant TE voltage setpoint
SET:VTE?	none	Queries the constant TE voltage setpoint
*SRE	1	Sets the Service Request Enable Register bits to allow generation of the user-selectable service requests
*SRE?	none	Queries the contents of the Service Request Enable Register
STATus?	none	Queries the contents of the Status Registers
*STB?	none	Queries the Status Byte Register
TIME?	none	Returns power on time
TIMER?	none	Returns Δt since last TIMER? query
TRIGger:IN:ENABle	1	Enables trigger in function
TRIGger:IN:ENABle?	none	Queries state of trigger in function
TRIGger:IN:START	1	Enters first trigger in temperature setpoint
TRIGger:IN:START?	none	Queries first trigger in temperature setpoint
TRIGger:IN:STEPsize	1	Enters trigger in temperature setpoint step size
TRIGger:IN:STEPsize?	none	Queries trigger in temperature setpoint step size
TRIGger:IN:STOP	1	Enters maximum trigger in temperature setpoint

Table 4.1 GPIB Command Summary Reference List

NAME	Parameters	FUNCTION
TRIGger:IN:STOP?	none	Queries maximum trigger in temperature setpoint
TRIGger:OUT:DELAY	1	Enters time required for temperature to stay in setpoint tolerance before trigger out is generated
TRIGger:OUT:DELAY?	none	Queries trigger out delay time
*TST?	none	Not implemented; always retains zero
*WAI	none	Prevents executing any further commands until all overlapped commands are completed

Command Reference

The Command Reference presents the commands for remote operation of the LDT-5900, listed in alphabetical order. See Command Syntax section in Chapter 3 for detailed instructions about using the commands.

BEEP

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The BEEP command is used to enable the beep function on or off. If enabled, the instrument will beep whenever a key is pressed.
Parameters	One <nrf> value is required. 0 = beep off, 1 = beep on.
Example	BEEP 1 action: Turns the beep function on.

BEEP?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The BEEP? query is used to report the state of the beep function.
Response	The returned value is either a 0 or a 1. 0 = beep off, 1 = beep on.
Example	BEEP? response: 1: The beep function is on..

CAL:

COMMON
DEVICE DEPENDENT
FRONT PANEL

The CAL: root command path is used to access the calibration commands and queries. The following commands may be reached from the CAL: command path.

CAL:COARSEDAC
CAL:COARSEDAC?
CAL:DEFault
CAL:ITE
CAL:ITE?
CAL:RAC
CAL:RAC?
CAL:SAVE
CAL:SENsor:VOLTage:10UA
CAL:SENsor:VOLTage:10UA?
CAL:SENsor:VOLTage:100UA
CAL:SENsor:VOLTage:100UA?
CAL:SENsor:VOLTage:1MA
CAL:SENsor:VOLTage:1MA?
CAL:SOURCE:SENsor:10UA
CAL:SOURCE:SENsor:10UA?
CAL:SOURCE:SENsor:100UA
CAL:SOURCE:SENsor:100UA?
CAL:SOURCE:SENsor:1MA
CAL:SOURCE:SENsor:1MA?
CAL:VTE
CAL:VTE?

CAL:COARSEDAC

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:COARSEDAC is used to initiate the calibration of the TE current setpoint by allowing the user to enter calibration coefficients.
Parameters	Two <nrf> values are required. The first one represents the TE current setpoint slope and the second represents the offset.
Notes	This is a service related command. Calibration mode should not be entered unless the user has the proper measurement equipment in place. See the Calibration section of Chapter 5 for complete calibration instructions.
Example	CAL:COARSEDAC 1,0 action: Enters a slope of 1 and offset of 0 for the TE current setpoint calibration.

CAL:COARSEDAC?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:COARSEDAC? query is used to report the current TE current setpoint calibration coefficients.
Response	The response data will be two values. The first represents represents the calibration slope. The second represents the offset.
Notes	See the Calibration sectionCalibration section for complete calibration instructions
Example	CAL:COARSEDAC? response: 1,0

CAL:DEFault

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:DEFault command sets all of the calibration constants to default (uncalibrated) values.
Parameters	None.
Notes	This command should only be used in the case that the calibration has become corrupted or the instrument needs recalibration. Measurements and setpoints are not guaranteed to meet accuracy specifications after this command is issued. Accuracy will remain unspecified until calibration is performed on the instrument. This is a service related command. Calibration mode should not be entered unless the user has the proper measurement equipment in place. See the Calibration section for complete calibration instructions. CAUTION: The CAL:DEFault command resets all of the calibration constants to their default values of 1 for slope and scale factor, and 0 for offset, thus invalidating the factory calibration. Default calibration values are also listed in Chapter 5.
Example	CAL:DEFault: The instrument sets all of its calibration constants to their default values.

CAL:ITE

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:ITE command is used to enter the calibration coefficients for the TE current measurement.
Notes	This is a service related command. Calibration mode should not be entered unless the user has the proper measurement equipment in place. See the Calibration section of Chapter 5 for complete calibration instructions
Example	CAL:ITE 10,0 action: a slope of 10 and offset of 0 is entered for TE current measurement calibration coefficient.

CAL:ITE?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:ITE? query returns the TE current measurement calibration coefficients.
Response	The response will be two values; the first represents slope and the second represents offset.
Notes	See the Calibration section of Chapter 5 for complete calibration instructions.
Example	CAL:ITE? response: 4.2, 0.5

CAL:RAC

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:RAC command is used to enter the calibration coefficients for the TE AC resistance measurement.
Notes	This is a service related command. Calibration mode should not be entered unless the user has the proper measurement equipment in place. See the Calibration section of Chapter 5 for complete calibration instructions.
Example	CAL:RAC 10,0 action: a slope of 10 and offset of 0 is entered for TE AC resistance measurement calibration coefficients.

CAL:RAC?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:RAC? query returns the TE AC resistance measurement calibration coefficients.
Response	The response will be two values; the first represents slope and the second represents offset.
Notes	See the Calibration section of Chapter 5 for compete calibration instructions.
Example	CAL:RAC? response: 4.2, 0.5

CAL:SAVE

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:SAVE is used to save all calibration coefficients in non-volatile memory.
Parameters	None.
Notes	This is a service related command. Calibration mode should not be entered unless the user has the proper measurement equipment in place. See the Calibration section fof Chapter 5 for complete calibration instructions.
Example	CAL:SAVE action: Saves all calibration coefficients.

CAL:SENsor:VOLTage:10UA

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:SENsor:VOLTage:10UA command is used to enter the calibration coefficients for the sensor voltage measurement with a 10 □A sensor supply current.
Parameters	Two values are required to set the sensor voltage calibration. The first represents the slope and the second represents the offset in voltage measurement.
Notes	This is a service command. Calibration mode should not be entered unless the user has the proper measurement equipment in place. See the Calibration section of Chapter 5 for complete calibration instructions.
Example	CAL:SEN:VOLT:10UA 1,0 action: Enters a slope of 1.0 V/V and an offset of 0 V for the sensor voltage measurement calibration.

CAL:SENsor:VOLTage:10UA?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:SENsor:VOLTage:10UA? query returns the calibration coefficients for the sensor voltage measurement with a 10 □A sensor supply current.
Response	The response is two values; the first represents the calibration voltage measurement slope and the second represents the voltage offset coefficients.
Notes	See the Calibration section of Chapter 5 for complete calibration instructions.
Example	CAL:SEN:VOLT:10UA? Response: 1,0 means a slope of 1.0 V/V and an offset of 0 V for the sensor voltage measurement calibration.

CAL:SENsor:VOLTage:100UA

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:SENsor:VOLTage:100UA command is used to enter the calibration coefficients for the sensor voltage measurement with a 100 □A sensor supply current.
Parameters	Two values are required to set the sensor voltage calibration. The first represents the slope and the second reprsents the offset in voltage measurement.
Notes	This is a service command. Calibration mode should not be entered unless the user has the proper measurement equipment in place. See the Calibration section of Chapter 5 for complete calibration instructions.
Example	CAL:SEN:VOLT:100UA 1,0 action: Enters a slope of 1.0 V/V and an offset of 0 V for the sensor voltage measurement calibration.

CAL:SENsor:VOLTage:100UA?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:SENsor:VOLTage:100UA? query returns the calibration coefficients for the sensor voltage measurement with a 100 □A sensor supply current.
Response	The response is two values; the first represents the calibration voltage measurement slope and the second represents the voltage offset coefficients.
Notes	See the Calibration section of Chapter 5 for complete calibration instructions.
Example	CAL:SEN:VOLT:100UA? Response: 1,0 means a slope of 1.0 V/V and an offset of 0 V for the sensor voltage measurement calibration.

CAL:SENsor:VOLTage:1MA

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:SENsor:VOLTage:1MA command is used to enter the calibration coefficients for the sensor voltage measurement with a 1 mA sensor supply current.
Parameters	Two values are required to set the sensor voltage calibration. The first represents the slope and the second represents the offset in voltage measurement.
Notes	This is a service command. Calibration mode should not be entered unless the user has the proper measurement equipment in place. See the Calibration section of Chapter 5 for complete calibration instructions.
Example	CAL:SEN:VOLT:1MA 1,0 action: Enters a slope of 1.0 V/V and an offset of 0 V for the sensor voltage measurement calibration

CAL:SENsor:VOLTage:1MA?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:SENsor:VOLTage:1MA? query returns the calibration coefficients for the sensor voltage measurement with a 1 mA sensor supply current.
Response	The response is two values; the first represents the calibration voltage measurement slope and the second represents the voltage offset coefficients.
Notes	See the Calibration section of Chapter 5 for complete calibration instructions.
Example	CAL:SEN:VOLT:1MA? Response: 1,0 means a slope of 1.0 V/V and an offset of 0 V for the sensor voltage measurement calibration.

CAL:SOURCE:SENsor:10UA

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:SOURCE:SENsor:10UA is used to enter the calibration coefficient for the 10 µA sensor current source.
Parameters	One <nrf value> is required representing the 10 µA scale factor.
Notes	This is a service related command. Calibration mode should not be entered unless the user has the proper measurement equipment in place. See the Calibration section of Chapter 5 for complete calibration instructions
Example	CAL:SOURCE:SEN:10UA 0.9217 Action: Scales the original sensor output current at the 10 µA setting by a factor of 0.9217.

CAL:SOURCE:SENsor:10UA?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:SOURCE:SENsor:10UA? query returns the calibration coefficient for the 10 µA sensor current source.
Response	The response is one value that represents 10 µA current source calibration coefficient.
Notes	See the Calibration section of Chapter 5 for complete calibration instructions
Example	CAL:SOURCE:SEN:10UA? Response: 0.93, means a scalefactor of 0.93 has been applied for the 10 □A current source calibration.

CAL:SOURCE:SENsor:100UA

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:SOURCE:SENsor:100UA is used to enter the calibration coefficient for the 100 µA sensor current source.
Parameters	One <nrf value> is required representing the 100 µA scale factor.
Notes	This is a service related command. Calibration mode should not be entered unless the user has the proper measurement equipment in place. See the Calibration section of Chapter 5 for complete calibration instructions
Example	CAL:SOURCE:SEN:100UA 1.234 Action: Scales the original sensor output current at the 100 µA setting by a factor of 1.234.

CAL:SOURCE:SENsor:100UA?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:SOURCE:SENsor:100UA? query returns the calibration coefficient for the 100 µA sensor current source.
Response	The response is one value that represents 100 µA current source calibration coefficient.
Notes	See the Calibration section of Chapter 5 for complete calibration instructions.
Example	CAL:SOURCE:SEN:100UA? Response: 1.204, means a scale factor of 1.204 has been applied for the 100 □A current source calibration.

CAL:SOURCE:SENsor:1MA

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:SOURCE:SENsor:1MA is used to enter the calibration coefficient for the 1 mA sensor current source.
Parameters	One <nrf value> is required representing the 1mA scale factor.
Notes	This is a service related command. Calibration mode should not be entered unless the user has the proper measurement equipment in place. See the Calibration section of Chapter 5 for complete calibration instructions
Example	CAL:SOURCE:SEN:1MA 1.056 Action: Scales the original sensor output current at the 1mA setting by a factor of 1.056.

CAL:SOURCE:SENsor:1MA?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:SOURCE:SENsor:1MA? query returns the calibration coefficient for the 1 mA sensor current source.
Response	The response is one value that represents the 1 mA current source calibration coefficient.
Notes	See the Calibration section of Chapter 5 for complete calibration instructions.
Example	CAL:SOURCE:SENsor:1MA? Response: 1.056, means a scale factor of 1.056 has been applied for the current source calibration.

CAL:VTE

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:VTE is used to enter the calibration coefficients for the TE voltage measurement.
Parameters	Two <nrf values> are required to set the VTE calibration. The first represents the slope and the second represents the offset in voltage.
Notes	This is a service related command. Calibration mode should not be entered unless the user has the proper measurement equipment in place. See the Calibration section of Chapter 5 for complete calibration instructions
Example	CAL:VTE 1,0 action: enters a slope of 1.0 V/V and an offset of 0 V for the TE voltage measurement calibration.

CAL:VTE?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CAL:VTE? query returns the calibration coefficients for the TE voltage measurement.
Response	The response is two values. The first represents the voltage slope. The second represents the voltage offset coefficients.
Notes	See the Calibration section of Chapter 5 for complete calibration instructions
Example	CAL:VTE? response: 0.954, 0.0123, means a slope of 0.954 V/V with an offset of 0.0123 V for the TE voltage measurement.

*CLS

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Clears the Standard Event Status Register (*ESR), the Event Registers (EVENT?), the Error Queue (ERR?), and all the corresponding bits in the Status Byte Register (*STB?)
Notes	Useful to clear registers before enabling service requests (SRQ).
Example	*CLS

CONST:

COMMON
DEVICE DEPENDENT
FRONT PANEL

The CONST: command path is used to access the calibration constant commands and queries.
The following commands may be reached directly from the CONST: command path:

CONST:ICI	CONST:ICI?
CONST:ICV	CONST:ICV?
CONST:RTD	CONST:RTD?

CONST:ICI

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CONST:ICI command sets the slope and offset coefficients for a current IC sensor.
Parameters	Two <nrf values> are required. The first represents the slope in µA/K and the second represents the offset (in µA).
Notes	Acceptable values for slope are 0 to 99.99 µA/K. Acceptable values for offset range between 9.99 and +99.99 µA. Current IC coefficients are typically supplied by the manufacturer.
Example	CONST:ICI 2.5,0 action: enters a slope of 2.5 µA/K and an offset of 0 □A for the ICI coefficients.

CONST:ICI?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CONST:ICI? query returns the slope and offset coefficients for a current IC sensor.
Response	The response is two values. The first represents the slope. The second represents the offset.
Notes	
Example	CONST:ICI? response: 2.5,0 means a slope of 2.5 µA / K and an offset of 0 µA for the current IC sensor coefficients.

CONST:ICV

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CONST:ICV command sets the slope and offset coefficients for a voltage IC sensor.
Parameters	Two <nrf values> are required. The first represents the slope in mV / K and the second represents the offset (in mV).
Notes	Acceptable values for slope are 0 to 99.99 mV / K. Acceptable values for offset range between -9.99 and +99.99 mV.
Example	CONST:ICV 4.2, -3.0 action: enters a slope of 4.2 mV / K and an offset of -3.0 mV for the ICV coefficients.

CONST:ICV?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CONST:ICV? query returns the slope and offset coefficients for a voltage IC sensor.
Response	The response is two values. The first represents the slope. The second represents the offset.
Notes	
Example	CONST:ICV? response: 4.2, -3.0 means a slope of 4.2 mV / K and an offset of -3.0 mV for the voltage IC sensor coefficients.

CONST:RTD

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CONST:RTD command sets the A, B, C and Ro coefficients for an RTD sensor.
Parameters	Four <nrf values> are required. The first represents the A coefficients, the second is the B coefficient, the third is the C coefficient and the fourth is the Ro, in Ohms. The scale factors for A, B, and C are programmed into the instrument and are as follows: A*1E-03, B*1E-07, and C*1E-12.
Notes	Acceptable values for A, B, and C are -99.99 to +999.99. Acceptable values for Ro are 0 to 99,999.99 Ohms. RTD coefficients are typically supplied by the manufacturer.
Example	CONST:RTD 3.4, 7.0, 5.0, 100.1 action: sets the RTD coefficients as follows: A=3.4, B=7.0, C=5.0, Ro = 100.1 □

CONST:RTD?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CONST:RTD? query returns the A, B, C and Ro coefficients for an RTD sensor
Response	The response is four values that represent the values of A, B, C, and Ro in that order.
Notes	These values are pre-scaled so that the exponential value is not given. The actual value of A is scaled by 10E-03, B by 10E-07, and C by 10E-12.
Example	CONST:RTD? response: 3.4,7.0,5.0,100.1: The RTD coefficients are A = 3.4, B = 7.0, C = 5.0 and R_0 = 100.1 □

CONST:THERMistor

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CONST:THERMistor command sets the Steinhart-Hart coefficients for thermistor.
Parameters	Three <nrf values> are required. The first represents C1, the second is the C2, the third is C3. The scale factors for C1, C2, and C3 are programmed into the instrument and are as follows: C1*1E-03, C2*1E-04, and C3*1E-07.
Notes	Acceptable values C1, C2, and C3 are 0 to +999.99. A thermistor's nominal Steinhart-Hart coefficients are typically supplied by the thermistor manufacturer. Precision calibrated 10 kohm thermistors can be purchased through ILX Lightwave. See Chapter 2 for more details on sensor constants.
Example	CONST:THERMistor 1.25, 2.36, 0.76 action: Sets the Steinhart-Hart coefficients to C1 =1 .25, C2 = 2.36, and C3 = 0.76.

CONST:THERMistor?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The CONST:THERMistor? query returns the values of the Steinhart-Hart coefficients.
Response	The response is three values that represent the values of C1, C2, and C3, in that order.
Notes	These values are prescaled so that the exponential value is not given. The actual value of C1 is scaled by 10E-03, C2 by 10E-04, and C3 by 10E-07.
Example	CONST:THERMistor? Response: 1.25, 2.36, 0.76: C1 = 1.25, C2 = 2.36, and C3 = 0.76.

DELAY

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The DELAY command is used to initiate a delay between commands.
Parameters	One <nrf> value is required. The value is the delay in milliseconds. The value range is from 0 to 60,000.
Example	DELAY 250 action: Initiates a delay of 250ms prior to the next command.

DISPlay

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The DISPlay command is used to turn the display on or off.
Parameters	One <nrf> value is required. 0= Display off, 1= Display on.
Example	DISP 1 action: Turns the display on.

DISPlay?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action The DISPlay? query returns the status of the display.
Response The returned value is either a 0 or a 1. 0= Display off, 1= Display on.
Example DISP? response: 1: The display is turned on.

ENABle:EVENT

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action The ENABle:EVENT command sets the controller Event Enable Registers. The bits in these registers specify the conditions that will cause a GPIB Service Request.
Parameters Two <nrf values> that represent the sum of the enabled bits for each register. The first represents the sum of the enabled bits for register 1 and the second represents the sum of the enabled bits for register 0
(e.g. ENAB:EVENT <Reg 1>, <Reg 0>

Event Enable Register 1

Bit Number	Condition	Default Value	Decimal Value
0	RAC Measurement Complete	0	1
1	Reserved	0	2
2	Output On	0	4
3	Measurement Within Setpoint Tolerance	0	8
4	Measurement Out of Setpoint Tolerance	0	16
5	Reserved	0	32
6	Reserved	0	64
7	Reserved	0	128
8	Reserved	0	256
9	Internal PCB Temperature Over Limit	0	512
10	Invalid Calibration Data	0	1024
11	DSP Reset	0	2048
12	TEC Temperature Runaway	0	4096
13	Reserved	0	8192
14	-15V PCB Supply Out of Tolerance	0	16384
15	Reserved	0	32768

Notes — Read these registers using the ENABle:EVENT? query. The factory default values for these registers are both 0, nothing enabled. The registers will be reset to zero at power-on if Power-on Status Clear has been enabled (See *PSC command). Bit 0 of the Service Request Enable Register (*SRE) must be set to enable GPIB Service Request generation for the conditions specified by the Event Enable Registers. See the Event Register section of Chapter 3 for additional details.

Examples — ENAB:OUTOFF 0,7 action: sets the controller Output Off Enable Registers so that only a Sensor Open (4) or an Upper or Lower Temperature Limit (1 and 2) condition will cause a GPIB Service Request.

Event Enable Register 0

Bit Number	Condition	Default Value	Decimal Value
0	Upper Temperature Limit	0	1
1	Lower Tempature Limit	0	2
2	Sensor Open	0	4
3	Sensor Shorted	0	8
4	TEC Current Upper Limit	0	16
5	TEC Current Lower Limit	0	32
6	TEC Voltage Upper Limit	0	64
7	TEC Voltage Lower Limit	0	128
8	TEC Open	0	256
9	TEC Shorted	0	512
10	Auto-Tune in Progress	0	1024
11	Sensor Upper Limit	0	2048
12	Sensor Lower Limit	0	4096
13	3V PCB Supply Out of Tolerance	0	8192
14	5V PCB Supply Out of Tolerance	0	16384
15	15V PCB Supply Out of Tolerance	0	32768

ENABle:EVENT?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action The ENABle:EVENT query returns the contents of the controller Event Enable Registers.

Response The response is two values which represent the sum of the enabled bits for register 1 and the sum of the enabled bits for register 0 respectively.

Event Enable Register 1

Bit Number	Condition	Default Value	Decimal Value
0	RAC Measurement Complete	0	1
1	Reserved	0	2
2	Output On	0	4
3	Measurement Within Setpoint Tolerance	0	8
4	Measurement Out of Setpoint Tolerance	0	16
5	Reserved	0	32
6	Reserved	0	64
7	Reserved	0	128
8	Reserved	0	256
9	Internal PCB Temperature Over Limit	0	512
10	Invalid Calibration Data	0	1024
11	DSP Reset	0	2048
12	TEC Temperature Runaway	0	4096
13	Reserved	0	8192
14	-15V PCB Supply Out of Tolerance	0	16384
15	Reserved	0	32768

Notes These registers can be set by using the ENABle:EVENT command.

Examples ENAB:EVENT response:0,8, means that the Sensor Short is the only condition that will cause a GPIB Service Request.

Event Enable Register 0

Bit Number	Condition	Default Value	Decimal Value
0	Upper Temperature Limit	0	1
1	Lower Tempature Limit	0	2
2	Sensor Open	0	4
3	Sensor Shorted	0	8
4	TEC Current Upper Limit	0	16
5	TEC Current Lower Limit	0	32
6	TEC Voltage Upper Limit	0	64
7	TEC Voltage Lower Limit	0	128
8	TEC Open	0	256
9	TEC Shorted	0	512
10	Auto-Tune in Progress	0	1024
11	Sensor Upper Limit	0	2048
12	Sensor Lower Limit	0	4096
13	3V PCB Supply Out of Tolerance	0	8192
14	5V PCB Supply Out of Tolerance	0	16384
15	15V PCB Supply Out of Tolerance	0	32768

ENABle:OUTOFF

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action — The ENABle:OUTOFF command sets the controller Output Off Enable Registers. The bits in these registers specify the conditions that will cause the controller to automatically turn off.

Parameters — Two <nrf values> that represent the sum of the enabled bits for each register. The first represents the sum of the enabled bits for register 1 and the second represents the sum of the enabled bits for register 0.

(e.g. ENAB:OUTOFF <Reg 1>, <Reg 0>)

1 = Enabled 0 = Disabled

Output Off Enable Register 1

Bit Number	Condition	Default Value	Decimal Value
0	Reserved	0	1
1	Reserved	0	2
2	Reserved	0	4
3	Reserved	0	8
4	Measurement Out of Setpoint Tolerance	0	16
5	Reserved	0	32
6	Reserved	0	64
7	Reserved	0	128
8	Reserved	0	256
9	Internal PCB Temperature Out of Tolerence*	1	512
10	Reserved	0	1024
11	Reserved	0	2048
12	TEC Current Runaway	0	4096
13	Reserved	0	8192
14	Reserved	0	16384
15	Reserved	0	32768

* This bit cannot be cleared.

Notes

Read these registers using the ENABle:OUTOFF? query.

The factory default values for these registers are 512 and 6159 for registers 1 and 0 respectively. The conditions that will cause the output to shut off are Upper or Lower Temperature Limit, Sensor Open or Shorted, Upper or Lower Sensor Limit, and Internal PCB Temperature Out of Tolerance.

If you set bit 4 in register 1, the output will shut off whenever the controlled temperature is out of tolerance (specified using the LIM:TOL command). If the temperature is not within the limits, you will not be able to turn on the output. You should wait until the temperature is within your tolerance specification before setting this bit. To clear these registers send ENAB:OUTOFF 0,0. To reset these registers to their default values send ENAB:OUTOFF:DEF.

Examples

ENAB:OUTOFF 0, 7 action: sets the TEC Output-Off enable registers so that only a Sensor Open (4) or an Upper or Lower Temperature Limit (1 and 2) condition will cause the output to be automatically turned off.

Output Off Enable Register 0

Bit Number	Condition	Default Value	Decimal Value
0	Upper Temperature Limit	1	1
1	Lower Temperature Limit	1	2
2	Sensor Open	1	4
3	Sensor Shorted	1	8
4	TEC Current Upper Limit	0	16
5	TEC Current Lower Limit	0	32
6	TEC Voltage Upper Limit	0	64
7	TEC Voltage Lower Limit	0	128
8	TEC Open	0	256
9	TEC Shorted	0	512
10	Reserved	0	1024
11	Sensor Upper Limit	1	2048
12	Sensor Lower Limit	1	4096
13	Reserved	0	8192
14	Reserved	0	16384
15	Reserved	0	32768

ENABle:OUTOFF?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action The ENABle:OUTOFF? query returns the contents of the controller Output Off Enable Registers.

Response The response is two values which represent the sum of the enabled bits for register 1 and the sum of the enabled bits for register 0 respectively.

Output Off Enable Register 1

Bit Number	Condition	Default Value	Decimal Value
0	Reserved	0	1
1	Reserved	0	2
2	Reserved	0	4
3	Reserved	0	8
4	Measurement Out of Setpoint Tolerance	0	16
5	Reserved	0	32
6	Reserved	0	64
7	Reserved	0	128
8	Reserved	0	256
9	Internal PCB Temperature Out of Tolerance	1	512
10	Reserved	0	1024
11	Reserved	0	2048
12	TEC Current Runaway	0	4096
13	Reserved	0	8192
14	Reserved	0	16384
15	Reserved	0	32768

Notes These registers can be set by using the ENABle:OUTOFF command.

Examples ENAB:OUTOFF response: 0, 8, means that the Sensor Short is the only condition that will cause the controller output to be automatically turned off.

Output Off Enable Register 0

Bit Number	Condition	Default Value	Decimal Value
0	Upper Temperature Limit	1	1
1	Lower Temperature Limit	1	2
2	Sensor Open	1	4
3	Sensor Shorted	1	8
4	TEC Current Upper Limit	0	16
5	TEC Current Lower Limit	0	32
6	TEC Voltage Upper Limit	0	64
7	TEC Voltage Lower Limit	0	128
8	TEC Open	0	256
9	TEC Shorted	0	512
10	Reserved	0	1024
11	Sensor Upper Limit	1	2048
12	Sensor Lower Limit	1	4096
13	Reserved	0	8192
14	Reserved	0	16384
15	Reserved	0	32768

ENABle:OUTOFF:DEFault

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action The ENABle:OUTOFF:DEFault command sets the controller Output Off Enable Registers to their factory default values of 512 for register 1 and 6159 for register 0.
Parameters None.
Example ENAB:OUTOFF:DEF
See the ENABle:OUTOFF command for more details.

ERRors?

COMMON
DEVICE DEPENDENT
FRONT PANEL

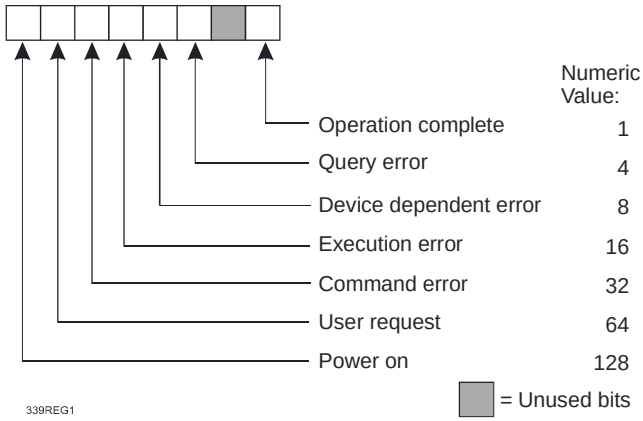
Action The ERRors? query returns the contents of the error log and then clears the error log.
Response The returned value is a list of the error codes. See Table 3.4 for a list of the error codes and their definitions.
Example ERR? response: 410, means the upper temperature limit caused the output to turn off.

*ESE <nrf value>

COMMON
DEVICE DEPENDENT
FRONT PANEL

Event Status Enable

Action Enables bits in the Standard Event Status Enable Register.
Parameter The value must be between 0 and 255.



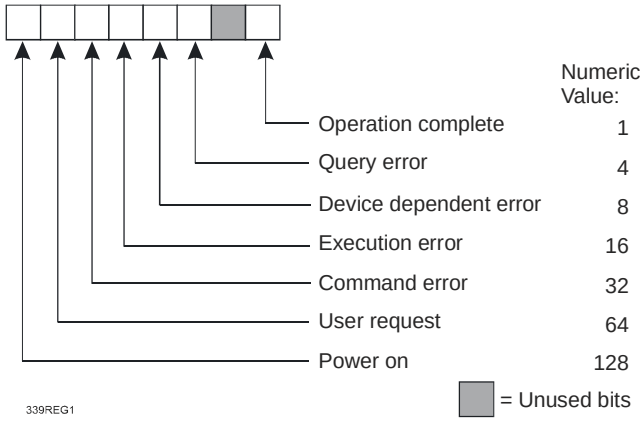
Notes Bit 5 of the Status Byte Register (*STB) is set if any enabled conditions are true.
Example *ESE 128 - Enables power-on status to be reported in the status byte bit 5.

*ESE?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Event Status Enable?

Action Requests the value in the Standard Event Status Enable Register.
Response The value must be between 0 and 255.



Notes Bit 5 of the the Status Byte Register (*STB) is set if any enabled conditions are true. Response is the sum of the enabled bits.
Example *ESE? - Response 128 means power-on status will be reported in the status byte bit 5.

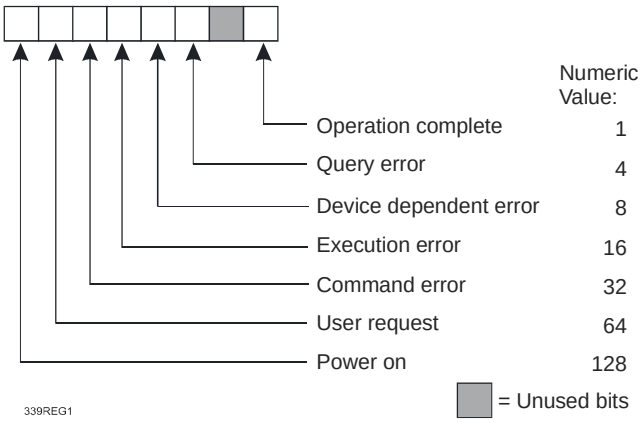
*ESR?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Standard Event Status Register?

Action Requests the value in the Standard Event Status Register.

Response The value must be between 0 and 255.



Notes Response is the sum of the status bits.

This command allows you to determine which type of error has occurred. The following three things will clear this register: the *ESR? query, a power on when *PSC is set true, and the *CLS command. See Chapter 3 for more information about register structure.

Example *ESR? - Response 32 means a command error happened.

EVENT?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action The EVENT? query returns the contents of the controller Event Registers and then clears the registers. These registers log the controller events that occurred since power-on or since the last EVENT? query.

Response The response is two values which represent the sum of the event bits for register 1 and the sum of the enabled bits for register 0 respectively.

Event Enable Register 1

Bit Number	Condition	Decimal Value
0	RAC Measurement Complete	1
1	Reserved	2
2	Output On	4
3	Measurement Within Setpoint Tolerance	8
4	Measurement Out of Setpoint Tolerance	16
5	Reserved	32
6	Reserved	64
7	Reserved	128
8	Reserved	256
9	Internal PCB Temperature Over Limit	512
10	Invalid Calibration Data	1024
11	DSP Reset	2048
12	TEC Temperature Runaway	4096
13	Reserved	8192
14	-15V PCB Supply Out of Tolerance	16384
15	Reserved	32768

Notes These registers can be used in conjunction with the ENABle:EVENT command.

Examples EVENT? response: 0,8, means that only the Sensor Short event has occurred. See the Event Registers section of Chapter 3 for additional details.

Event Enable Register 0

Bit Number	Condition	Decimal Value
0	Upper Temperature Limit	1
1	Lower Tempature Limit	2
2	Sensor Open	4
3	Sensor Shorted	8
4	TEC Current Upper Limit	16
5	TEC Current Lower Limit	32
6	TEC Voltage Upper Limit	64
7	TEC Voltage Lower Limit	128
8	TEC Open	256
9	TEC Shorted	512
10	Auto-Tune in Progress	1024
11	Sensor Upper Limit	2048
12	Sensor Lower Limit	4096
13	3V PCB Supply Out of Tolerance	8192
14	5V PCB Supply Out of Tolerance	16384
15	15V PCB Supply Out of Tolerance	32768

*IDN?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Requests the instrument to identify itself.
Response	Returns a comma delimited standard format ASCII identification string, from information stored in the instrument during manufacture.
Example	*IDN? response: ILX Lightwave,LDT-5948,59481234,05.19.10, means ILX Lightwave is the manufacturer, LDT-5948 is the model number, 59481234 is the serial number, and 05.19.10 is the firmware version.

KEY

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The KEY command is used to initiate a front panel key press or knob turn.
Parameters	One <nrf> value is required. Each key/knob is assigned a specific number. Key 0 --> Output Enable/Disable Key 1 --> Enter/Lock Key 2 --> Up arrow Key 3 --> Down arrow Key 4 --> Main/Local Key 5 --> Parameter Select Key 6 --> Mode Select Key 7 --> Reserved Key 8 --> Reserved Key 9 --> Reserved Key 10 --> Dial increment right Key 11 --> Dial decrement left
Example	KEY 5 action: initiates a key press for the Parameter Select button.

LIMit:ITE

COMMON
DEVICE DEPENDENT
FRONT PANEL

The LIMit:ITE: command path is used to access the ITE limit commands. The following commands may be reached directly from the LIMit:ITE: command path.

LIMit:ITE:HIgh
LIMit:ITE:HIgh?
LIMit:ITE:LOw
LIMit:ITE:LOw?

LIMit:ITE:HIgh

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LIMit:ITE:HIgh command sets the upper TE current limit value.
Parameters	An <nrf value> that represents the upper limit current, in Amps.
Notes	Maximum current limit is dependent on the instrument model and the cable type.
Example	LIM:ITE:HI 4.0 action: the upper current limit is set to 4.0 A.

LIMit:ITE:HIgh?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LIMit:ITE:HIgh? query returns the value of the upper TE current limit value.
Response	The response is a single value that represents the upper current limit.
Notes	The current limit is in effect in all control modes.
Example	LIM:ITE:HI? response: 0.9, means the upper current limit is 0.9 A.

LIMit:ITE:LOw

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LIMit:ITE:LOw command sets the lower TE current limit value.
Parameters	An <nrf value> that represents the lower limit current, in Amps.
Notes	Maximum current limit is dependent on the instrument model and cable type.
Example	LIM:ITE:LO 4.0 action: the lower current limit is set to 4.0 A.

LIMit:ITE:LOw?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LIMit:ITE:LOw? query returns the value of the lower TE current limit value.
Response	The response is a single value that represents the lower current limit.
Notes	The current limit is in effect in all control modes.
Example	LIM:ITE:LO? response: 0.9, means the lower current limit is 0.9 A.

LIMit:SENsor

COMMON
DEVICE DEPENDENT
FRONT PANEL

The LIMit:SENsor: command path is used to access the sensor limit commands. The following commands may be reached directly from the LIMit:SENsor: command path.
LIMit:SENsor:HIgh
LIMit:SENsor:HIgh?
LIMit:SENsor:LOw
LIMit:SENsor:LOw?

LIMit:SENsor:HIgh

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LIMit:SENsor:HIgh command sets sensor upper limit value.
Parameters	An <nrf value> that represents the upper sensor limit. Units depend on which sensor is selected. For thermistor and RTD units are Ohms, for ICI Amps, and for ICV Volts.
Notes	Acceptable values for thermistors are 1 to 600000 □. Acceptable values for RTD are 0.1 to 60000.0 □. Acceptable values for ICI are 0.000010 to 0.000600 Amps. Acceptable values for ICV are 0.100 to 6.000 Volts. The minimum upper limit value allowed will be determined by the value set with the LIMit:SENsor:LOw command By default, the controller output is turned off when the measured sensor exceeds this setting in Rsnsr mode. This feature can be disabled by clearing bit 11 in the Output Off Enable Register 0, using the ENABle:OUTOFF command.
Example	LIM:SEN:HI 450.100 action: Sets the sensor upper limit to a maximum of 450.1□.

LIMit:SENsor:HIgh?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LIMit:SENsor:HIgh? query returns the value of the sensor upper limit setting.
Response	The response is a single value that represents the upper limit and the units depend on which sensor is selected. For thermistor or RTD the value will be in Ohms, for ICI Amps, and for ICV Volts.
Notes	This limit is only in effect in R_{snsr} mode.
Example	LIM:SEN:HI? response: 450100.00000000 when the thermistor is selected means a upper sensor limit of 450,100 Ohms.

LIMit:SENsor:LOw

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action — The LIMit:SENsor:LOw command sets sensor lower limit value.

Parameters — An <nrf value> that represents the lower sensor limit. Units depend on which sensor is selected. For thermistor and RTD units are Ohms, for ICI Amps, and for ICV Volts.

Notes — Acceptable values for thermistors are 1 to 600000 □.
Acceptable values for RTD are 0.1 to 60000.0 □.
Acceptable values for ICI are 0.000010 to 0.000600 Amps.
Acceptable values for ICV are 0.100 to 6.000 Volts.

The maximum lower limit value will be determined by the value set by the LIMit:SENsor:HIgh command.

By default, the controller output is turned off when the sensor measurement falls below this setting in R_{snsr} mode. This feature can be disabled by clearing bit 12 in the Output Off Enable Register 0, using the ENABle:OUToff command.

Example — LIM:SEN:LO 95.2 action: Sets the sensor lower limit to a minimum of 95.2 □.

LIMit:SENsor:LOw?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action — The LIMit:SENsor:LOw? query returns the value of the sensor lower limit setting.

Response — The response is a single value that represents the lower sensor limit and the units depend on which sensor is selected. For thermistor or RTD the value will be in Ohms, for ICI Amps, and for ICV Volts.

Notes — This limit is only in effect in Rsnsr mode.

Example — LIM:SEN:LO? response: 1200.000 when thermistor is selected means a lower sensor limit of 1200 Ohms.

LIMit:Temp

COMMON
DEVICE DEPENDENT
FRONT PANEL

The LIMit:Temp: command path is used to access the temperature limit commands. The following commands may be reached directly from the LIMit:Temp: command path.

LIMit:Temp:HIgh
LIMit:Temp:HIgh?
LIMit:Temp:LOw
LIMit:Temp:LOw?

LIMit:Temp:HIgh

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LIMit:Temp:HIgh command sets the upper temperature limit value.
Parameters	An <nrf value> that represents the upper temperature limit, in degrees Celsius.
Notes	By default, the controller output is turned off when the measured temperature exceeds this setting. This feature can be disabled by clearing bit 0 in the Output Off Enable Register 0, using the ENABle:OUTOFF command. The maximum value possible for the upper temperature limit is 250.0 °C. The absolute minimum value possible is determined the by the value set with the LIMit:Temp:LOw command.
Example	LIM:T:HI 105.0 action: sets the high temperature limit to 105.0 ^{o}C.

LIMit:Temp:HIgh?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LIMit:Temp:HIgh? query returns the value of the upper temperature limit setting.
Response	The response is a single value that represents the upper temperature limit.
Notes	High temperature limit is valid for all modes of operation except R_{snsr}.
Examples	LIM:T:HI? response: 92.0, means the high temperature limit is 92.0 ^{o}C.

LIMit:Temp:LOw

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LIMit:Temp:LOw command sets the lower temperature limit value.
Parameters	An <nrf value> that represents the lower temperature limit, in degrees Celsius.
Notes	By default, the controller output is turned off when the measured temperature falls below this setting. This feature can be disabled by clearing bit 0 in the Output Off Enable Register 0, using the ENABle:OUTOFF command. The minimum value possible for the lower temperature limit is -50.0 °C. The absolute maximum value possible is determined the by the value set with the LIMit:T:HIgh command.
Example	LIM:T:LO -40 action: sets the lower temperature limit to -40 ^{o}C.

LIMit:Temp:LOw?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LIMit:Temp:LOw? query returns the value of the lower temperature limit setting.
Response	The response is a single value that represents the lower temperature limit.
Notes	Low temperature limit is valid for all modes of operation except R_{snsr}.
Example	LIM:T:LO? response: 55.0, means the lower temperature limit is 55.0 ^{o}C.

LIMit:TOLerance

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LIMit:TOLerance command sets the controlled setpoint tolerance limit.
Parameters	An <nrf value> that represents the tolerance is required. When the controlled quantity (temperature, sensor, current, or voltage) is within the tolerance window, the load is considered "in tolerance" and trigger out high will be set. The tolerance window is defined as the setpoint +/- tolerance limit.
Notes	The range of the tolerance window is 0 to 99.999. The units of this parameter depend on the mode of the instrument. In constant temperature mode, the units of the tolerance window are in degrees C, and constant voltage mode, the units are in V, in constant sensor mode the units depend on which sensor is selected (Amps for ICI, Ohms for thermistor and RTD, Volts for ICV,) etc. If the tolerance window is set too tight, the output may never reach tolerance.
Example	LIM:TOL 0.01 action: Sets the tolerance limit to $\pm$0.01 ^{o}C (if instrument is set to "T" mode). The output trigger will go high when the temperature is within $\pm$0.01 ^{o}C of the setpoint.

LIMit:TOLerance?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LIMit:TOLerance? query returns the value of the controlled setpoint tolerance limit.
Response	The response is a single value that represents the tolerance.
Notes	The units of the tolerance window match those of the mode (and in some cases the sensor type) of the instrument.
Example	LIMit:TOL? response: 0.005 means a tolerance window of $\pm$0.005k□, (if the instrument is set to Sensor mode, with a thermistor as the sensor)

LIMit:VTE

COMMON
DEVICE DEPENDENT
FRONT PANEL

The LIMit:VTE: command path is used to access the VTE limit commands. The following commands can be reached directly from the LIMit:VTE: command path.

LIMit:VTE:HIgh
LIMit:VTE:HIgh?
LIMit:VTE:LOw
LIMit:VTE:LOw?

LIMit:VTE:HIgh

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LIMit:VTE:HIgh command sets upper TE voltage limit value.
Parameters	An <nrf value> that represents the upper voltage limit, in Volts, is required.
Notes	Acceptable values are -12.0V to +12.0V. The output will only be disabled when the voltage exceeds this limit when the instrument is in VTE mode. In all other modes, the output will not be disabled when this voltage is reached, but the Voltage Limit LED indicator will illuminate. The output can be turned off for all operational modes when this limit is reached by enabling bit 6 of Register 0 through the ENABle:OUTOFF command.
Example	LIM:VTE:HI 6.0 action: Sets the upper voltage to 6.0V.

LIMit:VTE:HIgh?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LIMit:VTE:HIgh? query returns the value of the upper TE voltage limit setting.
Response	The response is a single value that represents the upper voltage limit.
Notes	This limit is only in effect in VTE mode or when bit 6, Register 0 of the ENABle:OUTOFF is set true.
Example	LIM:VTE:HI? response: 5.5 means an upper voltage limit of 5.5V.

LIMit:VTE:LOw

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LIMit:VTE:LOw command sets lower TE voltage limit value.
Parameters	An <nrf value> that represents the lower voltage limit, in Volts, is required.
Notes	Acceptable values are -12.0V to +12.0V. The output will only be disabled when the voltage exceeds this limit when the instrument is in VTE mode. In all other modes, the output will not be disabled when this voltage is reached, but the Voltage Limit LED indicator will illuminate. The output can be turned off when this limit is reached by enabling bit 7 of Register 0 through the ENABle:OUToff command.
Example	LIM:VTE:LO -4.0 action: Sets the lower voltage to -4.0V.

LIMit:VTE:LOw?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LIMit:VTE:LOw? query returns the value of the lower TE voltage limit setting.
Response	The response a single value that represents the lower voltage limit.
Notes	This limit is only in effect in VTE mode or when bit 7, register 0 of the ENABle:OUTOFFis set true.
Example	LIM:VTE:LO? response: -4.5 means a lower voltage limit of -4.5V.

LINEfreq

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LINEfreq command sets the A/D convertor line frequency filter to either 50 Hz or 60 Hz.
Parameters	An <nrf value> that represents the line frequency is required
Notes	Acceptable values are either 50 or 60. For optimal instrument performance and noise rejection, select either 50 or 60 Hz depending on your AC input line frequency.
Example	LINE 60 action: sets the A/D line frequency filter to reject 60 Hz.

LINEfreq?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The LINEfreq? query returns the value of the A/D convertor line frequency filter.
Response	The response is a single value that represents the filter setting.
Notes	Acceptable values are either 50 or 60. For optimal instrument performance and noise rejection, select either 50 or 60 Hz depending on your AC input line frequency.
Example	LINE? response: 60 means the A/D filters are set to reject 60 Hz

MEASure

COMMON
DEVICE DEPENDENT
FRONT PANEL

The MEAS: command path is used to access the measure commands. The following commands can be reached directly from the MEAS: command path. Measurements are updated approximately every 500 msec.

MEASure:3Volts?	MEASure:PTE?
MEASure:5Volts?	MEASure:RAC?
MEASure:15Volts?	MEASure:SENsor?
MEASure:IADC?	MEASure:INTTemp?
MEASure:ITE?	MEASure:Temp?
MEASure:NEG15Volts?	MEASure:VTE?

MEASure:3Volts?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The MEASure:3Volts? query returns the measured value of the internal 3.3V PCB power supply.
Response	The response is a single value that represents the measured voltage of the power supply.
Notes	The acceptable voltage ranges from 2.97 to 3.63V.
Example	MEAS:3V? response: 3.21 means the 3V supply is providing 3.21V

MEASure:5Volts?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The MEASure:5Volts? query returns the measured value of the internal 5V PCB power supply.
Response	The response is a single value that represents the measured voltage of the power supply.
Notes	The acceptable voltage ranges from 4.5 to 5.5V.
Example	MEAS:5V? response: 4.94 means the 5V supply is providing 4.94V.

MEASure:15Volts?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The MEASure:15Volts? query returns the measured value of the internal 15.0V PCB power supply.
Response	The response is a single value that represents the measured voltage of the power supply.
Notes	The acceptable voltage ranges from 13.5 to 16.5V.
Example	MEAS:15V? response: 14.91 means the 15V supply is providing 14.91V.

MEASure:IADC?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The MEASure:IADC? query returns the measured value of the TEC current as measured across an internal current sense register.
Response	The response is a single value that represents the measured TEC current, in Amps.
Notes	The response is the measured output current, regardless of control mode.
Example	MEAS:IADC? response: -3.75 means the measured output current is -3.75 A.

MEASure:INTTemp?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The MEASure:INTTemp? query returns the value of the measured internal temperature within the instrument.
Response	The response is a single value that represents the measured temperature within the instrument, in degrees Celsius.
Notes	The temperature sensor for this reading is located on the main PCB within the instrument. The acceptable internal temperature is -5 to 60 ^{o}C.
Example	MEAS:INTTemp? response: 36.7 means the internal temperature is at 36.7 ^{o}C.

MEASure:ITE?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The MEASure:ITE? query returns the value of the TE current.
Response	The response is a single value that represents the TE current, in Amps.
Notes	The response is the output current, regardless of control mode.
Example	MEAS:ITE? response: 4.2 means the controller output current is set to 4.2A.

MEASure:NEG15Volts?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The MEASure:NEG15Volts? query returns the measured value of the internal -15.0V PCB power supply.
Response	The response is a single value that represents the measured voltage of the power supply.
Notes	The acceptable voltage ranges from -11.5 V to -16.0 V.
Example	MEAS:NEG15V? response: -12.2 means the -15V supply is providing -12.2 V.

MEASure:PTE?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The MEASure:PTE? query returns the measured output power to the TEC.
Response	The response is a single value that represents the measured power in Watts.
Notes	The response is the measured output power, calculated by V*I, and is regardless of control mode.
Example	MEAS:PTE? response: 1.3 means the measured output power is 1.3W.

MEASure:RAC?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The MEASure:RAC? query returns the value of the last AC resistance measurement.
Response	The response is a single value that represents the measured RAC value, in Ohms.
Notes	This query will return the RAC value last measured by the instrument.
Example	MEAS:RAC? response: 1.437 means the last AC resistance measurement was 1.437□.

MEASure:SENsor?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The MEASure:SENsor? query returns the measured value of the sensor.
Response	The response is a single value that represents the measured sensor value.
Notes	The response is the measured sensor, regardless of control mode, and the units are dependent upon which sensor is selected. For thermistor or RTD, the value will be in ohms, ICI in Amps, ICV in Volts.
Example	MEAS:SEN? response: 0.0001323 means the measured sensor value is 132.3 µA, (if instrument sensor is set for ICI). Note: Returned values will be displayed in native units.

MEASure:Temp?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The MEASure:Temp? query returns the measured value of the temperature sensor.
Response	The response is a single value that represents the measured temperature, in degrees Celsius.
Notes	The response is the measured temperature, regardless of control mode.
Example	MEAS:T? response: 45.6 means the measured temperature is 45.6 ^{o}C.

MEASure:VTE?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The MEASure:VTE? query returns the measured value of the TE voltage.
Response	The response is a single value that represents the measured TE voltage, in Volts
Notes	The response is the measured output voltage, regardless of control mode.
Example	MEAS:VTE? response: 4.2 means the measured output current is 4.2V.

MESsage

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Stores an ASCII string into non-volatile memory.
Parameters	String is 1 to 15 non-zero ASCII characters. Strings longer than 15 characters will generate an error. The message should be contained within " ".
Notes	Useful as a "scratchpad" for storing intermediate test status or configuration information.
Example	MES "test complete" action: stores the string “test complete” into non-volatile memory.

MESsage?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The MESsage? command queries the status of the message.
Response	The response value is a 15 character long string.
Example	MES? response: “test complete” means a previously stored message was “test complete”.

MODE

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Selects the feedback control mode for the instrument.
Parameters	One <character data value> representing the control mode is required. The values accepted are T, SENSOR, VTE, ITE, and CAL.
Notes	Changing modes forces the output off.
Examples	MODE SENSOR action: changes the control mode to sensor (which is equivalent to R_{snsr} on the front panel.)

MODE?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The MODE? query returns the selected control mode.
Response	The response is a character response representing the control mode. The possible responses are "T", "SENSOR”, and "ITE, “VTE” or “RAC” (without quotes).
Notes	“SENSOR” mode is equivalent to “R_{snsr}” mode from the front panel.
Examples	MODE? response: T, means that the controller is in constant temperature control mode.

*OPC

Operation Complete

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Sets the operation complete bit in the Event Status Register when all pending overlapped commands have been completed.
Response	None.
Example	*OPC

*OPC?

Operation Complete Query

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Queries the status of all pending overlapped command operations.
Response	The response is a single value. A “1” indicates all overlapped commands are complete. A “0” indicates overlapped commands are not complete.
Notes	This instrument has no overlapped commands.
Example	*OPC? response: 1 means that commands are complete.

OUTPUT

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The OUTPUT command turns the controller output to the TEC on or off.
Parameters	An <nrf value>; 1 = on, 0 = off.
Notes	After the TEC output is turned on, it may be useful to wait until the output is stable before performing further operations, but it is not necessary. The character strings "OFF" and "ON" may be used in place of "0" and "1".
Examples	OUTPUT 1 action: turns the output on. OUTPUT OFF action: turns the output off.

OUTPUT?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The OUTPUT? query returns the controller output state.
Response	The response is a value that represents the output state.
Notes	Although the output is on, the output may not have reached the set point value. The output should always be off when connecting or disconnecting cables to the output connector.
Examples	OUTPUT? response: 0, means that the TEC is off. OUTPUT? response: 1, means that the TEC is turned on.

PID

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The PID command is used to set the PID constant for the instrument.
Parameters	Three <nrf values> are required. The first represents P (the proportional term), the second represents I (the integral term), and the third represents D (the derivative term).
Notes	Valid values for P are between 0 and 9999.99. Valid values for I are between 0 and 999.999. Valid values for D are between 0 and 999.999. PID constants are only applicable in temperature and sensor modes. See Chapter 2 for more details on setting PID constants.
Example	PID 24,5.6,8.0 action: sets P=24.00, I=5.600, and D=8.000

PID?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The PID? Query returns the values of the PID coefficients.
Response	The response is three integer values, the first being the P term, the second being the I term, and the third being the D term.
Notes	The optimal PID coefficients depend on the sensor used, the thermal system and the control mode. For optimizing PID coefficients see Chap 2.
Example	PID? response: 24.00, 5.600,8.000, means P=24.00, I=5.600, and D=8.000

*PSC

Power-on Status Clear

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Sets automatic power-on clearing of the enable registers.
Parameters	One <nrf value> representing the power-on status clear flag is required. 0 = disable power-on clearing, 1 = enable power-on clearing.
Notes	Any non-zero value is interpreted as 1. Facotry default is 1 (enabled). Registers affected: Service Request Enable (*SRE) Standard Event Status Enable (*ESE) Event Enable Registers (ENAB:EVENT) In the disabled state, the values of the enable registers are saved through power off/on. The power-on status clear flag (see PSC?) is set false, allowing service request interrupts after power-on. In the enabled state, the enable registers are cleared during power on. The power-on status clear flag (see PSC?) is set true, disallowing service request interrupts after power-on.
Examples	*PSC 0 Disable automatic power-on clearing of the enable registers. *PSC 1 Enable automatic power-on clearing of the enable registers.

*PSC?

Power-on Status Clear?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Requests the state of the power-on status clear flag.
Response	The response is a single value that represents the state of the power-on status clear flag. 0 = The enable registers are saved through power off/on. 1 = The enable registers are cleared during power on.
Example	*PSC? response: 1, means automatic power-on clearing of the enable registers is enabled.

*PUD

Program User Data

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Stores data unique to the instrument, such as calibration date and serial number. This data is protected from change by the "SECURE <nrf>" command and is usually entered by the factory.
Notes	The arbitrary block program data is exactly 25 bytes long.

*PUD?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Requests the factory-stored identification string.
Response	The response is an arbitrary data block with a maximum length of 25 bytes.

RADix

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The RADix command allows the programmer to select the radix type for status, condition, and event query response data. Decimal, binary, hexadecimal, and octal are allowed.
Parameters	One three letter <character data value> is required.
Notes	DECimal is the default type. Only the first three letters of the words decimal, hexadecimal, binary, or octal are required. When the RADIX is selected, all status, condition, and event queries will return values in the new radix. In the cases where the radix is not DECimal, the flexible numeric type <nrf value> (as shown in the Command Reference diagrams) will be replaced by HEX, BIN, or OCT representation. All of the above radixes may be used to enter program data at any time, without the need for issuing the RADix command. The proper prefix must also be issued with Hex (#H), binary (#B), or octal (#O). This command may be useful for setting up status reporting blocks. The bit-wise status representation may be more easily read in BIN, HEX, or OCT.
Example	"RAD dec" action: the decimal radix is selected.

RADix?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The RADix? query allows the programmer to determine which radix type for status, condition, and event query response data is currently selected. Decimal, binary, octal, and hexadecimal are allowed.
Notes	DEC is the default type.
	The RADix command is used to select the desired radix. Once it is changed, the new radix will remain in effect until the unit is power-cycled or a new RADix command is issued.
Example	"RAD?" -response: DEC, meaning the selected radix is decimal.

*RCL <nrf value>

Recall

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Recalls a stored setup configuration from memory.
Parameter	A single <nrf value> is required. The value can range from 0 to 9.
Notes	Setup 0 has a factory-set default configuration as shown in Chapter 2.
	If you use GPIB to recall setup 0 (*RCL 0), GPIB mode is set to REMOTE. If you recall setup "0" by the front panel, GPIB mode is set to LOCAL.
	Same function as RECALL on the front panel.
	Use *SAV to store various setup configurations for convenient recall.
	The current setup is automatically stored and recalled at next power-ON.
Examples	*RCL 0 action: recall the factory default setup.

*RST

Reset

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Recalls factory default setup.
Notes	This command is identical in function to *RCL 0.
Example	*RST

*SAV

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Saves the current setup configuration in memory.
Response	One value in the range of 1 to 9 is required.
Notes	Configuration 0 is reserved for a factory-set default configuration. See *RCL.
	It is normally not necessary to save the current setup for next power-ON. The current setup is automatically stored for recall at next power-ON.
Example	*SAV 2 action: saves the current setup configuration as #2.

SENsor

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The SENsor commands selects the sensor type and sense current.
Parameter	One <character data value> representing the sensor type is required. The values accepted are THERM10UA, THERM100UA, THERM1MA, ICI, ICV, RTD10UA, RTD100UA, or RTD1MA.
Notes	For thermistor or RTD sensors, a sense current is applied through the sensor, and the resulting voltage is measured by the instrument. The measured voltage range is 0-6V. The best sense current to use depends on the expected resistance at the setpoint. The largest possible voltage swing in the vicinity of the setpoint will result in the best stability. For more details regarding proper sensor selection and sense current, refer to Chapter 2.
Example	SEN THERM100UA action: sets the sensor to thermistor and the sense current to 100 µA.

SENsor?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The SENsor? query returns the selected sensor type and sense current (if appropriate).
Response	The response is a single character string that represents the selected sensor and is one of the following: THERM10UA, THERM100UA, THERM1MA, ICI, ICV, RTD10UA, RTD100UA, or RTD1MA.
Notes	
Example	SENsor? Response: ICI, means the ICI sensor is selected.

SET:

COMMON
DEVICE DEPENDENT
FRONT PANEL

The SET: command path is used to access the control mode setpoint commands and queries.

The following may be reached directly from the SET: command path:

SET:ITE	SET:ITE?
SET:SENsor	SET:SENsor?
SET:TEMP	SET:TEMP?
SET:VTE	SET:VTE?

SET:ITE

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The SET:ITE command sets the constant TE current control setpoint.
Parameter	A <nrf value> that represents the ITE current setpoint, in Amps, is required.
Notes	This setting is always stored, but is only used when the instrument is in ITE control mode.
Example	SET:ITE 2.5 action: sets the setpoint for ITE mode to 2.5A.

SET:ITE?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The SET:ITE? query returns the constant TE current setpoint.
Response	The response is a single value that represents the constant ITE set point value, in Amps.
Notes	The ITE set point is only in effect when the operating mode is ITE.
Examples	SET:ITE? response: -0.5, means the output current set point is -0.5 A.

SET:SENsor

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The SET:SENsor command sets the constant sensor setpoint.
Parameter	A <nrf value> that represents the constant sensor setpoint is required.
Notes	This setting is always stored, but is only used when the instrument is in sensor mode. The units of the parameter are in dependent upon which sensor is selected, (RTD and thermistor in Ohms, ICI in Amps, ICV in Volts).
Example	SET:SENsor 0.002932 action: sets the setpoint for the ICV sensor to 2.93mV.

SET:SENsor?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The SET:SENsor? query returns the constant sensor setpoint.
Response	The response is a single value that represents the constant sensor set point value.
Notes	The constant sensor set point is only in effect when the operating mode is constant sensor. The units of setpoint are dependent upon what sensor is selected (i.e. if ICI is selected, the setpoint will be in Amps).
Examples	SET:SEN? response: 19600, means the constant sensor set point is 19.6 k□ (if the sensor selected is a thermistor).

SET:Temp

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The SET:Temp command sets the constant temperature control setpoint.
Parameter	A <nrf value> that represents the constant temperature setpoint, in degrees Celsius, is required.
Notes	This setting is always stored, but is only used when the instrument is in constant temperature mode.
Example	SET:T 75.43 action: sets the temperature setpoint to 75.43 ^{o}C.

SET:Temp?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The SET:Temp? query returns the constant temperature setpoint.
Response	The response is a single value that represents the constant temperature setpoint value, in ^{o}C.
Notes	The constant temperature setting is only in effect when the operating mode is T.
Examples	SET:T? response: 17.3 means the temperature setting is 17.3 ^{o}C.

SET:VTE

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The SET:VTE command sets the constant TE voltage setpoint.
Parameter	An <nrf value> that represents the constant voltage setpoint, in Volts, is required.
Notes	This setting is always stored, but is only used when the instrument is in VTE mode.
Example	SET:VTE 1.75 action: sets the VTE setpoint to 1.75V.

SET:VTE?

COMMON
DEVICE DEPENDENT
FRONT PANEL

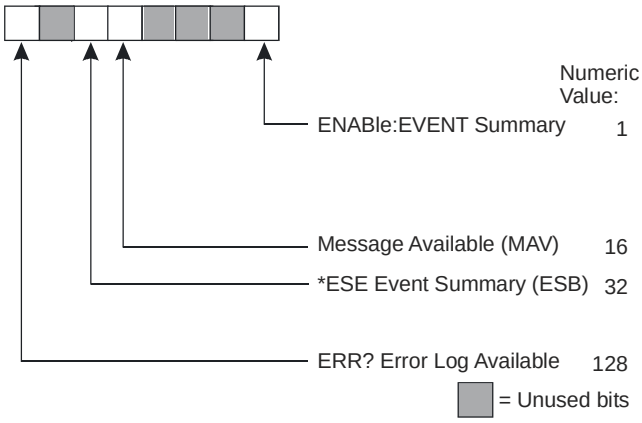
Action	The SET:VTE? query returns the constant TE voltage setpoint.
Response	The response is a single value that represents the constant voltage setpoint value, in Volts.
Notes	This setting is only in effect when the instrument is in VTE mode.
Example	SET:VTE? Response: -2.75 means sets the VTE setpoint is -2.75V.

*SRE <nrf value>

COMMON
DEVICE DEPENDENT
FRONT PANEL

Service Request Enable

Action Enables bits in the Service Request Enable Register.
Parameter The value must be between 0 and 255.



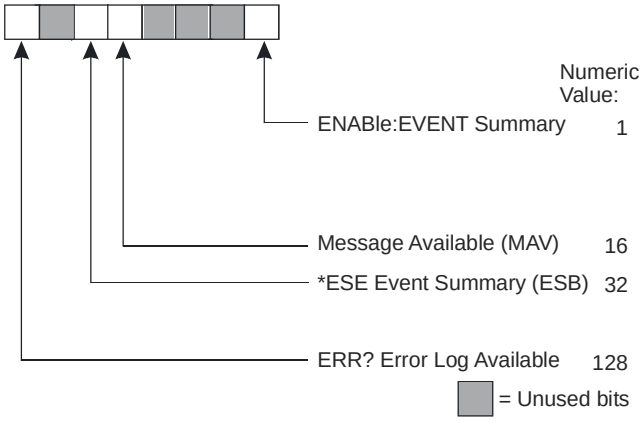
Notes Setting bits in this register enables GPIB Service Request (SRQ) generation.
Example *SRE 128 - Enables SRQ generation if the Error Log contains data (errors).

*SRE?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Service Request Enabled?

Action Requests the value in the Service Request Enable Register.
Response The value must be between 0 and 255.



Notes Refer to the GPIB IEEE488.2-1992 standard for more information on Service Requests.
Example *SRE? - Response 0 means the SRQ generation is disabled.

STATUS?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action The STATUS? query returns the contents of the controller Status Registers..

Response The response is two values which represent the sum of the status bits for register 1 and the sum of the status bits for register 0 respectively.

Status Register 1

Bit Number	Condition	Decimal Value
0	RAC Measurement Complete	1
1	Reserved	2
2	Output On	4
3	Measurement Within Setpoint Tolerance	8
4	Measurement Out of Setpoint Tolerance	16
5	Reserved	32
6	Reserved	64
7	Reserved	128
8	Reserved	256
9	Internal PCB Temperature Over Limit	512
10	Invalid Calibration Data	1024
11	DSP Reset	2048
12	TEC Temperature Runaway	4096
13	Reserved	8192
14	-15V PCB Supply Out of Tolerance	16384
15	Reserved	32768

Notes These registers represent the current real-time status of the controller and sensors.

Example STATUS? -response: 0, 8, means that there currently is a Sensor Short condition. See the Status Registers section of Chapter 3 for additional details.

Status Register 0

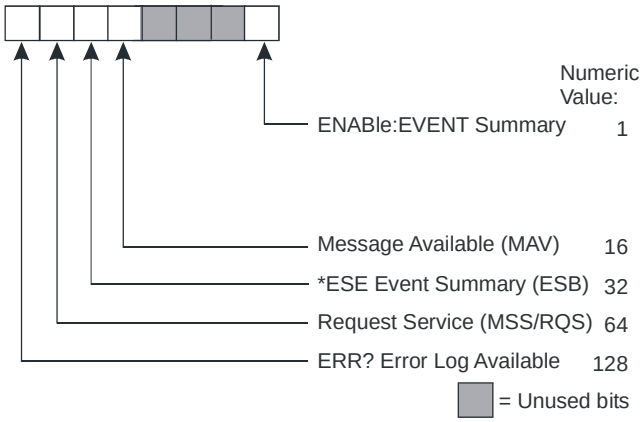
Bit Number	Condition	Decimal Value
0	Upper Temperature Limit	1
1	Lower Temperature Limit	2
2	Sensor Open	4
3	Sensor Shorted	8
4	TEC Current Upper Limit	16
5	TEC Current Lower Limit	32
6	TEC Voltage Upper Limit	64
7	TEC Voltage Lower Limit	128
8	TEC Open	256
9	TEC Shorted	512
10	Auto-Tune in Progress	1024
11	Sensor Upper Limit	2048
12	Sensor Lower Limit	4096
13	3V PCB Supply Out of Tolerance	8192
14	5V PCB Supply Out of Tolerance	16384
15	15V PCB Supply Out of Tolerance	32768

*STB?

Status Byte?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Requests the value in the Status Byte Register.
Response	The value must be between 0 and 255.



Notes	Refer to the GPIB IEEE488.2-1992 standard for more information on Service Requests.
Example	*STB? - Response 1 means an ENABle:EVENT condition has occured.

TIME?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The TIME? query returns the power on time of the instrument.
Response	The response is a single value that represents the power on time of the instrument.
Notes	The maximum time for this register is 1193:02:46.
Example	TIME? Response: 0:32:01 means 32 minutes and one second have elapsed since power on.

TIMER?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The TIMER? query returns the elapsed time since the last TIMER? command.
Response	The response is a value that represents the change in time since the last TIMER? query.
Notes	
Example	TIMER? Response: 0:12:07 means 12 minutes and 7 seconds have elapsed since the last TIMER? query.

TRIGger:IN

COMMON
DEVICE DEPENDENT
FRONT PANEL

The TRIGger:IN: command path is used to access the input trigger commands. The following commands can be reached directly from the TRIGger:IN: command path. (See Trigger In section of Chapter 2 for more information)

TRIGger:IN:ENABle	TRIGger:IN:STEPsize
TRIGger:IN:ENABle?	TRIGger:IN: STEPsize?
TRIGger:IN:START	TRIGger:IN:STOP
TRIGger:IN:START?	TRIGger:IN: STOP?

TRIGger:IN:ENABle

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The TRIGger:IN:ENABle command sets enables the trigger input.
Parameters	An <nrf value> that represents the desired setting is required. The number 1 represents the input trigger enabled, and number 0 represents the input trigger disabled.
Notes	The trigger input will allow an external TTL signal to trigger the instrument to the next temperature setpoint.
Example	TRIG:IN:ENAB 1 action: Enables the input trigger.

TRIGger:IN:ENABle?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The TRIGger:IN:ENABle? query returns the value of the trigger input enable status.
Response	The response is a single value that represents the input trigger enable status. The number 1 means the input trigger is enabled, and the number 0 means the input trigger is disabled.
Notes	
Example	TRIG:IN:ENAB? response: 0 means the input trigger is disabled.

TRIGger:IN:START

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The TRIGger:IN:START command sets the starting temperature setpoint.
Parameters	An <nrf value> that represents the desired starting temperature setting is required, in ^{O}C.
Notes	Valid input range is limited to the LIM:TEMP:HI and LIM:TEMP:LO settings.
Example	TRIG:IN:START 20 action: Sets the starting temperature setpoint to 20 ^{O}C.

TRIGger:IN:START?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The TRIGger:IN:START? query returns the value of the starting temperature setpoint.
Response	The response is a single value that represents the starting temperature setpoint, in ^{o}C.
Notes	
Example	TRIG:IN:START? response: 20, means the starting temperature setpoint is 20 ^{o}C.

TRIGger:IN:STEP

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The TRIGger:IN:STEP size command sets the temperature step size.
Parameters	An <nrf value> that represents the desired temperature step size is required, in ^{o}C. Valid step size values range from -100 ^{o}C to +100 ^{o}C.
Notes	To increase temperature from the starting point, a positive step size must be entered.
‘	To decrease temperature from the starting point, a negative step size must be entered.
Example	TRIG:IN:STEP 1.505 action: Sets the temperature step size to 1.505 ^{o}C increments.

TRIGger:IN:STEP?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The TRIGger:IN:STEP? query returns the value of the temperature step size.
Response	The response is a single value that represents the temperature step size, in ^{o}C.
Notes	
Example	TRIG:IN:STEP? response: 1.505, means the temperature step size is 1.505 ^{o}C.

TRIGger:IN:STOP

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The TRIGger:IN:STOP command sets the stopping temperature setpoint.
Parameters	An <nrf value> that represents the desired stopping temperature setting is required, in ^{o}C.
Notes	Valid input range is limited to the settings for LIM:TEMP:HI and LIM:TEMP:LO. If a trigger is sent after the stop temperature is reached, the temperature will return to the starting temperature.
Example	TRIG:IN:STOP 40 action: Sets the stopping temperature setpoint to 40 ^{o}C.

TRIGger:IN:STOP?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The TRIGger:IN:STOP? query returns the value of the stopping temperature setpoint.
Response	The response is a single value that represents the stopping temperature setpoint, in ^{o}C.
Notes	
Example	TRIG:IN:STOP? response: 40, means the stopping temperature setpoint is 40 ^{o}C.

TRIGger:OUT:DELAY

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The TRIGger:OUT:DELAY command sets the delay between the setpoint being in tolerance and the output trigger going high.
Parameters	An <nrf value> that represents the desired delay time, in seconds, is required.
Notes	This command can be used to delay when the output trigger goes high to insure the thermal load is stable. Valid input range is 0 to 60.000 seconds.
Example	TRIG:OUT:DELAY 5 action: Sets a 5 second delay between when the temperature is within set tolerance and when the output trigger goes high. (The temperature must stay within tolerance during the entire delay period.)

TRIGger:OUT:DELAY?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	The TRIGger:OUT:DELAY? query returns the value of the trigger out delay.
Response	The response represents the delay time, in seconds.
Example	TRIG:OUT:DELAY? response: 5, means the control feedback measurement (temperature) must remain within the setpoint tolerance for 5 seconds before trigger out will go high.

*TST?

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Performs internal self-test, then reports results.
Response	0 = test completed with no errors. Non-zero = test not completed, or was completed with errors.
Notes	No internal self-test is implemented; *TST? will always retain zero.
Example	*TST? response: 0, indicates the self test was completed with no errors detected.

*WAI

Wait to Continue

COMMON
DEVICE DEPENDENT
FRONT PANEL

Action	Prevents the instrument from executing any further commands until OPC (operation complete) status is true.
Note	This command has no effect for sequential commands and all commands for this instrument are sequential.
Example	*WAI action: wait until OPC status is true.

CHAPTER 5

CALIBRATION AND TROUBLESHOOTING

This chapter describes calibration and troubleshooting of the LDT-5900 Series Temperature Controllers. Descriptions of the required test instruments, calibration conditions, and detailed procedures for calibration of the temperature controllers are included. A troubleshooting guide is also offered for common failure problems.

ILX Lightwave Corporation provides in-house and on-site calibration services for ILX instruments. Most ILX instruments require yearly calibration to ensure performance to published specifications. ILX factory calibrations employ NIST traceable measurement instrumentation, and our calibration engineers and technicians use automated test equipment to accurately and efficiently capture and record calibration data. An original certificate of calibration authenticity is provided with all instrument calibrations, and a detailed report showing any pre-calibration out-of-tolerance conditions is available upon request. Calibration turn-times are normally five business days or less. On-site calibrations can be performed around your production schedule, night or day, seven days a week. Please contact ILX Customer Support (see Comments, Suggestions, and Problems on page xii for contact information) for additional calibration information.

For further assistance with technical solutions and troubleshooting, visit the www.ilxlightwave.com Support Library for Application Notes and Technical Notes.

Calibration

Several calibrations must be performed to fully calibrate the LDT-5948 and LDT-5980. These calibrations consist of adjustments to the Analog-to-Digital and Digital-to-Analog Converters for the TE Voltage Sensor, TE Current Sensor, bipolar TE output current, Temperature Sensor output current and Temperature Sensor voltage measurement.

Calibrate the unit every 12 months or whenever performance indicates recalibration is required. Signs that calibration may be required include differences between set point and measurement display values that exceed the accuracy specification. Calibrate the unit in a normal laboratory temperature range, namely 23°C ± 3°C. If possible, calibrate the unit at its intended use temperature (if this is within the specified operating temperature range of 10 - 40°C.

Note: Turn on and warm up the unit with output enabled at 5 Amps for a minimum of five minutes prior to calibration.

Recommended Equipment

A digital voltmeter comparable to an Agilent 34401A is required for instrument calibration. The pertinent specifications are listed below.

DC Voltage Measurement Accuracy (0 - 10VDC)	± 0.002%
4-wire (Kelvin) Resistance Measurement Accuracy (0 - 1MΩ)	± 0.002%
Input Resistance (ranges 10V and lower)	> 10 GΩ

Several different resistive loads are required for calibration as shown below:

Sensor Measurement Calibration	10 Ω, 100 Ω, 1 kΩ, 10 kΩ, and 100 kΩ resistors, 1%, 1/4 W, 1 PPM temperature coefficient
TE Measurement / Output Calibration	1 Ω resistor, 1%, 100W or greater, 25 - 50 PPM temperature coefficient, adequately heatsunk (TE output calibration); 6 Ω resistor, 1%, 5W or greater, 25 - 50 PPM temperature coefficient, adequately heatsunk (RAC calibration)

Low resistance cabling capable of running at five Amperes continuous duty is required to connect between the unit's output connector and the TE test load. The TE cabling should be twisted together as one bundle and the sensor cabling twisted together in a separate bundle to minimize noise. The "TEC Sense" and "Sensor Sense" lines must be connected to their corresponding loads at the same

location as the remaining output wires. Failure to do this will result in voltage differentials that will degrade the calibration accuracy. Finally, pins 4 and 17 and 5 and 18 must be shorted together to allow operation at maximum current.

A computer capable of GPIB or RS232 communications is required in order to calibrate the instrument. CALIBRATION VIA THE FRONT PANEL IS NOT POSSIBLE. It shall be assumed that the computer and instrument are already connected and communicating correctly.

Calibration Procedure

1 WARMUP

1a Using the multimeter's 4-wire (Kelvin) resistance measurement mode, accurately measure the resistance of the TE cal and sensor measurement cal resistors. Allow the measurement to sit undisturbed for at least 1 minute before recording any readings to allow any heating or excess noise due to handling to dissipate.

1b Connect one end of the calibration/test cable to the output of the instrument to be calibrated and the other end to the appropriate cal resistors.

1c Go into the Parameter Limits menu and set each limit to its maximum value.

1d Place unit in ITE Mode, set output to 5 A and enable.

1e Allow unit to warm up a minimum of 5 minutes with the output on before proceeding with calibration.

1f Note: Calculated values for slope and scale factor should be close to 1.00. Offset values should be close to 0.00.

1g Record the current calibration values by querying each calibration command. This should be done in case of an error so the previous calibration state can be recovered. A list of all calibration commands can be found in Figure 3.1 and Table 4.1.

2 VTE MEASUREMENT CALIBRATION

2a Enable Cal Mode by entering the remote command **MODE CAL**.

2b Reset the calibration constants to default values of 1.0 for slope and 0.0 for offset by entering the command **CAL:DEFault**; **CAL: SAVE**.

Note: This command sets ALL calibration values to default.

2c Enable ITE Mode by entering the remote command **MODE ITE**.

2d Set output to -5 A (-4.5 A if 5948 to prevent current limit from enabling) and connect the DMM (Digital MultiMeter) across the TE Cal resistor to measure voltage. Pay attention to polarity.

2e Allow one minute for current to stabilize if output has just been enabled.

2f Record the TE voltage as measured by the instrument [(Unit Under Test (UUT)]. A more accurate method to determine VTE_{UUT1} is by averaging several readings obtained by querying the instrument via the **MEASure:VTE?** Command.

Note: Note: Allow a minimum of 2 seconds to elapse between readings to ensure the instrument has had enough time to perform another round of measurements.

2g Record the actual TE voltage as measured by the DMM (VTE_{DMM1}). Again, it is more accurate to determine VTE_{DMM1} by averaging several readings obtained by remote querying the DMM.

2h Set output to +5 A (+4.5 A if 5948).

2i Record VTE_{UUT2} (preferably via **MEASure:VTE?**).

2j Record VTE_{DMM2}.

2k Disable output.

2l Calculate the VTE Measurement Slope and Offset using the following formulae:

$$m_{VTE} = \frac{VTE_{DMM2} - VTE_{DMM1}}{VTE_{UUT2} - VTE_{UUT1}}$$

$$b_{VTE} = VTE_{DMM2} - m_{VTE} \cdot VTE_{UUT2}$$

2m Enable Cal Mode by entering the remote command **MODE CAL**.

2n Enter the new calibration values using the command: **CAL:VTE** m_{VTE}, b_{VTE}

2o Save the new values to flash memory by using the **CAL:SAVE** command.

2p Return to ITE Mode by the **MODE ITE** command.

2q To verify the cal values have been correctly stored, use the **CAL:VTE?** command to query them.

3 ITE MEASUREMENT CALIBRATION

3a Set output to -5 A (-4.5 A if 5948 to prevent current limit from enabling) and connect the DMM (Digital MultiMeter) across the TE Cal resistor to measure voltage. Pay attention to polarity.

3b Allow one minute for current to stabilize if output has just been enabled.

3c Record the TE current (ITE_{UUT1}) as measured by the UUT using the **MEASure:IADC?** command.

Note: Note: Allow a minimum of 2 seconds to elapse between readings to ensure the instrument has had enough time to perform another round of measurements.

3d Record the TE voltage (VTE_{DMM1}) as measured by the DMM.

3e Set output to +5 A (+4.5 A if 5948).

3f Record ITE_{UUT2} (preferably via **MEASure:IADC?**).

3g Record VTE_{DMM2}.

3h Disable output.

3i Calculate the ITE Measurement Slope and Offset using the following formulae:

$$m_{ITE} = \frac{VTE_{DMM2} - VTE_{DMM1}}{R_{TE} \cdot (ITE_{UUT2} - ITE_{UUT1})}$$

$$b_{ITE} = \frac{VTE_{DMM2}}{R_{TE}} - m_{VTE} \cdot ITE_{UUT2}$$

3j Enable Cal Mode by entering the remote command **MODE CAL**.

3k Enter the new calibration values using the command: **CAL:ITE** m_{ITE}, b_{ITE}

3l Save the new values to flash memory by using the **CAL:SAVE** command.

3m Return to ITE Mode by the **MODE ITE** command.

3n To verify that the calibration values were correctly saved, query the instrument with the **CAL:ITE?** command.

4 ITE OUTPUT CALIBRATION

4a Set output to -5.000 A (-4.500 A if 5948 to prevent current limit from enabling) and connect the DMM (Digital MultiMeter) across the TE Cal resistor to measure voltage. Pay attention to polarity.

4b Allow one minute for current to stabilize if output has just been enabled.

4c Record the TE voltage (VTE_{DMM1}) as measured by the DMM.

4d Set output to +5.000 A (+4.500 A if 5948).

4e Record VTE_{DMM2}.

4f Disable output.

4g Calculate the ITE Output Slope and Offset using the following formulae:

For Model 5948

$$m_{ITE} = \frac{9.0 \cdot R_{TE}}{VTE_{DMM2} - VTE_{DMM1}}$$

For Model 5980

$$m_{ITE} = \frac{10.0 \cdot R_{TE}}{VTE_{DMM2} - VTE_{DMM1}}$$

For Model 5948

$$b_{ITE} = 4.5 - m_{ITE} \cdot \frac{VTE_{DMM2}}{R_{TE}}$$

For Model 5980

$$b_{ITE} = 5.0 - m_{ITE} \cdot \frac{VTE_{DMM2}}{R_{TE}}$$

4h Enable Cal Mode by entering the remote command **MODE CAL**.

4i Enter the new calibration values using the command: **CAL:COARSEDAC** m_{ITE}, b_{ITE}

4j Save the new values to flash memory by using the **CAL:SAVE** command.

4k Return to ITE Mode by the **MODE ITE** command.

4l Verify the calibration values are correct by using the query **CAL:COARSEDAC?** to check them.

5 SENSOR OUTPUT CURRENT CALIBRATION

5a Select Sensor Mode and connect 100 k□ resistor across sensor loads.

5b Connect DMM across 100 k□ resistor (R_{sens1}) to measure voltage. Pay attention to polarity.

5c Select 10 µA thermistor current from Sensor Parameter Menu.

5d Record voltage (V_{sens1}) across 100 k□ resistor .

5e Replace 100 k□ resistor with 10 k□ resistor (R_{sens2}).

5f Select 100 µA thermistor current from Sensor Parameter Menu.

5g Record voltage (V_{sens2}) across 10 k□ resistor.

5h Replace 10 k□ resistor with 1 k□ resistor (R_{sens3}).

5i Select 1 mA thermistor current from Sensor Parameter Menu.

5j Record voltage (V_{sens3}) across 1 k□ resistor.

5k Calculate scale factor for each current setting from the following:

for i = 1 - 3

$$scalefactor_i = \begin{cases} 10\,\mu A \\ 100\,\mu A \\ 1mA \end{cases} \frac{R_{sens_i}}{V_{sens_i}}$$

Note: Pay attention to units; $scalefactor_i$ is dimensionless.

5l Enable Cal Mode by entering the remote command **MODE CAL**.

5m Enter the new 10 µA scale factor via the command **CAL:SOURCE:SENsor:10UA** $scalefactor_1$.

5n Enter the new 100 µA scale factor via the command **CAL:SOURCE:SENsor:100UA** $scalefactor_2$.

5o Enter the new 1 mA scale factor via the command **CAL:SOURCE:SENsor:1MA** $scalefactor_3$.

5p Save the new values to flash memory by using the **CAL:SAVE** command.

5q Return to Sensor Mode by using the **MODE SENSOR** command.

5r Enter the commands **CAL:SOURCE:SENsor:10UA?**, **CAL:SOURCE:SENsor:100UA?**, and **CAL:SOURCE:SENsor:1MA?** to verify that the factors were stored correctly.

6 SENSOR VOLTAGE MEASUREMENT CALIBRATION

6a NOTE: The sensor voltage measurement must be calibrated for each thermistor current setting.

6b Select 10 µA thermistor current from Sensor Parameter Menu. Connect the 1 k□ resistor (R_{sens1a}) to the sensor leads. Connect the DMM across the resistor as well to measure voltage.

6c Record voltage (V_{sens1a}) across R_{sens1a} as measured by DMM.

6d Record UUT-measured resistance (R_{1a}) using the **MEASure:SENsor?** command.

6e Replace 1 k□ resistor with 100 k□ resistor (R_{sens1b}) and record voltage (V_{sens1b}) across resistor as measured by DMM.

6f Record UUT-measured resistance (R_{1b}) using the **MEASure:SENsor?** command.

6g Calculate, using Ohm's Law, the voltage drop corresponding to the UUT-measured resistances.

for *x = a & b*

$$V_{1x} = \left[\frac{V_{sens1x}}{R_{sens1x}}\right] R_{1x}$$

6h Calculate the 10 □A Sensor Voltage Measurement slope and offset using the equations below:

$$m_{vsens1} = \frac{V_{sens1b} - V_{sens1a}}{V_{1b} - V_{1a}}$$

$$b_{vsens1} = V_{sens1b} - m_{vsens1} V_{1b}$$

6i Enable Cal Mode by entering the remote command **MODE CAL**.

6j Enter the new calibration values by using the command **CAL:SENsor:VOLTage:10UA** m_{vsens1}, b_{vsens1}.

6k Save the new values to flash memory by using the **CAL:SAVE** command.

6l Return to Sensor Mode by using the **MODE SENSOR** command.

6m Verify the correct storage of the calibration values by entering **CAL:SENsor:VOLTage:10UA?**.

6n Begin calibration of 100 □A thermistor current by selecting 100 □A thermistor current from Sensor Parameter Menu. Connect 100 □ resistor (R_{sens2a}) to sensor leads. Connect the DMM across the resistor as well to measure voltage.

6o Record voltage (V_{sens2a}) across R_{sens2a} as measured by DMM.

6p Record UUT-measured resistant (R_{2a}) using the **MEASure:SENsor?** command.

6q Replace 100 □ resistor with 10 k□ resistor (R_{sens2b}) and record voltage (V_{sens2b}) across resistor as measured by DMM.

6r Record UUT-measured resistance (R_{2b}) using the **MEASure:SENsor?** command.

6s Calculate, using Ohm's Law, the voltage drop corresponding to the UUT-measured resistances.

for *x* = *a* & *b*

$$V_{2x} = \left[\frac{V_{sens2x}}{R_{sens2x}}\right] R_{2x}$$

6t Calculate the 100 mA Sensor Voltage Measurement slope and offset using the equations below:

$$m_{vsens2} = \frac{V_{sens2b} - V_{sens2a}}{V_{2b} - V_{2a}}$$

$$b_{vsens2} = V_{sens2b} - m_{vsens2} \cdot V_{2b}$$

6u Enable Cal Mode by entering the remote command **MODE CAL**.

6v Enter the new calibration values by using the command **CAL:SENSor:VOLTage:100UA** m_{vsens2}, b_{vsens2}.

6w Save the new values to flash memory by using the **CAL:SAVE** command.

6x Return to Sensor Mode by using the **MODE SENSOR** command.

6y Verify the correct storage of the calibration values by entering **CAL:SENSor:VOLTage:100UA?**

6z Begin calibration of 1 mA thermistor current by selecting 1 mA thermistor current from Sensor Parameter Menu. Connect 10Ω resistor (R_{sens3a}) to sensor leads. Connect the DMM across the resistor as well to measure voltage.

6aa Record voltage (V_{sens3a}) across R_{sens3a} as measured by DMM.

6ab Record UUT-measured resistance (R_{3a}) using the **MEASure:SENsor?** command.

6ac Replace 10 Ω resistor with 1kΩ resistor (R_{sens3b}) and record voltage (V_{sens3b}) across resistor as measured by DMM.

6ad Record UUT-measured resistance (R_{3b}) using the **MEASure:SENsor?** command.

6ae Calculate, using Ohm's Law, the voltage drop corresponding to the UUT-measured resistances.

for *x* = *a* & *b*

$$V_{3x} = \left[\frac{V_{sens3x}}{R_{sens3x}}\right] R_{3x}$$

6af Calculate the 1 mA Sensor Voltage Measurement slope and offset using the equations below:

$$m_{vsens3} = \frac{V_{sens3b} - V_{sens3a}}{V_{3b} - V_{3a}}$$

$$b_{vsens3} = V_{sens3b} - m_{vsens3} \cdot V_{3b}$$

6ag Enable Cal Mode by entering the remote command **MODE CAL**.

6ah Enter the new calibration values by using the command **CAL:SENSor:VOLTage:1MA** m_{vsens3}, b_{vsens3}.

6ai Save the new values to flash memory by using the **CAL:SAVE** command.

6aj Return to Sensor Mode by using the **MODE SENSOR** command.

6ak Verify the correct storage of the calibration values by entering **CAL:SENSor:VOLTage:100UA?**

7 RAC Calibration

7a NOTE: R_{AC} mode and the subsequent recalibration thereof is only possible with firmware version 01.03.09 and above.

7b Select R_{AC} mode and connect TE output across TE Cal resistor R_{TE}. *To ensure highest possible accuracy, ensure TE voltage sense lines are connected to the same points on the TE Cal resistor as the TE output.*

7c Enable R_{AC} measurement by sending the remote command **OUTput ON**

7d Record the first measurement for R_{AC1} by querying the instrument with **MEASure:RAC?**

7e Re-enable R_{AC} measurement with another **OUTput ON** command followed by a **MEASure:RAC?** query and record this second R_{AC1} measurement.

7f Repeat this process several additional times to generate a well-defined mean value for R_{AC1}.

7g Replace R_{TE} with R_{AC} Cal resistor R_{RAC}.

7h Take several measurements of R_{RAC} using **OUTput ON** and **MEASure:RAC?** to generate a well-defined mean value for R_{AC2}.

7i Calculate the R_{AC} Slope and Offset values using the following formulae:

$$m_{RAC} = \frac{R_{RAC} - R_{TE}}{R_{AC2} - R_{AC1}}$$

$$b_{RAC} = R_{RAC} - m_{RAC} \cdot R_{AC2}$$

7j Enable Cal Mode by entering the remote command **MODE CAL**

7k Enter the new calibration values using the command **CAL:RAC** m_{RAC}, $-b_{RAC}$

NOTE: The offset value that must be entered in the above step is the ***negative*** of the value calculated in step i.

7l Save the new values to flash memory by using the **CAL:SAVE** command.

7m Return to R_{AC} mode by the **MODE RAC** command.

7n Verify the calibration values are correct by issuing the query **CAL:RAC?** to check them.

Troubleshooting

This section is a guide to troubleshooting the LDT-5900 Series Temperature Controllers. Some of the more common symptoms are listed here, and the appropriate troubleshooting actions are given. If problems persist, contact ILX Customer Service (see page xii for contact information). Also check the www.ilxlightwave.com Support page, and the Library page for Application Notes and Technical Notes.

Table 5.1 Problem and Action

SYMPTOM	CORRECTIVE ACTIONS
General	
Unit will not power up.	Check AC Power line voltage and power cord connection.
Power on, but outputs have been shut off. Instrument is locked up or instrument resets itself.	This may occur if the instrument loses power (AC line) briefly or line voltage drops below specification. If instrument is locked up, power it off and then on to restart.
Output has been shutoff.	Check for output off enable conditions (Chapter 3); make sure the cable is securely connected to the unit and the load.
TE Controller	
Power on, but no TE current output.	Check the load connections and operating mode. Make sure the cable between the instrument and the load is secure.
Power on, but temperature is not controlled or is unstable.	If there is a SENSOR OPEN indication (E412), check the sensor connections (pins 14,15). Check that the proper sensor current range is selected. The 10 □A setting is required if the thermistor resistance is more than 50 k□. See Application note #2 at www.ilxlightwave.com or contact ILX Customer Service. The 1 mA setting is required for resistances less than 1 k□. Check that the appropriate coefficients have been set for your sensor. Refer to “Sensor Options” in Chapter 2. Check that the P, I and D constants are optimized for your thermal load and that the current limit value is not too low. Refer to “PID / Auto-Tune” in Chapter 2. See Technical Solutions on the Support page at www.ilxlightwave.com.
Unable to adjust output or parameter.	Ensure that the desired parameter is highlighted. Ensure that you are not trying to set a setpoint to a higher value than the limits. Verify lock indicator is not on. Press Enter button after adjusting parameter.

Table 5.1 Problem and Action

SYMPTOM	CORRECTIVE ACTIONS
Output turns off or turns off intermittently.	Check that the AC power cord connection is secure. Power-line dropouts may reset the unit and when power is restored, the output will be off. Check the TE module connections. A high impedance on the TE load can cause the output to exceed the compliance voltage momentarily. If enabled with GPIB, this condition will shut off the output. There are other events or conditions that will turn the output off if enabled with GPIB. See Output Off Registers in Chapter 3 for more information. Check the sensor connections at the module and the load. Changing control modes while the output is on will turn the output off.
Cannot increase current limit to 5A/10A.	Verify output cable is securely connected to output connector and that the Cable ID jumpers are correct.

Error Codes

The LDT-5900 indicates general TEC operational error conditions on the display or through the GPIB using the ERR? command. This section contains descriptions of the errors that are specific to the LDT-5900.

Front panel Error Indicators

When an error occurs, the error code and message appears on the front panel display.

Table 5.2 LDT-5980/5948 Error Codes

Range	Area of Operation
E-100 to E-199	Command / Parser Errors
E-200 to E-299	Execution Control Errors
E-300 to E-399	Remote Operation Errors
E-400 to E-499	TEC Control Errors
E-700 to E-799	System Errors
E-800 to E-899	Internal Errors
Error Code	**Explanation**
0	No errors found
123	Command not found
124	Look-up failed because query / command match failed
125	Parser syntax error

Error Code	Explanation
126	End of data error
127	Invalid parameter for command
130	Query not supported
131	Command not supported
201	Parameter value out of range
202	Error in conversion of parameter type
203	Command is a "secure" command, but secure commands are disabled
214	Response is too long to output
226	Error in arbitrary block specification
228	Delimiter not found
230	Invalid internal response
301	No data found error
302	Not empty error
401	Controller output off error
402	Calibration failed
403	DSP reset failed
404	Calibration constant error
405	Invalid sensor error
407	Invalid mode error
408	DSP controller communication failure
410	Upper Temperature Limit caused controller output to turn off
411	Lower Temperature Limit caused controller output to turn off
412	Open sensor caused controller output to turn off
413	Shorted sensor caused controller outputcontroller output to turn off
414	Upper Current Limit caused controller output to turn off
415	Lower Current Limit caused controller output to turn off
416	Upper Voltage limit caused controller output to turn off
417	Lower Voltage Limit caused controller output to turn off
418	Open TEC Module caused controller output to turn off
419	Shorted TEC Module caused controller output to turn off
420	Sensor over resistance caused controller output to turn off
421	Sensor under resistance caused controller output to turn off
422	Plus 3V supply out-of-tolerance condition caused controller output to turn off
423	Plus 5V supply out-of-tolerance condition caused controller output to turn off
424	Plus 15V supply out-of-tolerance condition caused controller output to turn off

Error Code	Explanation
425	Measurement out of setpoint tolerance caused controller output to turn off
426	PCB Temperature out-of-tolerance caused controller output to turn off
427	Invalid calibration data caused controller output to turn off
428	DSP reset caused controller output to turn off
429	Current limit and thermal runaway caused controller output to turn off
430	Cable change caused controller output to turn off
431	Neg 15V supply out-of-tolerance condition caused controller output to turn off
432	Setpoint over upper limit caused controller output to turn off
433	Setpoint under lower limit caused controller to turn off
714	Display error
715	Logic error
821	Command handler couldn't send message
832	UART received bad length byte
850	Internal mail list access list failed
851	Unknown TEC ID command
854	Invalid UART ID
855	UART transmit buffer overflow
856	UART receive buffer overflow

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