User's Guide

Quantum Cascade Laser Controller
LDC-3736

ILX Lightwave
A Newport Company

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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

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

WARNING

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

WARNING

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 to your authorized local ILX Lightwave distributor, for service or repair to ensure that safety features are maintained.

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

Safety Symbols

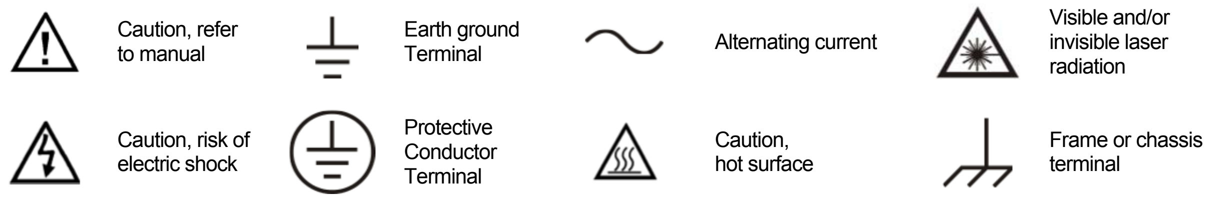
This section describes the safety symbols and classifications.

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.
- IEC Class I Equipment (grounded type)
- Mains supply voltage fluctuations are not to exceed ±10% of the nominal supply voltage.
- Pollution Degree II
- Installation (overvoltage) Category II for transient over-voltages
- Maximum Relative Humidity: <85% RH, non-condensing
- Operating temperature range of 10 °C to 40 °C
- Storage and transportation temperature of –40 °C to 70 °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 may 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.



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:

- Obtain a Return Merchandise Authorization number (RMA) from ILX Customer Service.
- 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.
- Attach the anti-static protective caps that were shipped with the instrument.
- 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.
- Secure the packing box with fiber reinforced strapping tape or metal bands.
- Send the instrument, transportation pre-paid, to ILX Lightwave. Clearly write the return merchandise 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:

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

Fax (406) 586-9405

E-mail sales@ilxlightwave.com

Or mail to:

ILX Lightwave Corporation

31950 East Frontage Road

Bozeman, Montana, U.S.A 59715-8642

www.newport.com/ilxlightwave

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 Merchandise Authorization (RMA) 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 chapter is an introduction to the LDC-3736 Quantum Cascade Laser Controller and contains unpacking information, instructions on how to install and apply power, maintenance information, specifications and listings of the LDC-3736 options and accessories.

- ✓ Safety Considerations and unpacking information
- ✓ Product Overview
- ✓ Options and accessories
- ✓ Specifications

Safety Considerations

WARNING

If any of the following symptoms exist, or are even suspected, remove the LDC-3736 instrument from service. Do not use the LDC-3736 instrument 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 LDC-3736 instrument to ILX Lightwave for service and repair to ensure that safety features are maintained.

Initial Inspection

When you receive your LDC-3736 Quantum Cascade Laser Controller, verify that the following items were shipped with the instrument

- LDC-3736 Quantum Cascade Laser Controller Manual
- Power Cord
- Shipping Kit
- LNF-320 Low Noise Filter

Shipping Kit

The shipping kit for the LDC-3736 Quantum Cascade Laser Controller includes a USB A/B cable and a CD containing the ILX Lightwave USB Driver.

Product Overview

The LDC-3736 Quantum Cascade Laser Controllers are high performance combination current source/temperature controllers. The current source provides a high stability output with a fully redundant current limit and multiple laser protection features. The built-in temperature controller can work with a wide range of temperature sensors and thermoelectric modules to deliver precise laser temperature control over a wide range of temperatures. The LDC-3736's fast, sophisticated GPIB and USB interfaces ensure trouble-free remote programming and readout.

If cleaning is required, use a clean dry cloth. Do not use solvents.

Figure 1.1 – LDC-3736 Front Panel

Figure 1.2 – LDC-3736 Rear Panel

Options and Accessories

Options and accessories available for LDC-3736 Quantum Cascade Laser Controller include the following:

DESCRIPTION	MODEL / PART NUMBER
Single Rack Mount Kit	RM136
Current Source Interconnect Cable (unterminated)	CC306S
Current Source Interconnect Cable (terminated)	CC305S
10 Amp TE Interconnect Cable	CC-594H
5 Amp TE/LDM Interconnect Cable (terminated with 9-pin DSUB)	CC-595S
10 Amp TE Interconnect Cable (terminated with 7W2 DSUB)	CC-596H
Calibrated 10 kΩ Thermistor	TS-510
Quantum Cascade Laser Mounting Fixture, C-mount	LDM-487201
Quantum Cascade Laser Mounting Fixture, Alpes COC	LDM-487202

LDC-3736 Specifications

LASER CURRENT SOURCE

LDC-3736

DRIVE CURRENT OUTPUT [1]

Output Current Range:	0–1000mA	0–2000mA	0–4000mA
Setpoint Resolution (Display):	0.1mA	0.1mA	0.1mA
Setpoint Resolution (Remote):[12]	20µA	40µA	80µA
Setpoint Accuracy (% of FS):	±0.15% of SP ± 1mA	±0.15% of SP ± 1mA	±0.15% of SP ± 1mA
Compliance Voltage:	0–18V adjustable	0–18V adjustable	0–18V adjustable
Temperature Coefficient:	<50ppm/°C	<50ppm/°C	<50ppm/°C
Short-Term Stability (one-hour):[2]	<20ppm	<20ppm	<20ppm
Long-Term Stability (24-hour):[3]	<40ppm	<40ppm	<40ppm
Noise and Ripple (rms)[4]			
High Bandwidth Mode (rms):	30µA	60µA	100µA
Low Bandwidth Mode (rms):	30µA	50µA	90µA
Low Bandwidth Mode (with LNF-320):	10µA	15µA	50µA
Transients			
Operational:[5]	<4mA	<4mA	<4mA
1 kV EFT/Surge:[6]	<15mA/<8mA	<15mA/<8mA	<15mA/<8mA

COMPLIANCE VOLTAGE ADJUST

Range:	0–18V	0–18V	0–18V
Setpoint Resolution (Display):	0.1V	0.1V	0.1V
Setpoint Resolution (Remote):	60mV	60mV	60mV
Accuracy:	±2.5%	±2.5%	±2.5%

DRIVE CURRENT LIMIT SETTINGS

Range:	1–1010mA	1–2020mA	0–4040mA
Resolution:	5mA	10mA	20mA
Accuracy:	±20mA	±40mA	±101mA

PHOTODIODE FEEDBACK

Type:	Differential	Differential	Differential
Photodiode Reverse Bias:	0–5V adjustable	0–5V adjustable	0–5V adjustable
Photodiode Current Range:	5 to 10000µA	5 to 10000µA	5–10000µA
Output Stability:[7]	0.02%	0.02%	0.02%
Setpoint Accuracy:	±0.05% of FS	±0.05% of FS	±0.05% of FS

EXTERNAL ANALOG MODULATION

Input:	0–10V, 1 kΩ	0–10V, 1 kΩ	0–10V, 1 kΩ
Transfer Function:	100mA/V	200mA/V	400mA/V
Bandwidth (3dB)			
High Bandwidth:[8]	DC to 250kHz	DC to 250kHz	DC to 250Hz
Low Bandwidth:[9]	DC to 17kHz	DC to 17kHz	DC to 17Hz

TRIGGER OUTPUT

Type:	TTL	TTL	TTL
Pulse Width:	10 µs	10 µs	10 µs
Delay:	2.5 mS	2.5 mS	2.5 mS

MEASUREMENT (DISPLAY)

Output Current			
Range:	0–1000.0mA	0–2000.0mA	0–4000mA
Resolution:	0.1mA	0.1mA	0.1mA
Accuracy:	±0.1% FS	±0.1% FS	±0.1% FS
Photodiode Current			
Range:	0–10000µA	0–10000µA	0–10000µA
Resolution:	1µA	1µA	1µA
Accuracy:	±4µA	±4µA	±4µA
Photodiode Responsivity			
Range (µA/mW):[10]	0.00–1000.00	0.00–1000.00	0.00–1000.00
Resolution:	0.01µA/mW	0.01µA/mW	0.01µA/mW
Optical Power			
Range (mW):	0.00–20000.0	0.00–20000.0	0.00–20000.0
Resolution:	0.1mW	0.1mW	0.1mW
Forward Voltage			
Range:	0.000–18.000V	0.000–18.000V	0.000–18.000V
Resolution:	1mV	1mV	1mV
Accuracy:[11]	±2mV	±2mV	±2mV

GENERAL

I/O Connectors	
TEC I/O:	Female, 25-pin, D-sub
Analog Input:	BNC
Remote Interface:	GPIB IEEE 488.1; USB 2.0 (B-Type)
Power Requirements[1]	AC Input Selector; 115/230 VAC; 100-120 VAC / 220-240 VAC; 500W;
50-60 Hz	
Size (HxWxD):	5.0" x 13.9" x 13.6"; 127 mm x 353 mm x 345 mm
Weight:	26.3 lbs.; 11.93 kg.
Operating Temperature:	10°C to 40°C
Storage Temperature:	-30°C to 70°C
Humidity:	<85% relative, non-condensing
Compliance:	CE

1 Output de-rating = 0.3 Volts and 0.04 Amps per input Volt AC below 100 VAC to a minimum of 90 VAC

CURRENT SOURCE NOTES

1 All values relate to a one-hour warm-up period.
2 Over any one-hour period, half-scale output.
3 Over any 24-hour period, half-scale output.
4 Measured electrically with a frequency range of 100Hz to 340kHz (High Bandwidth), 100Hz to 17kHz (Low Bandwidth).
5 Maximum output current transient resulting from normal operational situations (e.g. power on/off, current on/off), as well as accidental situations (e.g. power line plug removal). To protect the laser in all conditions, it is recommended to set both the current and voltage limit just above typical operating conditions.
6 Maximum output current transient resulting from a 1000V power line transient spike. Tested to ILX Technical Standard #LDC-00196; request ILX App Note #13.
7 Maximum monitor photodiode current drift over any 30 minute period. Assumes zero drift in responsivity of photodiode.
8 50% modulation at mid-scale output. Higher bandwidth is possible with smaller modulation signal.
9 Small signal specification is for typical 10% modulation depth. Large signal specification assumes 50% modulation depth at mid-scale output.
10 Responsivity value is user-defined and is used to calculate the optical power.
11 Four wire voltage measurement at the load. Voltage measurement accuracy while driving calibration load. Accuracy is dependent upon load and cable used.
12 Based on resolution of digital to analog converts used in circuit.

TEMPERATURE CONTROL

	LDC-3736
Temperature Control Range:[2]	
Thermistor Sensor:	−100°C to +200°C
IC Sensor:	−100°C to +150°C
RTD Sensor:	−100°C to +200°C
Temperature Setpoint and Measurement Repeatability and Accuracy:[3]	
0°C:	±0.001°C / ±0.01°C
25°C:	±0.002°C / ±0.04°C
50°C:	±0.007°C / ±0.15°C
75°C:	±0.05°C / ±0.9°C
Temperature Stability:[4]	
1 Hour:	±0.002°C
24 Hours:[4]	±0.003°C

TEMPERATURE SENSOR

Types:	
Thermistor:	NTC (2-wire)
IC-V Semiconductor IC Sensor:	LM-335 voltage output; 5 to 14 mV/K
IC-I Semiconductor IC Sensor:	AD-590 current output; 1 μA/K
RTD Sensor	Platinum 100Ω / 1000Ω (2-wire)
Thermistor Sensor Resistance	
10 μA Bias Setting	
Range:	0 to 450 kΩ
Resolution (Display):[6]	0.01 kΩ
Accuracy:	±180 Ω
100 μA Bias Setting	
Range:	0 to 45 kΩ
Resolution (Display):[6]	0.001 kΩ
Accuracy:	±18 Ω
IC-V Sensor Voltage	
Nominal Bias:	1 mA
Range:	0 to 6V
Resolution (Display):[6]	0.0001 V
Accuracy:	±2 mV
IC-I Sensor Current	
Nominal Bias:	5 to 15 V
Range:	0 to 600 μA
Resolution (Display):[6]	0.001 μA
Accuracy:	±0.18 μA
RTD Sensor Resistance	
1 mA Bias Setting	
Range:	0 to 1500 Ω
Resolution (Display):[6]	0.01 Ω
Accuracy:	±0.8 Ω
2.5 mA Bias Setting	
Range:	0 to 200 Ω
Resolution (Display):[6]	0.001 Ω
Accuracy:	±0.1 Ω
User Sensor Calibration	
Thermistor:	Steinhart-Hart, 3 constants
IC Sensors:	Slope, Offset
RTD	R_0, A, B, C

TEC OUTPUT

Output Type:	Bi-directional, linear
Isolation:	Floating with respect to earth ground
Current Setpoint	
Range:	-8.00A to +8.00A
Resolution (Display):[6]	0.01A
Accuracy:	±0.05A
Current Limit	
Range:	-8.05A to +8.05A
Accuracy:	±0.05A
Voltage Measurement [7]	
Range:	-16.00V to +16.00V
Resolution (Display):[6]	0.01V
Accuracy:	±0.02V
Compliance Voltage:	±16V
Maximum Output Power:	128W
Current Noise and Ripple:[5]	<2.5 mA rms

AUXILIARY I/O SPECIFICATIONS

Analog Control Input	
Input Voltage Range:	-5V to +5V
Input Resistance:	>100 kΩ
Gain:[9]	2 °C/V
Bandwidth:	5 Hz
External Fan Control Output [8]	
Output Voltage Range:	0 to +12V
Maximum Current:	500 mA

TEMPERATURE CONTROL NOTES

1 All values are specified for an ambient temperature of 23±5°C after a 1 hour warm up unless otherwise specified.
2 Software limits of range. Actual range depends on the physical load, sensor type, and TEC module used.
3 Accuracy figures represent the uncertainty that the LDC-3706 series adds to the measurement. This figure does not include the sensor calibration uncertainties. Thermistor accuracy figures are quoted for a typical 10 kΩ thermistor and 100 μA current setting for -5°C to 50°C.
4 Temperature stability measurements made in a stable, ambient environment ±0.5°C with a 10 kΩ thermistor on the 100 μA setting after a 2 hour warm up period. Stability is defined as ±(Tmax-Tmin)/2 over the measurement period.
5 Measured over the full DC current range into a 1Ω load.
6 Maximum resolution available when operating in the control mode (using the 7-segment display) resolution will be reduced when displayed on the lower display. In remote operation, six significant digits of resolution are reported.
7. Measured at the output connector. Users may enter in cable resistance to provide an accurate voltage measurement at the load.
8. Unregulated output and requires a minimum of a 120mA current draw.
9. Transfer function is applicable to linear sensors only. Use of non-linear sensors, such as thermistors, may result in a non-linear transfer function which varies over the temperature modulation range.

ORDERING INFORMATION

LDC-3736	Quantum Cascade Laser Controller
LDM-487201	Quantum Cascade Laser Mount, C-Mount
LDM-487202	Quantum Cascade Laser Mount, Alpes COC
CC-305S	Current Source/Laser Diode Mount Interconnect Cable
CC-306S	Current Source/Unterminated Interconnect Cable
CC-594H	TE Controller/Unterminated Interconnect Cable
CC-595S	TE Controller / Laser Diode Mount Interconnect Cable
CC-596H	TE Controller/High Power Laser Diode Mount Interconnect Cable

LabVIEW® Instrument Driver

Chapter 2:
General Operation

This chapter is an overview of the operation of the LDC-3736 Quantum Cascade Laser Controller. It offers instructions for connecting your laser to the current source and temperature controller and describes powering up the instrument. This chapter also contains step by step procedures that teach you how to operate your controller in Constant Current Mode, Constant Power Mode, and to operate the temperature controller in Constant Temperature Mode. ILX recommends that you review the contents of this chapter at a minimum before operating your new controller.

- ✓ Power requirements
- ✓ Front panel operation
- ✓ General operating procedures

Grounding Requirements

The LDC-3736 Quantum Cascade Laser 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

The LDC-3736 Quantum Cascade Laser Controller can be configured to operate at nominal line voltages of either 115 VAC or 230 VAC. The user may change the line voltage by a switch on the rear panel. These line voltages may vary from nominal by no more than ±10 % and the frequency of the AC source must be 50 – 60 Hz. For input voltages below 100VAC, a de-rating of 0.3 V and 0.4 Amps per input AC volt applies down to a minimum of 90 VAC input voltage.

WARNING

Check the power switch on the rear panel is in the proper position prior to power up. Damage to internal fuses and other internal circuitry may occur if the wrong line voltage is selected.

The Power Up Sequence

WARNING

Prior to power up ensure the fan inlet located on the rear of the instrument has no obstructions that would impede airflow.

WARNING

Never position the instrument such that the power cord is difficult to remove. Never use a power cable with ratings other than those of the original power cord that was shipped with the instrument by ILX Lightwave.

With the LDC-3736 instrument connected to an appropriate AC power source (verify the requirements of the instrument listed on the rear panel prior to connection to an AC mains supply), pressing the **POWER button** supplies AC line power to the instrument and starts the power up sequence. The power up sequence consists of the following steps, each lasting two to three seconds.

- All front panel indicators are ON, all 7-segment displays indicate "8"
- All front panel indicators OFF
- Left display shows the model number, the serial number, and the firmware version of the controller
- The displays show the calibration dates for the instrument

During the front panel indicator test, the LDC-3736 instrument performs a self-test to ensure that the internal hardware and software are communicating properly. If the LDC-3736 instrument cannot successfully complete the test, an error message is displayed. See Chapter 5 for a complete list of error messages. After the self-test, the LDC-3736 instrument configuration is set to the same state as when the power was last turned off.

To quickly set a different configuration you can use the recall function. See the *Store Button* and *Recall Button* descriptions in the Front Panel Operation section of this chapter for more information.

Firmware Upgradeability

The firmware on the LDC-3736 instrument can be reinstalled or upgraded via USB. Contact ILX Lightwave technical support for information on upgrading the software of the LDC-3736 instrument.

GPIB Communication

The IEEE 488 GPIB interface connector is located on the rear panel, directly above the power input module (See Figure 1.2 on page 2). Attach the GPIB cable to the 24-pin connector located on the rear panel. The connector is tapered to ensure proper orientation. Finger-tighten the two screws on the GPIB 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 allows more than one cable to be attached to any one device. However, the maximum length of the GPIB cables must not exceed 20 meters (65 feet) total, or 2 meters (6.5 feet) per device. As good practice, the number of GPIB cables connected to one instrument should be limited to less than 6.

USB Communication

The USB connector is located on the back rear panel, next to the GPIB connector. This USB connector is the square "B"-style connector. A standard USB A/B cable is required to communicate with the instrument. To communicate with the instrument using USB, please install the USB Driver found on the accompanying CD or from the ILX Lightwave website prior to connecting the unit to the PC. Please refer to Chapter 3 for more detailed instructions on operating the instrument through USB.

Tilt Foot Adjustment

The LDC-3736 Quantum Cascade Laser Controller has front legs that extend to make it easier to view the display. To use them, rotate the legs downward until they lock into position.

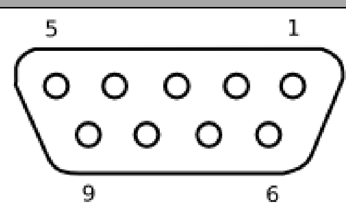
Rack Mounting

The LDC-3736 Quantum Cascade Laser Controller may be rack mounted by installing the appropriate rack mount flange on either side of the enclosure. All rack mount accessory kits contain detailed mounting instructions. Refer to the Options and Accessories table in Chapter 1 for applicable rack mount accessory part numbers.

Connections

Current Source Output: A 9-pin D-sub connector is located on the rear panel of the instrument. The connections for this connector are shown below.

LDC-3736



PIN NUMBER	CONNECTION
1	Interlock
2	Interlock
3	Chassis Ground
4	Laser Cathode Voltage Sense (-)
5	Laser Cathode (-)
6	Photodiode Cathode (+)
7	Photodiode Anode (-)
8	Laser Anode Voltage Sense (+)
9	Laser Anode (+)

Interlock Connections: In order for the laser output to be enabled, a short must exist between the Interlock pins (pins 1 and 2) of the current source output connector. The short can be a direct short across the pins or a switch to prevent laser operation until the switch is closed. If a short does not exist between these two pins, the INTERLOCK LED illuminates on the front panel and the laser output is disabled.

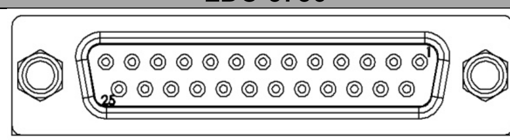
CAUTION

The interlock terminals on the LASER connector, pins 1 and 2, must be kept isolated from all other connections including earth ground.

WARNING

The Current Source output terminals of the LDC-3736 Quantum Cascade Laser Controller (Laser Anode and Laser Cathode) should never be shorted together or loaded with less than 0.1 Ω. Doing so may result in damage to the instrument.

Temperature Control Output: A 25-pin D-sub connector is located on the back panel of the instrument. The connections are shown below.

LDC-3736	
	
PIN NUMBER	**CONNECTION**
1	Sensor (+) Sense Terminal
2	Sensor (-) Sense Terminal
3	Fan (+)
4	N/C
5	N/C
6	Sensor / TE Module Shield
7	TE Module (+) Sense Terminal
8	TE Module (-) Sense Terminal
9	TE Module (+)
10	TE Module (+)
11	N/C
12	TE Module (-)
13	TE Module (-)
14	Sensor (-)
15	Sensor (+)
16	Fan (-)
17	Cable ID 1
18	Cable ID 2
19	N/C
20	N/C
21	TE Module (+)
22	TE Module (+)
23	N/C
24	TE Module (-)
25	TE Module (-)

TEC Grounding Considerations: The TEC output connections of the LDC-3736 instruments are isolated from the chassis ground, allowing either output terminal to be grounded. If a terminal is grounded, be sure to connect it only to the Earth ground.

CAUTION

Connecting one of the TEC output terminals to analog or digital ground causes catastrophic damage to the instrument.

For the TEC connector, if any one terminal pin is grounded, then no other terminal pin can be grounded. Do NOT connect the Sensor (-) and TE Module (-) to the same ground; damage to the instrument and devices will occur.

WARNING

The Temperature Control output terminals of the LDC-3736 Quantum Cascade Laser Controller (TE Module (+) and TE Module (-)) should never be shorted together or loaded with less than 0.1 Ω. Doing so may result in damage to the instrument.

Analog Modulation Input: An isolated BNC connector is located on the front panel of the LDC-3736 instrument and provides the capability to modulate the output of the laser current source. This connector can accept a signal from 0 to 10 V, and a nominal input impedance of 1 kΩ. The transfer function and bandwidth of this input is dependent on the mode of operation of the instrument. For further details please consult the *Specifications* section of *Chapter 1*. This feature is useful in applications requiring modulation of the output current without using either GPIB or USB remote interfaces.

Analog Temperature Control Input: An isolated BNC connector is located on the rear panel of the LDC-3736 instrument that provides the capability to adjust the temperature setpoint by applying a voltage signal. The LDC-3736 can accept a signal from -5 V to +5 V, with a gain of 2 °C/V and bandwidth of 5 Hz. This feature is useful in applications requiring sweeping of the temperature without using GPIB or USB remote interface.

External Fan Control: The LDC-3736 instrument features the ability to control an external fan through the 25-pin DSUB connector. This circuit can provide up to 500 mA and may be controlled from 1 to 12 VDC. The circuit will automatically increase the voltage to 12 VDC to start a fan from a stopped condition and will regulate to the desired voltage once more than 20 mA is drawn.

Pseudo 4-Wire Temperature Control Measurements: The LDC-3736 instrument offers a pseudo 4-wire temperature sensor measurement feature which helps to minimize errors induced by cable resistance both in thermistor/RTD sensor modes as well as on the TEC output terminals. This feature is enabled by connecting the appropriate 'sense' terminals and is disabled by leaving them disconnected.

External Trigger Output: For applications where an external measurement must be made synchronously with the operation of the LDC-3736, a TTL level trigger output is provided through a grounded, female BNC connector on the rear of the instrument. For further information please consult the *Specifications* section of *Chapter 1.*

Connecting to the Laser Controller

When connecting your quantum cascade laser or any other sensitive devices to the LDC-3736 Quantum Cascade Laser Controller, ILX recommends that the instrument be powered up and the LASER output be in the off position (with the ON indicator LED unlit). In this condition, a low impedance shunt is active across the output terminals. When disconnecting devices, it is necessary to turn the LASER Output off, but the instrument may be left powered on.

ILX also recommends that the connections to the LDC-3736 output be made using twisted pairs with an earth-grounded shield (See Figure 2.1 below). The output terminals of the instrument are left floating with respect to earth ground to suppress AC power-on/power-off transients that may occur through an earth-ground referenced path. If the output circuit is earth-grounded at any point (such as through the laser package and mount), the user must be careful to avoid multiple earth ground in the circuit. Multiple earth grounds may provide circuit paths that induce spurious currents in the photodiode feedback circuit and output leads.

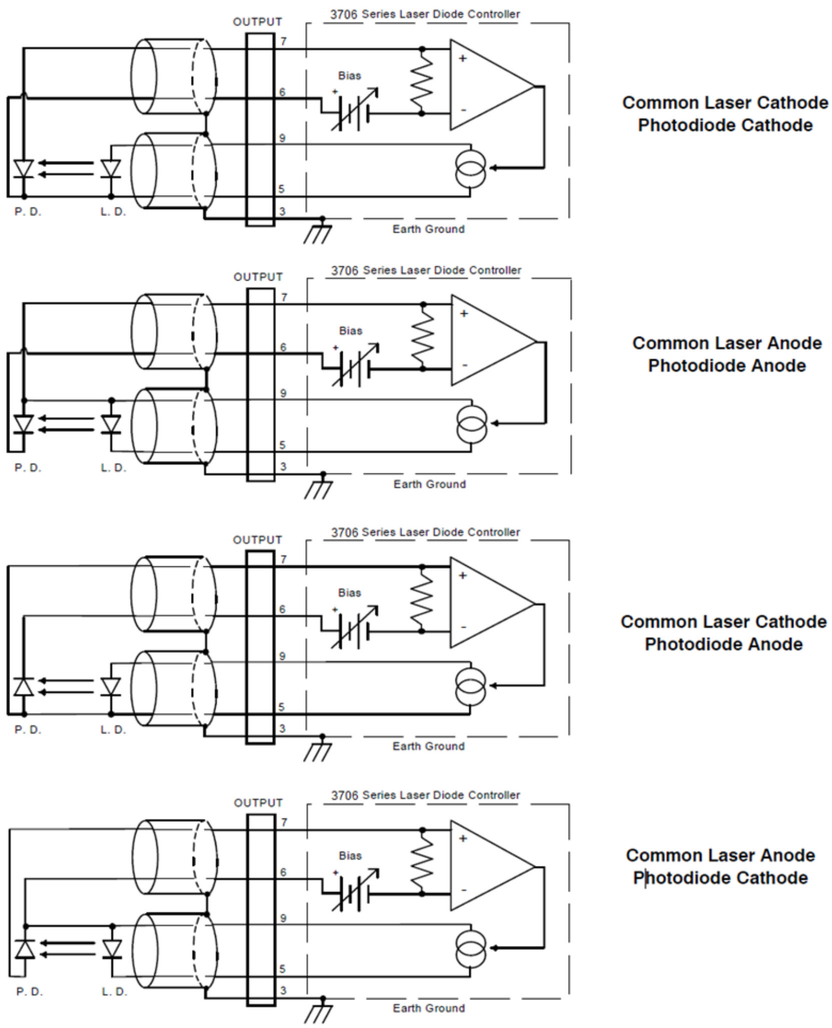


Figure 2.1 - Laser Diode Connection Configurations

Photodiode Connections: Many laser diode modules contain an internal photodiode that monitors the back-facet emission of the laser. Usually, this photodiode is internally connected to either the laser anode or cathode. The photodiode and laser connections of the LDC-3736 Quantum Cascade Laser Controller are electrically isolated from ground and each other. So, if a 4-pin connection is made (no common connections) no additional jumpers are required. Figure 2.1 (above) shows the recommended connections and shielding for 3-pin lasers (where the common connection is internal to the device). A 4-pin laser should be connected with the same shielding as shown in Figure 2.1, but the common connection (between the photodiode and the laser) is optional.

Photodiode Bias: The LDC-3736 provides an adjustable reverse bias of 0 to 5 VDC for the photodiode. To set the photodiode bias to the desired value, use the parameter buttons, menu structure and adjustment knob. Refer to the *Front Panel Operation* section of this chapter for further details.

Front Panel Operation

General Operation: This section describes the fundamentals of operation for the LDC-3736 Quantum Cascade Laser Controller. The order of descriptions will follow the normal progression of how the user would typically configure the instrument for use for the first time.

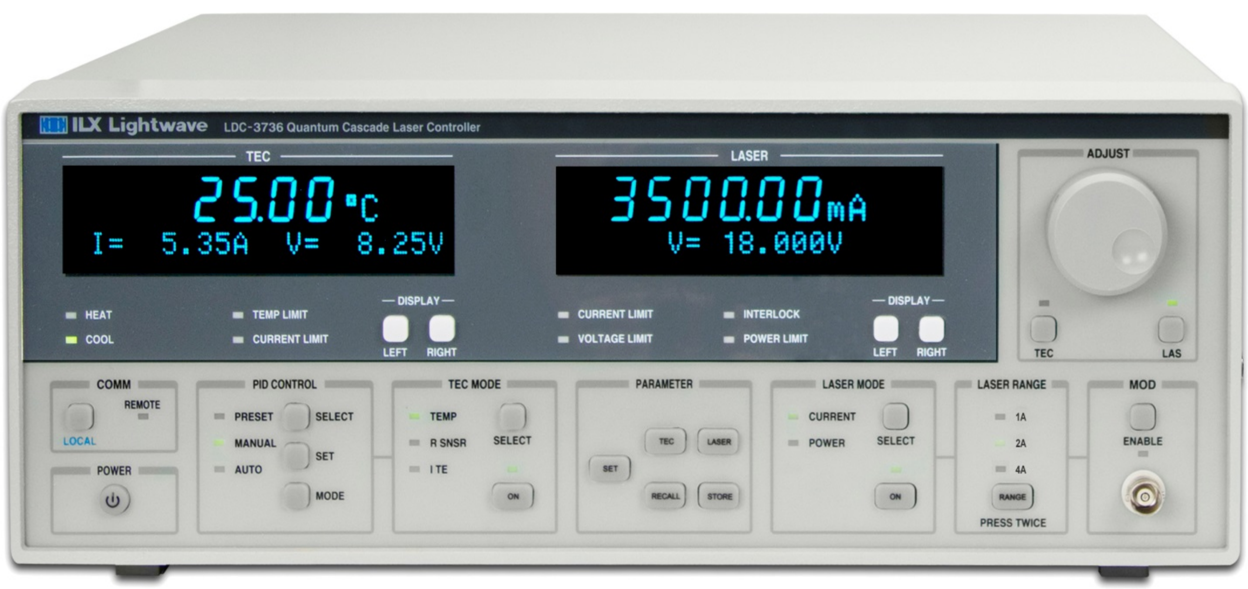


Figure 2.2 – Front Panel Display

Power On / Off

The POWER button applies power to the LDC-3736 instrument and starts the power up sequence described above.

Adjust Knob and Enable Button

The ADJUST knob and enable buttons (TEC and LAS located below the ADJUST knob) is located on the upper right side of the LDC-3736 front panel. It is used to change the setpoints, enter parameter values, enter the GPIB address, enter Save or Recall bin numbers or enter instrument calibration data. The enable button LEDs indicate the three modes of operation of the knob:

Disabled (both LEDs off), TEC adjustment enabled (TEC LED on), and LASER adjustment enabled (LAS LED on).

Temperature Controller Setup

SET Button – Allows the user to adjust settings under TEC, LASER, RECALL and STORE. The SET button will allow the user to open a sub menu or allow the user to adjust the currently selected parameter. When a parameter is being adjusted, the units will flash at a constant frequency. To return to the main menu, the sub menu will contain one option that reads "Return <SET>."

TEC Button – Uses a menu system for temperature controller setup functions including Limits, Sensor, Sensor Calibration Constants, External Fan Control, Cable Resistance and Analog Input. The SET button selects the currently displayed menu item or allows the user to adjust the currently displayed parameter. The ADJUST knob can be used to cycle through and select or modify the following parameters:

Limits: The Limits menu allows the user to select and modify the temperature, current, and sensor upper and lower limits:

- Temperature High / Low Limits
- Current Positive / Negative Limits
- Sensor High / Low Limits

Depending on the sensor selected, the user can configure high and low limits for resistance, current or voltage.

Sensor: The Sensor parameter allows the user to select the type of sensor for the application: Thermistor, RTD, IC-V, or IC-I. For more information on temperature sensors see the *Sensor Options* section later in this chapter. The sensor type selections are:

- Thermistor (100 µA, 10 µA, Auto Ranging)
- RTD (1 mA, 2.5 mA, auto-ranging)
- IC – Current
- IC - Voltage

Sensor Calibration Constants: The calibration constants menu allows the user to enter sensor constants for thermistor, current and voltage IC, and RTD. For more information see the *Sensor Options* later in this chapter.

External Fan Control: Allows the user to enable or disable the external fan. The user can also set the voltage applied to the external fan.

Analog Control Input: Enables and disables the analog input feature, for optimal stability if a signal is not being applied to it, the analog control input should be disabled.

Calibration: This menu allows calibration of sensor readings (10 µA thermistor, 100 µA thermistor, 1 mA RTD, 2.5 mA RTD, ICI, and ICV), TEC current output and readings, and TEC voltage readings. See Chapter 5 for more details.

PID Temperature Control

SELECT Button (Left) – In PRESET temperature control mode, pressing SELECT (left) displays the available preset gain ranges. In MANUAL temperature control mode, pressing SELECT (left) displays the last PID values used and in AUTO-TUNE mode, pressing SELECT (left) displays the option to start the auto-tune by pressing SET. Pressing SELECT (left) repeatedly or using the ADJUST knob cycles through the presets and PID values.

SET Button – In PRESET temperature control mode, pressing SET (left) selects the preset gain range on the display. In MANUAL temperature control mode, pressing SET (left) allows the user to adjust the value currently on the display. SET (left) in the AUTO-TUNE mode starts the auto-tune procedure.

MODE Button –Cycles through PRESET, MANUAL and AUTO-TUNE modes. The selected mode is indicated by an illuminated LED. The output will not be disabled if the user changes the PID Control Mode.

> **Preset:** The user can select one of the preprogrammed gain ranges by first selecting the PRESET LED using the MODE button then pressing the SELECT (left) button or ADJUST knob to display the correct preset gain for the thermal load and pressing the SET (left) button to select the gain. Presets have also been implemented for specific ILX Lightwave mounts. When a preset has been selected for a mount, the LDC-3736 instrument will set the PID values, sensor type, and current limits. The following mounts are directly compatible with the LDC-3736 instrument: LDM-4872 Quantum Cascade Laser Mount.
>
> **Manual:** In MANUAL mode the user can adjust the PID values or view the preset PID values that were last loaded (note: if the user adjusts the preset PID values in manual PID mode, the change will not permanently affect the preset PID value). To manually adjust the PID values first select the MANUAL LED by pressing MODE, then press SELECT (left) to change between P, I, and D. To adjust the PID value, press SET (left); to move to the next value press SELECT (left).
>
> To load a preset PID value use the MODE button to cycle to the MANUAL LED, and then press the SELECT (left) button, then using the SELECT (left) or ADJUST knob, display the Adjust Preset menu. Press the SET (left) button and cycle through the presets until the correct preset is displayed then press the SET button to load the values. Use the SELECT (left) button to view the loaded preset P, I, and D values.
>
> **Auto-tune** – The auto-tune mode will calculate a thermal system's PID coefficients through an iterative PID temperature control process. To enter the auto-tune mode first press MODE until the AUTO LED is illuminated, and then SELECT to ready the instrument for the auto-tune process. The screen will say ""Start Autotune <SET>". While this is displayed, press SET to begin the auto-tune procedure. When the LDC-3736 instrument successfully completes the auto-tune the instrument will revert back to MANUAL PID mode and the calculated PID values will overwrite the current PID values in MANUAL mode. If the auto-tune process fails an error will be displayed on the screen. For more information on the auto-tune process see Appendix B. Additional auto-tune methods may be available in the future via a firmware upgrade, for more information contact sales at 800-459-9459 / sales@ilxlightwave.com.

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

- Thermal systems requiring the proportional term to be less than 0.5
- Noisy temperature measurements
- Reaching any output off enable condition (such as temperature or voltage limits) during the auto-tune operation.

If the auto-tune algorithm fails for a particular thermal system, it may be necessary to modify the PID coefficients manually.

Temperature Control Mode

SELECT Button (Middle) – Selects constant temperature, constant sensor and constant current mode. The selected mode is indicated by an illuminated LED. The output is disabled when the control mode is changed.

ON Button (Left) – Enables and disables the temperature controller output. An enabled output is indicated by an illumined LED above the ON button (left). A disabled output is indicated by an unlit LED above the ON button (left).

- TEMPERATURE – Sets the LDC-3736 temperature controller to maintain a constant temperature
- SENSOR – Controls the LDC-3736 temperature controller to a constant sensor value
- TE CURRENT – Sets the LDC-3736 temperature controller to output a constant current
- HEAT – Illuminated when negative current is flowing
- COOL– Illuminated when positive current is flowing
- TEMP LIMIT – Illuminated if the LDC-3736 has exceeded the user defined temperature limits
- CURRENT LIMIT (Left) – Illuminated if the LDC-3736 temperature controller has reached the user defined current limit

Laser Current Source Setup

LASER Button – Uses a menu system for temperature controller setup functions including limits and modulation state. The SET (right) button selects each menu item and a second SET (right) press allows the user to adjust each parameter. The ADJUST knob can be used to cycle through and select or modify the following parameters:

WARNING

For the best laser diode protection it is recommend to set the current limit slightly above your expected operating current this should be below the maximum current as stated on the laser diode datasheet. In addition the voltage limit should be set to just above the typical operating voltage this should also be below the maximum voltage as stated on the laser diode datasheet.

Limits: The Limits menu allows the user to select and modify the laser current source limits:

- Laser Current Limits
- Laser Voltage Limits
- Laser Power Limits

Bandwidth: This selects between low-bandwidth and high-bandwidth modes for the modulation input. The maximum frequency for each bandwidth mode is listed in the specifications in Chapter 1.

Photodiode Responsivity: The photodiode responsivity in µA/mW for the laser system currently being controlled is set here.

Photodiode Bias Voltage: The LDC-3736 Quantum Cascade Laser Controller provides an adjustable reverse bias of 0 – 5 VDC for the photodiode. The bias can be adjusted by the front panel under the Parameter Laser selection or via GPIB/USB.

TEC Disable Output: "LD TEC Error" when enabled will disable the current source output if the temperature controller exceeds the temperature limits or if the TEC output is disabled either by the user or due to an error. When this mode is active, the laser current source will not enable unless the TEC output is enabled.

Brightness: This allows the user to select a level of brightness for the front panel displays. Values between 1 (dim) and 10 (bright) can be selected from the front panel. This value can also be controlled remotely (see Chapter 4).

Laser Calibration: This menu allows for calibration of the laser diode current output and reading, laser diode voltage readings, and the monitor diode current reading. See chapter 5 for more details.

STORE Button – Stores instrument parameters for control mode, setpoints, limits, sensor type, sensor calibration constants, and PID values for bins numbered 1 – 10.

RECALL Button – Recalls instrument parameters for control mode, setpoints, limits, sensor type, sensor calibration constants, and PID values for bins numbered 1 – 10. Recall bin 0 will reset all parameters to the factory defaults.

Non-volatile memory is used for saving the instrument parameters. When a store operation is performed, all of the current instrument parameters are stored to a "bin" number (1 - 10). When that "bin" number is recalled, the instrument configuration is recalled to the stored values.

To enter the STORE/RECALL mode, press either the STORE or RECALL button which will display the current "bin" number in the bottom of the screen. The current "bin" number will be flashing and the ADJUST knob can be used to select a new "bin". The store or recall operation is performed when the SET button is pressed. If the SET button isn't pressed after three seconds the LDC-3736 instrument will time out and the new "bin" number will not be stored or recalled.

Modulation State: The Modulation State parameter allows the user to select whether the Laser Modulation Analog input is enabled or not. For best results, when not modulating the laser through the BNC input port on the front of the instrument, make sure that the Modulation State is set to the OFF condition by pressing the Enable button until the ENABLE LED is unlit.

Current Control Mode

SELECT Button (Right) – Selects constant current or constant power mode. The selected mode is indicated by an illuminated LED. The output is disabled when the control mode is changed.

ON Button (Right) – Enables and disables the current output. An enabled output is indicated by an illumined LED above the ON button (right). A disabled output is indicated by an unlit LED above the ON button (right).

- CURRENT – Controls the LDC-3706 current source to constant operating current.
- POWER – Controls the LDC-3706 to a constant power or constant photodiode current.

LASER RANGE Button (Right) – Selects between the output ranges of the LDC-3736.

	LDC-3736
Range 1	0 - 1 A
Range 2	0 - 2 A
Range 3	0 - 4 A

Display

The two large 7-segment VFD displays show the measured value in the selected operating mode. When the setpoint is being adjusted, the 7-segment LED display will show “set” after the dimension and revert back to reporting the measured value after the three second timeout. The dot matrix display, at the bottom of the screen, cycles through available measurements and the mode setpoint. The available measurement and setpoint parameters are listed under *General Operation Procedures* section in this chapter.

The setpoint values are indicated by a colon, as in Figure **2.3 a**, and the measured values are indicated by an equal sign, as in Figure **2.3 b**.

Figure 2.3a – The Setpoint Current

Figure 2.3b – The Measured Current

Temperature Controller Display

LEFT Button (Left) – Cycles left-half of the left-hand (TEC) display through the available temperature controller measurement and setpoint parameters that can be displayed.

RIGHT Button (Left) – Cycles right-half of the left-hand (TEC) display through the available temperature controller measurement and setpoint parameters that can be displayed

Laser Current Source Display

LEFT Button (Right) – Cycles left-half of the right-hand (Laser) display through the available laser current source measurement and setpoint parameters that can be displayed

RIGHT Button (Right) – Cycles right-half of the right-hand (Laser) display through the available laser current source measurement and setpoint parameters that can be displayed

When the same parameter is displayed on the left and right display the LDC-3736 will automatically center the parameter and provide the maximum resolution allowed.

Error Indicators

The LDC-3736 instrument indicates operational errors on the measurement display with an error code and brief description of the error that has occurred. A complete list of error codes can be found in Chapter 5.

General Operating Procedures

The discussion below presents guidelines for operation as well as some common operating procedures. Remote operations are discussed in the next chapter.

WARNING

The output terminals of the LDC-3736 instrument should never be shorted together or loaded with less than 0.1 Ω. Doing so may result in damage to the instrument.

Warm-Up and Environmental Considerations

To achieve the rated accuracy, allow the LDC-3736 instrument to warm-up for at least one hour before use. Always operate the controller within the environmental limits specified in the *Specifications* section of *Chapter 1*. The best accuracy is achieved near the calibration temperature of 23°C.

Operating the Laser Current Source from the Front Panel

This section describes fundamentals of operation for your LDC-3736 Quantum Cascade Laser Controller Laser Current Source in two operating modes, Constant Current (I), and Constant Power (P). The current mode of operation is indicated by a lit LED next to the mode of operation in use in the Laser Mode section of the front panel. The mode of operation may be adjusted using the Select (right) button in this section of the front panel.

Operating a Laser in Constant Current (Current) Mode

1. Plug the LDC-3736 into an appropriate AC power source supplying the correct mains voltage and frequency for your instrument (refer to the rear panel for the correct ratings)

2. Turn on the LDC-3736. The laser output will be disabled at power up and the unit will automatically configure its parameters to the state which existed when the power was last shut off.

3. If the temperature controller is required please refer to the section below on temperature control prior to enabling the laser current output.

4. Press the **LASER MODE** soft button until the **CURRENT** LED is illuminated.

5. Select the maximum output current range for your laser by pressing the **RANGE** soft button under **LASER RANGE**. For best performance select the lowest range that allows you to run at the maximum desired output current for your laser diode or quantum cascade laser.

6. Press **LASER** under **PARAMETER** to adjust the laser current limit, voltage limit, power limit (if applicable), calibration PD value, photodiode reverse voltage bias, and LD TEC error link.

   Note: For best low noise operation the modulation frequency bandwidth should be set to LOW and the MOD LED should be turned off and the LNF-320 Low Noise Filter should be installed on the back of the instrument.

7. Under the **ADJUST** section press the **LASER** soft button and use the knob to adjust the output current to your desired output. Press the **ON** soft button under **LASER MODE**. It is advised when using a new laser or connection to the laser to set the output to zero prior to enabling the output. Once the output is enabled slowly ramp the current to your desired output.

8. The user can display measured voltage, photodiode current, calculated photodiode power, and current setpoint on either the left or right side of the **LASER** display by pressing the **LEFT** or **RIGHT** display soft buttons under the **LASER** display.

Operating a Laser in Constant Current (Current) Mode with Analog Modulation

1. Plug the LDC-3736 into an appropriate AC power source supplying the correct mains voltage and frequency for your instrument (refer to the rear panel for the correct ratings)

2. Turn on the LDC-3736. The laser output will be disabled at power up and the unit will automatically configure its parameters to the state which existed when the power was last shut off.

3. If the temperature controller is required please refer to the section below on temperature control prior to enabling the laser current output.

4. Press the **LASER MODE** soft button until the **CURRENT** LED is illuminated.

5. Select the maximum output current range for your laser by pressing the **RANGE** soft button under **LASER RANGE**. For best performance select the lowest range that allows you to run at your maximum desired output current for your laser diode or quantum cascade laser.

6. Press **LASER** under **PARAMETER** to adjust the laser current limit, voltage limit, power limit (if applicable), calibration PD value, photodiode reverse voltage bias, and LD TEC error link. Also make sure to adjust to either **LOW** or **HIGH** bandwidth mode, based on your maximum required modulation frequency. The maximum frequency bandwidth for each range can be found in the specifications in Chapter 1.

7. Press the soft button under **MOD** to enable the input BNC jack and connect the voltage signal that will be superimposed on to the output. See the *Specifications in Chapter 1* for details on transfer function and maximum bandwidth. Note that all limits also apply to the modulated output, thereby protecting your laser in all operating modes.

WARNING

Be sure not to exceed the specified modulation voltage level or damage to the instrument may result.

8. Under the **ADJUST** section press the **LASER** soft button and use the knob to adjust the output current to your desired output. Press the **ON** soft button under **LASER MODE**. It is advised when using a new laser or connection to the laser to set the output to zero prior to enabling the output. Once the output is enabled slowly ramp the current to your desired output.

9. The user can display measured voltage, photodiode current, calculated photodiode power, and current setpoint on either the left or right side of the **LASER** display by pressing the **LEFT** or **RIGHT** display soft buttons under the **LASER** display.

Operating a Laser in Constant Power Mode

The LDC-3736 Quantum Cascade Laser Controller allows you to operate the laser current source driver in a Constant Power mode. In this mode, the controller drives current to the laser to the extent required to reach a setpoint power value (in mW). The control loop feedback parameter is photodiode current, which the controller converts into optical power via the user-defined Photodiode Responsivity Parameter. If laser power changes due to internal or external environmental conditions, the controller will increase or decrease the current to the laser (as appropriate) in order to maintain the power setpoint.

1. Plug the LDC-3736 instrument into an appropriate AC power source supplying the correct mains voltage and frequency for your instrument (refer to the rear panel for the correct ratings)

2. Turn on the LDC-3736. The laser output will be disabled at power up and the unit will automatically configure its parameters to the state which existed when the power was last shut off.

3. If the temperature controller is required please refer to the section below on temperature control prior to enabling the laser current output.

4. Press the **LASER MODE** soft button until the **POWER** LED is illuminated.

5. Select the maximum output current range for your laser by pressing the **RANGE** soft button under **LASER RANGE**. For best performance select a range closest to your maximum output current for your laser diode or quantum cascade laser.

6. Press **LASER** under **PARAMETER** to adjust the laser current limit, voltage limit, power limit, calibration PD responsivity value, photodiode reverse voltage bias, and LD TEC error link.

   To calculate the calibrated photodiode responsivity value first measure the output of the laser with a calibrated detector. Second measure the corresponding photodiode current either with the LDC-3736 or a calibrated current meter. The calibrated PD responsivity is calculated by dividing the photodiode current by the output power (µA / mW).

7. Under the **ADJUST** section press the **LASER** soft button and use the knob to adjust the output power to your desired output. Press the **ON** soft button under **LASER MODE**. It is advised when using a new laser or connection to the laser to set the output to zero prior to enabling the output. Once the output is enabled slowly ramp the current to your desired output.

8. The user can display measured voltage, photodiode current, photodiode power set point, and measured current in either the left or right side of the **LASER** display by pressing the **LEFT** or **RIGHT** display soft buttons under the **LASER** display.

Using the LDC-3736 Controller's Trigger Output Function

For applications where you need to synchronously initiate a measurement task for a remote instrument with the LDC-3736, the controller offers a TTL level trigger output signal. The trigger pulse is initiated with any change in setpoint of the laser current source and after the analog output has settled. A typical application for utilization of this feature is laser characterization tasks where an L-I-V curve is generated. For programmed steps in laser current, a light measurement can be triggered for each step in laser current. The trigger output is always enabled.

NOTE: The minimum time required for setpoint to be reached varies based on the type of setpoint change. Care should be exercised with respect to the timing of any setpoint commands in relation to the actual hardware function. The trigger signal may be missed if the program step time is too fast.

A one shot trigger pulse will occur on power up of the instrument due to the states of the processor I/O connections.

A grounded female BNC connector on the rear panel of the LDC-3736 Quantum Cascade Laser Controller is available for connecting any standard BNC terminated cable and connecting to equipment that can accept the levels produced by the LDC-3736 instrument trigger out signal.

Operating the Temperature Controller from the Front Panel

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 LDC-3736 Quantum Cascade Laser Controller 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 LDC-3736 instrument measures temperature based on 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 µA or 10 µA) through the thermistor which results in a voltage across the thermistor. This voltage is used as a feedback signal by the LDC-3706 Series instrument digital control loops to maintain a constant temperature. The thermistor should be connected across the Sensor+ and Sensor- pins (pins 1 and 2 of the TEC output connector for the LDC-3736, as described above).

When using a thermistor in constant temperature mode, the quantity that is maintained constant by the controller is the sensor resistance. In constant temperature mode, the LDC-3736 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 non-linear resistance versus temperature characteristics of typical thermistors. Calibrating a thermistor consists of measuring its resistance at various temperatures and fitting this measured data to the Steinhart-Hart equation. The resulting coefficients C1, C2, and C3 effectively describe the thermistor for a specific temperature range. For more information about the Steinhart-Hart equation, see ILX Lightwave Application Note #4 Thermistor Calibration and the Steinhart-Hart Equation.

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 into the temperature controller. If the exact temperature is not crucial (within ±1.5 °C) and you are using a 10 kΩ thermistor, use the default constants provided by the LDC-3706 Series instrument.

Thermistor resistance changes with temperature. The LDC-3736 supplies a constant current, either 10 µA or 100 µA, 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 100 kΩ thermistor is to use the 10 µA range for temperatures between -30 °C and +30 °C and for 10 kΩ thermistor the 100 µA range for temperatures between 10 °C to 70 °C. Select the thermistor sense current of 10 µA or 100 µA in the front panel TEC parameter menu. Using 10 µA as the thermistor current allows you to use a maximum thermistor resistance of 450 kΩ. The 100 µA setting allows a 45 kΩ maximum.

The LDC-3736 instrument has the ability to select the temperature sensor current range based on the resistance of the measurement and will automatically switch between the 10 µA and 100 µA modes. Thermistor auto range can be selected under the SENSOR submenu within the TEC parameters menu.

To ensure proper thermistor 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 2.4, 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 2.4, the thermistor resistance is 25 kΩ at 20°C. Deviations of one degree at 20 °C cause a resistance variation of about 2 kΩ. If using the 10 µA setting, there is 20 mV of feedback to the control circuit. Using the 100 µA 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.

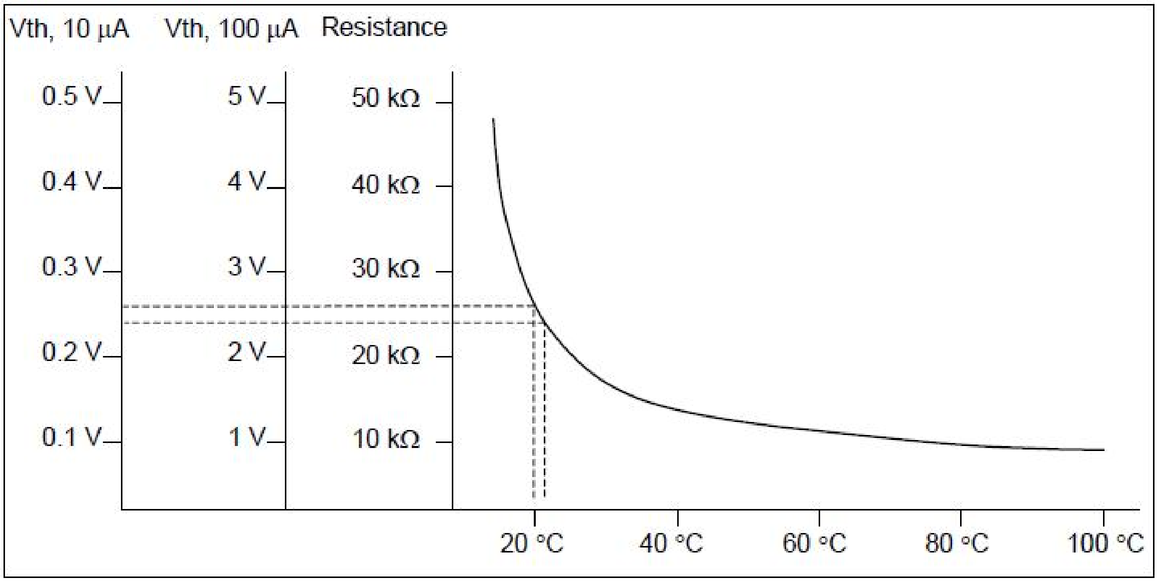


Figure 2.4 - Example Thermistor Resistance vs. Temperature

IC-I SENSORS – When an IC-I sensor is selected, the LDC-3736 Quantum Cascade Laser Controller measures temperature based on the current passed through the sensor. An example of an IC-I sensor is the Analog Devices AD590. This device delivers 1 µA/K or approximately 298 µA at 25 °C. The (+) terminal of the transducer should be connected to the Sensor+ pin and the (-) terminal should be connected to Sensor-. The nominal slope for the AD590 is 1 µA/K and the offset is nominally 0 µA but both can be adjusted to calibrate your particular sensor by entering the TEC parameter menu.

The sensor will have approximately 9 V across it at 25 °C but will vary over the temperature range. In IC-I sensor mode, the LDC-3736 has a sensor current limit of 600 µA, which is approximately 325 °C.

WARNING

For IC-Current sensors used with the LDC-3736 the 4-wire sensor measurements (pins 7 and 8) should not be connected. The use of the 4-wire sensor will cause inaccurate sensor measurements.

IC-V SENSORS – When an IC-V sensor is selected the LDC-3736 instrument measures temperature based on the voltage across the sensor. An example of an IC-V sensor is the National Semiconductor LM335A. This device delivers 10 mV/K or approximately 2.98 V at 25 °C. The (+) terminal of the transducer should be connected to the Sensor+ pin and the (-) terminal should be connected to Sensor-. The nominal slope for the LM335A is 10 mV/K and the offset is nominally 0 mV but both can be adjusted to calibrate your particular sensor by entering the PARAM menu.

The sensor will have approximately 1 mA of current through it at all times. In IC-V sensor mode, the LDC-3736 instrument has a sensor voltage limit of 6 V, which is approximately 325 °C.

RTD SENSORS – When an RTD sensor is selected, the LDC-3736 measures temperature based on the resistance of the sensor. 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 Sensor+ and Sensor- pins (pins 7 and 8).

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 (Ω) at 0 °C
R_T = Resistance (Ω) at temperature T (°C)
T = Temperature in °C

The A, B, and C, are derived from resistance measurements at 0 °C (R_0), 100 °C (R_{100}) and 260 °C (R_{260}), and are defined as follows:

$A = \alpha + (\alpha * \delta)/100$

$B = (-\alpha * \delta)/100^2$

$C_{T<0} = (-\alpha * \beta)/100^4$

where: $\alpha = (R_{100} - R_0)/(100 + R_0)$
ß = Constant for T < 0 °C, zero otherwise
$\delta = (R_0 * (1 + \alpha * 260) - R_{260})/(4.16 * R_0 * \alpha)$

For temperatures greater than 0 °C, the LDC-3736 Quantum Cascade Laser Controller derives the temperature by solving the following quadratic equation:

$$T = \frac{-R_0 A \pm \sqrt{{R_0}^2 A^2 - 4R_0 B(R_0 - R_T)}}{2R_0 B}$$

These sensor coefficients (A, B, C and R_0) are required for the LDC-3736 instrument to accurately report the temperature when utilizing an RTD sensor. Where R_0 is the resistance of the RTD at 0 °C. Typical RTDs have a nominal resistance (R_0) of 100 Ω or 1000 Ω.

Common Callendar-Van Dusen constants are listed below and are used as default values in the LDC-3706 Series Laser Diode Controller.

- $A = 3.908 \times 10^{-3}$
- $B = -5.775 \times 10^{-7}$
- $C = -4.183 \times 10^{-12}$

For optimal accuracy and stability, the 1 mA current source should be selected for RTD sensors with resistance of 200 Ω to 1500 Ω and the 2.5 mA range should be used with resistance of 1 Ω to 200 Ω. In general, the change in resistance per change in temperature is much lower for a typical 100 Ω RTD than that of a typical 10 kΩ 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.

Safety Limits

TEC modules may be damaged by excessive current, so module manufacturers typically specify a maximum safe operating current for their module. The temperature controller of the LDC-3736 provides a current limit feature that allows you to set the maximum current that the temperature controller supplies.

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 be lit in the TEC section (left) of the front panel when the controller is in a current limited condition.

If the Hot Side heatsink is too small for the application, it eventually becomes heat-saturated, wherein the heatsink can no longer dissipate the heat being generated. When the heatsink becomes saturated, the TEC current increases in an attempt to cool the load. The additional current creates more heat that cannot be dissipated and subsequently, more TEC current is applied. This situation is referred to as *thermal runaway* and can cause a load and temperature controller to become damaged.

To help avoid damage caused by thermal runaway, the LDC-3736's temperature controller provides a high-temperature limit setting. When the load temperature exceeds the temperature limit, the LDC-3736's temperature controller turns off the TEC current (and laser current source output, if the LD TEC error link is enabled) and generates an error on the TEC display.

Constant Temperature Mode Operation

1. Plug the LDC-3736 Instrument into an appropriate AC power source supplying the correct mains voltage and frequency for your instrument (refer to the rear panel for the correct ratings)

2. Turn on the LDC-3736. The TEC output will be disabled at power up and the unit will automatically configure its parameters to the state which existed when the power was last shut off

3. Press the **SELECT** soft button in the TEC MODE section of the front panel until the TEMP LED is selected

4. Press the **TEC** soft button in the PARAMETER section of the front panel to adjust the applicable limits, sensor type, sensor calibration constants, and external fan control

5. Adjust the temperature setpoint by enabling the ADJUST KNOB for TEC parameter adjustment by pressing the **TEC** button in the ADJUST section of the front panel (upper right). Use the ADJUST KNOB to change the setpoint temperature to the desired value by rotating clockwise to increase the parameter and counter-clockwise to decrease. The new parameter is now stored in non-volatile memory

6. The user can display measured voltage, current, or sensor value or the temperature setpoint on the TEC side display (LEFT) and cycle through the available display parameters by pressing the **LEFT** (left) and **RIGHT** (left) display buttons
7. Enable the TEC output of the LDC-3736 by pressing the **ON** soft button (left) in the TEC MODE section of the front panel. This button has a toggling action so pressing this button once more will disable the TEC output.

Constant Sensor Mode Operation

1. Plug the LDC-3736 Quantum Cascade Laser Controller into an AC power source supplying the correct mains voltage and frequency for your instrument (refer to the rear panel for the correct ratings)

2. Turn on the LDC-3736. The TEC output will be disabled at power up and the unit will automatically configure its parameters to the state which existed when the power was last shut off

3. Press the **SELECT** soft button in the TEC MODE section of the front panel until the SENSOR LED is selected

4. Press the TEC button in the PARAMETER section of the front panel to enable the menu structure and adjust the applicable limits, sensor type, sensor calibration constants, and external fan control. Use the **SET** button to select the parameter you wish to adjust and then use the ADJUST KNOB to change the parameter to the desired value. Clockwise rotation will increase the parameter and counter-clockwise rotation will decrease the parameter. Allow the parameter adjustment to time out (three seconds) or press the **SET** button to save the new parameter in non-volatile memory

5. Adjust the sensor value setpoint by enabling the TEC adjustment mode by pressing the **TEC** button in the ADJUST section of the front panel and rotate the ADJUST KNOB to the desired value.

6. The user can display measured voltage, current, or temperature or the sensor setpoint on the TEC side (left) display by pressing the **LEFT** (left) and **RIGHT** (left) display buttons
7. Enable the TEC output of the LDC-3706 Series instrument by pressing the **ON** soft button (left) in the TEC MODE section of the front panel. This button has a toggling action so pressing this button once more will disable the TEC output.

Constant Current Mode Operation

1. Plug the LDC-3736 instrument into an AC power source supplying the correct mains voltage and frequency for your instrument (refer to the rear panel for the correct ratings)

2. Turn on the LDC-3736. The output will be disabled at power up and the unit will automatically configure its parameters to the state which existed when the power was last shut off

3. Press the **SELECT** soft button in the TEC MODE section of the front panel until the TE CURRENT LED is selected

4. Press the **TEC** button in the PARAMETER section of the front panel to enable the menu structure and adjust the applicable limits, sensor type, calibration constants, and external fan control. Use the **SET** button to select the parameter you wish to adjust and then use the ADJUST KNOB to change the parameter to the desired value. Clockwise rotation will increase the parameter and counter-clockwise rotation will decrease the parameter. Allow the parameter adjustment to time out (three seconds) or press the **SET** button to save the new parameter in non-volatile memory

5. Adjust the TEC current setpoint by enabling the TEC adjustment mode by pressing the **TEC** button in the ADJUST section of the front panel and rotate the ADJUST KNOB to the desired value.

6. The user can display measured voltage, sensor value, or temperature or the current setpoint on the TEC side (left) display by pressing the **LEFT** (left) and **RIGHT** (left) display buttons

7. Enable the TEC output of the LDC-3736 instrument by pressing the **ON** soft button (left) in the TEC MODE section of the front panel. This button has a toggling action so pressing this button once more will disable the TEC output

Resistive Heater Mode Operation

1. Plug the LDC-3736 Controller into an AC power source supplying the correct mains voltage and frequency for your instrument (refer to the rear panel for the correct ratings)

2. Turn on the LDC-3736. The TEC output will be disabled at power up and the unit will automatically configure its parameters to the state which existed when the power was last shut off.

3. Press the **SELECT** soft button in the TEC MODE section of the front panel until the TEMPERATURE LED on the SENSOR LED is selected

4. Press the TEC button in the PARAMETERS section of the front panel to enable the menu structure and adjust the applicable limits, sensor type, calibration constants, and external fan control. Use the **SET** button to select the parameter you wish to adjust and then use the ADJUST KNOB to change the parameter to the desired value. Clockwise rotation will increase the parameter and counter-clockwise rotation will decrease the parameter. Allow the parameter adjustment to time out (three seconds) or press the **SET** button to save the new parameter in non-volatile memory. For Resistive Heater Mode ensure that the positive current limit (I+) is set to zero

5. Adjust the TEC temperature or sensor value setpoint by enabling the TEC adjustment mode by pressing the **TEC** button in the ADJUST section of the front panel and rotate the ADJUST KNOB to the desired value.

6. The user can display measured voltage, current, or temperature or the sensor setpoint on the TEC side (left) display by pressing the **LEFT** (left) and **RIGHT** (left) display buttons in constant sensor mode. The user can display measured voltage, current, or sensor value or the temperature setpoint on the TEC side display (LEFT) by pressing the **LEFT** (left) and **RIGHT** (left) display buttons in constant temperature mode.
7. Enable the TEC output of the LDC-3736 by pressing the **ON** soft button (left) in the TEC MODE section of the front panel. This button has a toggling action so pressing this button once more will disable the TEC output

Chapter 3: Remote Operation

This chapter is an overview of the remote operation of the LDC-3736 Quantum Cascade Laser Controller.

- ✓ Fundamentals of Remote Operation
- ✓ Command Syntax

Test and measurement equipment with remote operation capability will generally communicate through either GPIB or USB interfaces. 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. USB (Universal Serial Bus) is the common serial communication protocol used by most computers for relatively fast communication. Everything that can be done from the front panel can also be done remotely, and in some cases, with more flexibility. The following sections explain the fundamentals of operating the LDC-3736 Quantum Cascade Laser Controller remotely through either the GPIB or USB computer interface.

GPIB Address

The talk and listen addresses on the LDC-3736 are identical. This GPIB address is read locally by pressing the **LOCAL** button in the COMM section of the front panel until the GPIB Address is displayed on one of the dot matrix displays. The instrument comes from the factory configured with the GPIB address set to 1. You can change the LDC-3736's GPIB address locally (via the front panel). A procedure for changing the address can be found in the section *changing the GPIB Address*.

Basic GPIB Concepts

The information in this section is normally not necessary to successfully operate the LDC-3736 instrument through its GPIB interface because the host computer's GPIB controller usually handles the details. However, it is a useful introduction to understanding GPIB.

Data and Interface Messages

GPIB devices communicate with each other by sending data and interface messages. Data contains device-specific information such as programming instructions, measurement results, and instrument status. Each device has an address number, and ignores all data traffic not addressed to it. Depending on its content, data is often called a "device dependent message" or a "device dependent command". Interface messages manage the bus, with functions such as initializing the bus and addressing or un-addressing devices. In addition, some individual bus lines are designated for this purpose.

Talkers, Listeners, and Controllers

Every GPIB system consists of one or more "talkers" and "listeners", and often at least one "controller". Talkers supply data while listeners accept data. A system can consist of simply a talker and listener, as in a system comprised of a meter connected to a data logger or chart recorder. Controllers designate talkers and listeners. A controller is necessary when the active talkers or listeners must be changed. When the controller is a computer, it may also designate itself as a listener when it needs to collect data from designated talkers.

If there is more than one controller, only one can be the Controller in Charge (CIC). Control can be passed from one computer to another. In a multiple-controller system, there can be one "System Controller" capable of asserting control (becoming CIC).

GPIB Cable Connections

Standard GPIB connectors can be connected together (stacked) allowing the system to be configured linearly, or in a star configuration.

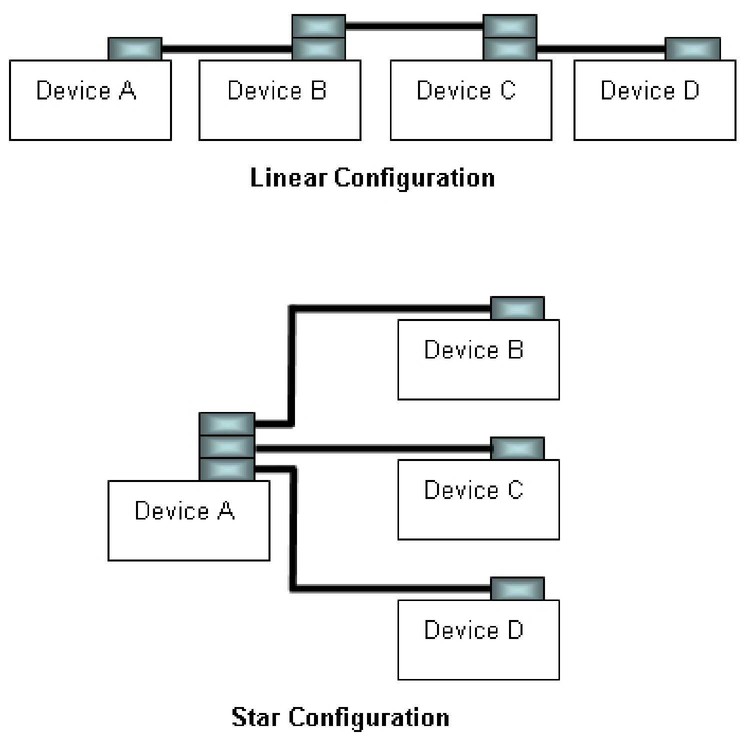


Figure 3.1 – GPIB Cable Connection

The GPIB Connector

The standard GPIB connector consists of 16 signal lines in a 24-pin stackable connector. The extra pins are used to make twisted pairs with several of the lines. There are eight data input/output lines, three handshake lines, and five interface management lines.

Eight data I/O (DIO) lines carry both data (including device dependent commands) and interface messages. The ATN interface management line determines whether these lines contain data or interface messages.

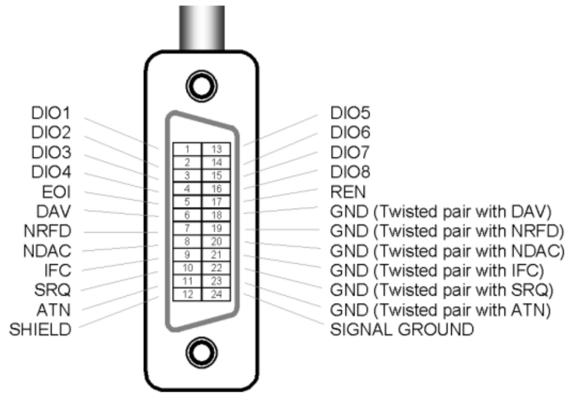


Figure 3.2 – GPIB Connector

Three handshake lines ensure that all data and messages are reliably transferred:

- NRFD (not ready for data) indicates whether a device can receive the next byte of data or message.
- NDAC (not data accepted) indicates whether a receiving device has accepted a byte of data or message.
- DAV (data valid) indicates that the signal levels on the data lines are stable and available for the receiving device(s) to accept.

Five interface management lines control the flow of information:

- ATN (attention) is set by the controller in charge to define the I/O lines for data or interface messages.
- IFC (interface clear) is set by the system controller to initialize the bus and assert itself as controller in charge.
- REN (remote enable) is set by the controller to place addressed devices into remote or local (front panel) control mode.
- SRQ (service request) can be set by any device in the system to request service from the controller.
- EOI (end or identify) is used by talkers to identify the end of a message.

Reading the GPIB Address

Before operating the LDC-3706 Series instrument remotely, its GPIB address must be known. Simply press the **LOCAL** button in the COMM section of the front panel until GPIB Address is displayed on the display. The factory default address is 1.

Changing the GPIB Address

Every device on the GPIB bus must have a unique address. If it is necessary to change the address, press the **LOCAL** button in the COMM section of the front panel until the GPIB address is displayed. Then adjust the knob until the desired address value is shown. The new GPIB address is stored in nonvolatile memory when the display times out. The allowable address range is 1 – 30 for primary GPIB addressing. It is not recommended that zero be used for an address as that is typically reserved for the GPIB controller installed in the computer. Extended GPIB addressing is not implemented.

Basic USB Concepts

Universal Serial Bus (USB) is a specification to establish communication between devices and a host controller, which has effectively replaced a variety of earlier interfaces such as serial and parallel ports. There are several USB standards available, including USB 1.1, USB 2.0, and USB 3.0. The 3736 is designed to conform to the USB 2.0 standard and USBTMC 488 substandard. USB cables use 4 lines - Power, Ground and a twisted pair differential +/- data lines. The USB connectors are designed so that power and ground are applied before the signal lines are connected. When the host powers up it performs the enumeration process by polling each of the Slave devices in turn (using the reserved address 0), assigning each one a unique address and finding out from each device what its speed is and what type of data transfer it wishes to perform. The enumeration process also takes place whenever a device is plugged into an active network. The design of the connectors, the process of enumeration, the host software, and the device firmware allows devices to be described as "Plug-and-Play".

When the USB device is enumerated and gets an address from the host, it presents the host with information about itself in the form of a series of descriptors. The device descriptor tells the host the vendor and the product ID. The configuration descriptors offer a power consumption value and a number of interface descriptors. Each of these interface descriptors define a number of endpoints, which are the sources and destinations for data transfers. The endpoint descriptors provide the following details: transfer type: bulk, interrupt or isochronous; direction; packet sizes; bandwidth requirement; and repeat interval.

In USB communication, a typical transaction consists of a number of packets; a packet contains a token indicating the type of data that the host is sending or requiring, the data, and in some cases an acknowledgement. Each packet is preceded by a sync field and followed by an end of packet marker. These transactions are used to provide four basic data transfer mechanisms, including control, interrupt, bulk, and isochronous types.

USBTMC stands for **USB Test and Measurement Class**. USBTMC is a protocol built on top of USB that allows GPIB-like communication with USB devices. From the user's point of view, the USB device behaves just like a GPIB device. For example, you can use VISA Write to send the *IDN? Query and use VISA Read to get the response. The USBTMC protocol supports service request, triggers and other GPIB specific operations. USBTMC allows instrument manufacturers to upgrade the physical layer from GPIB to USB while maintaining software compatibility with existing software, such as instrument drivers and any application that uses VISA.

Changing Between Local and Remote Operation

Sending a command over the GPIB or USB bus automatically puts the instrument in Remote mode. The Remote indicator identifies when the controller is in remote operation mode. When the instrument is in Remote mode, all front panel controls are disabled except for the Local button. Pressing the Local button returns the instrument to Local control mode unless the Local Lockout state has been activated by the host computer. Local Lockout disables all front panel controls, including the Local button, until this condition is changed by the host computer. When the instrument is placed in Local Lockout Mode by the host computer, the Remote indicator will light on the instrument display.

GPIB vs. USB Communication

The USB interface uses the same command set as the GPIB interface. Command syntax does not vary between communication protocols. However, the commands which affect GPIB hardware operation will not be useful. For example, "*SRE" may be sent using USB but service request (SRQ), normally supported by GPIB, would not be visible since USB has no hardware to support it. This is because SRQ is a function of the GPIB interface hardware and is not available via USB.

The 3736 acknowledges all commands received by the USB interface by transmitting "Ready" when the command operation is complete. Queries are acknowledged by a response message that is specific to the query. 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 LDC-3736 terminates all responses it transmits with <CR><LF> (Carriage Return – Line Feed) characters. The LDC-3736 expects all commands or queries to be terminated with a <CR> (Carriage Return) or a <LF> (Line Feed).

Command Syntax

This section describes command syntax and structure. This information must be understood in order to effectively write GPIB control programs. The syntax of GPIB commands follows the rules defined in the IEEE 488.2 standard.

Letters

Any GPIB command or query must contain all of the letters or all of the upper case letters which are shown in the command definition. Upper/lower case does not matter; upper case is used in this manual to identify the required letters. Lower case indicates optional letters. If any of the optional letters are included, they must all be included, in the correct sequence. Some examples of what works and what does not are shown below.

Table 3.1 – Acceptable and Not Acceptable Spelling

ACCEPTABLE	NOT ACCEPTABLE
DISP	DS
DISPlay or DISPLAY	Displa or DISPL

White Space

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

Table 3.2 – White Space

ACCEPTABLE	NOT ACCEPTABLE
INSTR:SEL TEC	INSTR:SELTEC

To enhance readability, one or more white spaces may be used before a comma, semicolon, or terminator. Since the computer normally places the terminator at the end of each command string (line), this simply means that an extra space character at the end of the command line works acceptably.

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

Table 3.3 – Query Formatting

ACCEPTABLE	NOT ACCEPTABLE
DISPLAY?	DISPLAY ?

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

Terminators

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

- <NL>
- <^END> (GPIB EOI)
- <NL><^END>

Many computers terminate GPIB strings with <CR><NL><^END> (Carriage Return – New Line – EOI). A carriage return (<CR>) is read as white space.

The LDC-3736 instrument terminates its GPIB responses with <CR><NL><^END>.

If problems are encountered with GPIB communications, the terminator string can sometimes be the cause. Refer to the computer's GPIB controller manual for information on configuring its terminator string.

Command Separators

More than one command may be placed in the same command string if each command is separated by a semicolon. The semicolon can be preceded by one or more spaces. For example:

DISPLAY ON;*IDN?;READ?

DISPLAY ON ; *IDN?; READ?

Parameters

Some commands require a parameter. The parameter must be separated by at least one white space.

The syntax symbol <nrf value> refers to the flexible numeric representation defined by the GPIB standard. It means that numbers may be represented 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:

Table 3.4 – Parameters

NR1	Integer	20	+20
NR2	Floating Point	20.0	+20.0
NR3	Scientific Notation	2.0E+1 2.0e+1	+2.0E+1 +2.0e+1

For more information on these definitions, refer to the IEEE 488.2 standard.

There are no default values for omitted parameters. If a command is expecting a parameter and nothing is entered, an error is generated.

For further clarity in programming, the Boolean values of one (1) and zero (0) may be used. Other acceptable names are indicated in Table 3.5. Parameters of a Boolean type are sometimes referred to as <bool>.

Table 3.5 – Substitute Parameter Values

SUBSTITUTE NAME	VALUE
ON	1
OFF	0

Syntax Summary

Remote commands must contain all of the letters shown in uppercase in the command definition. Optional letters shown in lowercase for some device dependent commands in the command reference (Chapter 4) are useful for clarity. If any of the optional letters are included, they must all be included, in the correct sequence.

A single white space must separate a command from its parameters or data. White space is normally the space character. Other control characters are also interpreted as white space. Do not use white space before the question mark in a query command.

More than one command may be in the same command string if the commands are separated with semicolons.

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

The following are examples of invalid syntax command strings that will produce errors:

Table 3.6 – Invalid Syntax Command Strings

COMMAND	COMMENT
SOURCE:CURR:LIM HIGH?	Missing colon between “LIM” and “HIGH”.
OUTPUT ON SYST:VERS?	Missing semicolon; ”SYST:VERS” command causes an error.
DISPLAY ?	Space not allowed before question mark.
SOURCE:POW:LIM1.2	Space missing between “LIM” command and the parameter value 1.2.

IEEE 488.2 Common Commands

The 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.

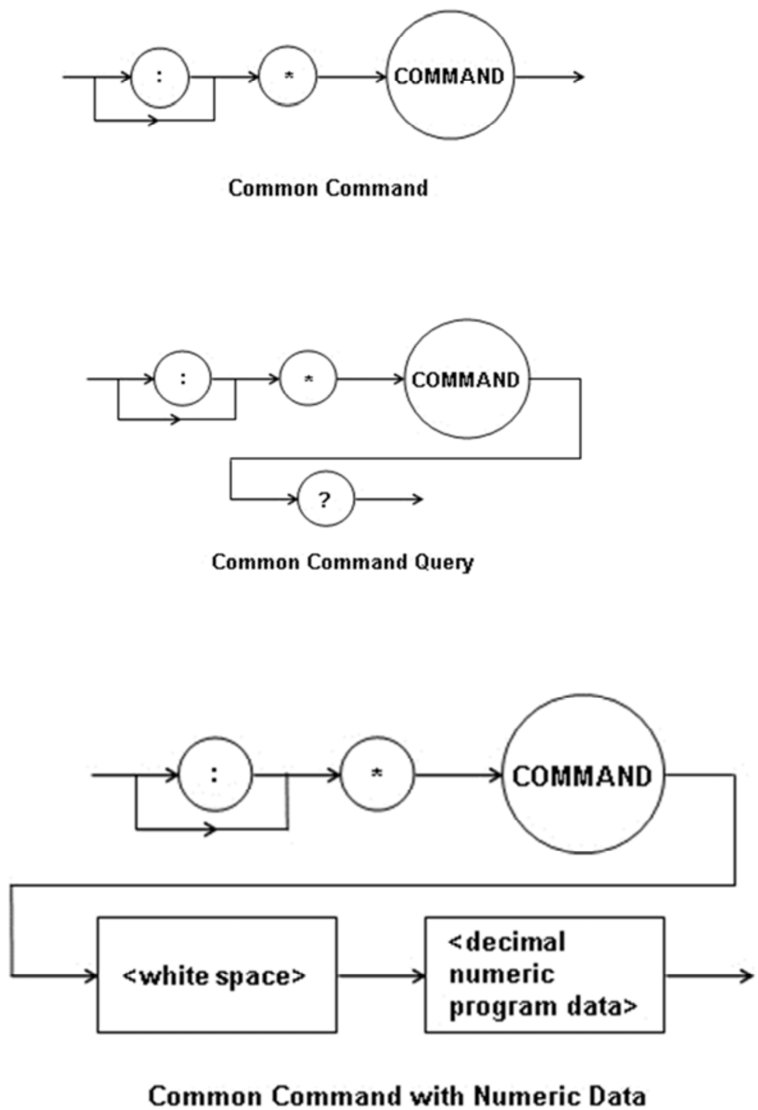


Figure 3.4 – Common Command Diagrams

Numeric data is required with *RCL (0 – 10, see front panel RECALL function), *SAV (1 – 10, see front panel STORE function), and *ESE (0 – 255, see Figure 3.2 – GPIB connector diagram).

All the IEEE 488.2 Common Commands supported by the LDC-3736 are listed below:

Table 3.7 – IEEE 488.2 Common Commands Supported by LDC-3706 Series instrument

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

See Chapter 4 – Command Reference for descriptions of all commands, including common commands, supported by the LDC-3736.

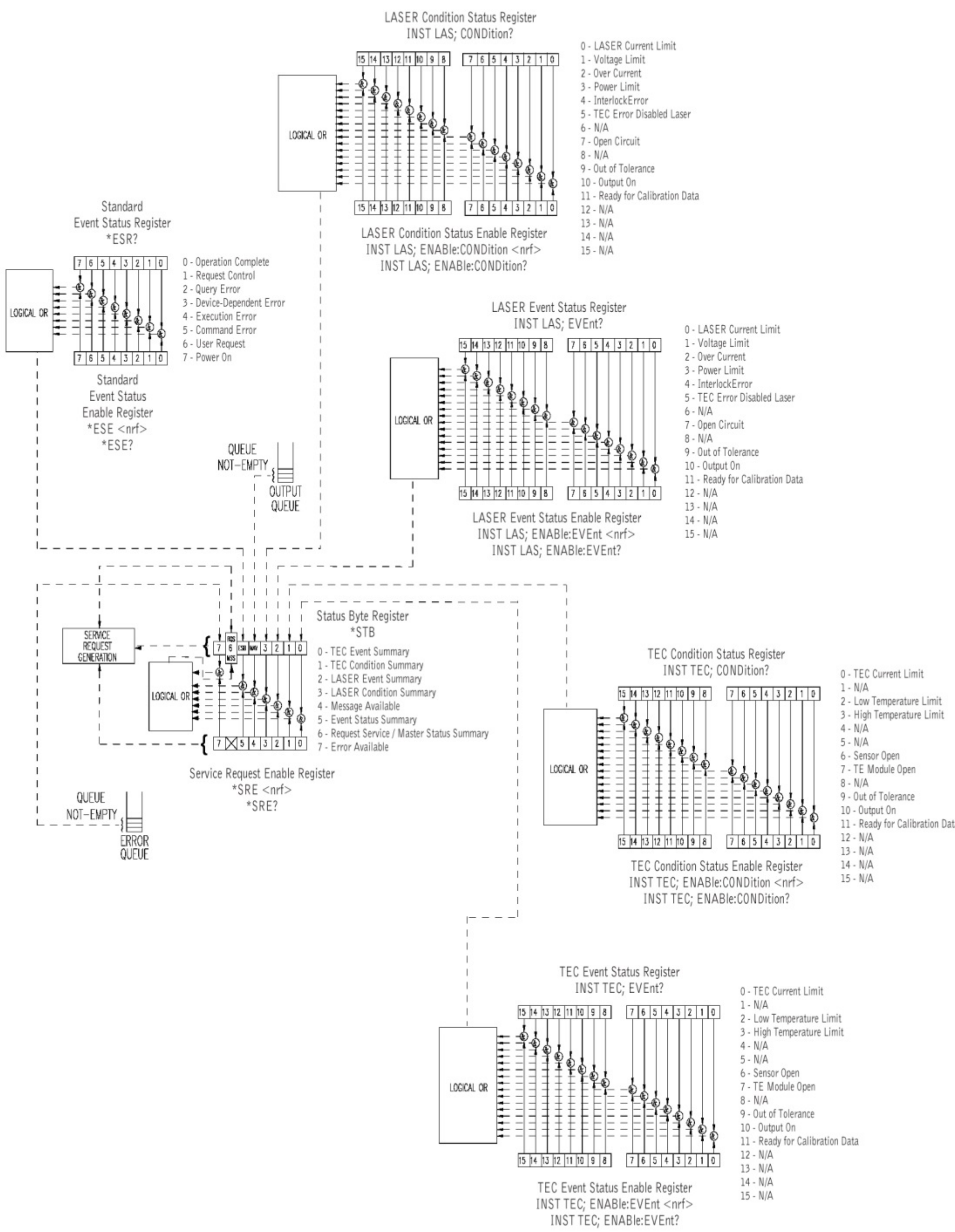


Figure 3.5 – Status Reporting Scheme

Command Timing

This section describes, for each device-dependent command, whether that command is performed in an overlapped or sequential manner. In other words, it states whether the next command may begin while the first is being executed, or if it must wait until the first command is completed before its execution begins. See the Operation Complete Definition earlier in this chapter for conditions about setting the operation complete flag.

Sequential / Overlapped Commands

All device-dependent commands are executed in an overlapped manner: subsequent commands may begin before the current command has completed. Some common commands are sequential; the next command must wait until this command has completed. The operation complete flag is set after the conditions outlined in the Operation Complete Definition have been satisfied.

The *WAI (common command) is an example of a sequential command which forces the next command to wait until the no-operation 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).

Commands which change the status of the instrument limits, or change its mode, or status enable registers, will not have their OPC flag set until all current writing to non-volatile memory has been completed. This ensures the OPC flag is never set prematurely.

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.

Chapter 4:
Command Reference

This chapter is a guide to all of the device-dependent commands for the LDC-3736 Quantum Cascade Laser Controller. This chapter is divided into three parts.

- ✓ Overview of the remote commands
- ✓ List of remote commands in alphabetical order
- ✓ LDC-3736 Compatible Commands

Remote Command Reference Summary

This section contains all of the commands for the LDC-3736, listed in alphabetical order. Table 4.1 contains a list and a description of each IEEE 488.1 common command. Table 4.2 contains the instrument specific commands. Unless otherwise noted, each of the instrument specific commands has a corresponding query without a parameter. See Figure 3.3 for the command path tree structure.

Table 4.1 – Remote Command Summary of IEEE 488.1 Common Commands

COMMAND SYNTAX	FUNCTION
*CLS	Resets the Standard Event Register, Status Byte and Error Queue to zero.
*ESE <integer>	Sets the Standard Event Status Enable Register.
*ESE?	Returns the value of the Standard Event Status Enable Register.
*ESR?	Returns the value of the Standard Event Status Register.
*IDN?	Returns the Device Identification string.
*OPC	Generates the Operation Complete message in the Standard Event Status Register.
*OPC?	Places an ASCII character 1 into the Output Queue.
*RCL <integer>	Used to recall a stored setup configuration.
*RST	Forces a device reset.
*SAV <integer>	Saves the current setup configuration.
*SRE <integer>	Sets the Service Request Enable Register bits to allow generation of user-selectable service requests.
*SRE?	Returns the current contents of the Service Request Enable Register.
*STB?	Returns the current contents of the Status Byte Register.
*TST?	Initiates an internal self-test and returns a response when complete.
*WAI	Prevents executing any further commands until the No-Operation-Pending flag is true.

Table 4.2 – Instrument Specific Command Summary Reference List

NAME	FUNCTION
CALCulate:TRANsform:POWer: RESPonsivity <nrf>	Set photodiode responsivity.
CALCulate:TRANsform:POWer: RESPonsivity?	Reports photodiode responsivity
CALCulate:TRANsform:TEMPerature: CVDusen:A <nrf>	Set coefficient A (CVD A) for the Callender-Van Dusen RTD equation.
CALCulate:TRANsform:TEMPerature: CVDusen:A?	Report coefficient A (CVD A) for the Callender-Van Dusen RTD equation.
CALCulate:TRANsform:TEMPerature: CVDusen:B <nrf>	Set coefficient B (CVD B) for the Callender-Van Dusen RTD equation.
CALCulate:TRANsform:TEMPerature: CVDusen:B?	Report coefficient B (CVD B) for the Callender-Van Dusen RTD equation.
CALCulate:TRANsform:TEMPerature: CVDusen:C <nrf>	Set coefficient C (CVD C) for the Callender-Van Dusen RTD equation.
CALCulate:TRANsform:TEMPerature: CVDusen:C?	Report coefficient C (CVD C) for the Callender-Van Dusen RTD equation.
CALCulate:TRANsform:TEMPerature: CVDusen:R <nrf>	Set offset R (CVD R0) for the Callender-Van Dusen RTD equation.
CALCulate:TRANsform:TEMPerature: CVDusen:R?	Report offset R (CVD R0) for the Callender-Van Dusen RTD equation.
CALCulate:TRANsform:TEMPerature: ICI[:GAIN] <nrf>	Set gain (slope) term for ICI current to temperature equation.
CALCulate:TRANsform:TEMPerature: ICI[:GAIN]?	Report gain (slope) term for ICI current to temperature equation.
CALCulate:TRANsform:TEMPerature: ICI:OFFSet <nrf>	Set offset term for ICI current to temperature equation.
CALCulate:TRANsform:TEMPerature: ICI:OFFSet?	Report offset term for ICI current to temperature equation.
CALCulate:TRANsform:TEMPerature: ICV[:GAIN] <nrf>	Set gain (slope) term for ICV voltage to temperature equation.
CALCulate:TRANsform:TEMPerature: ICV[:GAIN]?	Report gain (slope) term for ICV voltage to temperature equation.
CALCulate:TRANsform:TEMPerature: ICV:OFFSet <nrf>	Set offset term for ICV voltage to temperature equation.
CALCulate:TRANsform:TEMPerature: ICV:OFFSet?	Report offset term for ICV voltage to temperature equation.
CALCulate:TRANsform:TEMPerature: SHHart:A <nrf>	Set coefficient A in Steinhart-Hart resistance to temperature equation for thermistors.
CALCulate:TRANsform:TEMPerature: SHHart:A?	Report coefficient A in Steinhart-Hart resistance to temperature equation for thermistors.
CALCulate:TRANsform:TEMPerature: SHHart:B <nrf>	Set coefficient B in Steinhart-Hart resistance to temperature equation for thermistors.
CALCulate:TRANsform:TEMPerature: SHHart:B?	Report coefficient B in Steinhart-Hart resistance to temperature equation for thermistors.
CALCulate:TRANsform:TEMPerature:	Set coefficient B in Steinhart-Hart resistance

SHHart:C <nrf>	to temperature equation for thermistors.
CALCulate:TRANsform:TEMPerature: SHHart:C?	Report coefficient B in Steinhart-Hart resistance to temperature equation for thermistors.
CALibrate:CUR100UA:STARt	Initiate calibration of 100 µA thermistor current source.
CALibrate:CUR100UA[:DATA] <nrf>	Send measured current to 100 µA calibration procedure.
CALibrate:CUR10UA:STARt	Initiate calibration of 10 µA thermistor current source.
CALibrate:CUR10UA[:DATA] <nrf>	Send measured current to 10 µA calibration procedure.
CALibrate:DATE <nrf>, <nrf>, <nrf>	Update calibration date of instrument (LAS/TEC). Parameters are month, date, year.
CALibrate:DATE?	Report calibration date of instrument.
CALibrate:MDI:STARt	Initiate photodiode current measurement calibration.
CALibrate:MDI[:DATA] <nrf>	Send measured photocurrent to MDI calibration procedure.
CALibrate:PDI:STARt	Initiate photodiode current measurement calibration. This is the same procedure as CALibrate:MDI:STARt
CALibrate:PDI[:DATA] <nrf>	Send measured photocurrent to PDI calibration procedure.
CALibrate:RTD1000UA:STARt	Initiate 1 mA RTD calibration.
CALibrate:RTD1000UA:[DATA] <nrf>	Send measured RTD resistance to 1 mA RTD calibration procedure.
CALibrate:RTD2500UA:STARt	Initiate 2.5 mA RTD calibration.
CALibrate:RTD2500UA:[DATA] <nrf>	Send measured RTD resistance to 2.5 mA RTD calibration procedure.
CALibrate:SENSORI:STARt	Initiate ICI sensor current measurement calibration.
CALibrate:SENSORI:[DATA] <nrf>	Send measured ICI sensor current to IC current calibration procedure.
CALibrate:SENSORV:STARt	Initiate ICV sensor voltage measurement calibration.
CALibrate:SENSORV:[DATA] <nrf>	Send measured ICV sensor voltage to sensor voltage calibration procedure.
CALibrate:VALues <string>, <nrf>, <nrf>	Set calibration constants manually for various measurements. See Command Reference below for more information.
CALibrate:VALues? <string>	Report calibration constants for various measurements. See Command Reference below for more information.
CALibrate:VALues:ERASe <string>	Reset calibration constants to default settings.

CALIbrate:VMEAS:STARt <nrf>	Initiate LDV or VTE measurement calibration, based on which instrument mode is currently selected.
CALIbrate:VMEAS[:DATA] <nrf>	Send measured LDV or VTE voltage to VMEAS calibration procedure.
CONDition?	Report selected instrument's Condition status register.
DISPlay:BRIGhtness <nrf>	Set display brightness.
DISPlay:BRIGhtness?	Report display brightness setting.
DISPlay[:ENABle] <nrf>	Turn display on or off.
DISPlay[:ENABle]?	Reports display on or off condition.
ENABle:CONDition <nrf>	Set value of selected instrument's Condition Enable register.
ENABle:CONDition?	Report value of selected instrument's Condition Enable register.
EVEnt?	Report selected instrument's Event status register.
ENABle:EVEnt <nrf>	Set value of selected instrument's Event Enable register.
ENABle:EVEnt?	Report value of selected instrument's Event Enable register.
INPut:BIAS:VOLTage <nrf>	Set photodiode bias voltage.
INPut:BIAS:VOLTage?	Report photodiode bias voltage.
INPut:FILTer:[LPASs]:[:STATe] <bool>	Enable or disable laser current low-pass filter.
INPut:FILTer:[LPASs]:[:STATe]?	Report state of low-pass filter.
INSTrument:CATalog?	Reports the possible instrument type settings available.
INSTrument:NSELect <nrf>	Selects between Laser current source or TE controller instrument operating modes.
INSTrument:NSELect?	Reports currently selected instrument operating mode.
INSTrument[:SELect] <string>	Selects between Laser current source or TE controller instrument operating modes.
INSTrument[:SELect]?	Reports currently selected instrument operating mode.
MEASure[:SCALar]:[F]RESistance?	Report TE sensor resistance measurement.
MEASure[:SCALar]:CURRent[1]?	Report LDI or ITE, depending on currently selected instrument mode.
MEASure[:SCALar]:CURRent2?	Report photodiode current measurement.
MEASure[:SCALar]:POWer?	Report photodiode power measurement.
MEASure[:SCALar]:TEMPerature?	Report temperature measurement.

MEASure[:SCALar]:VOLTage?	Report LDV or VTE, depending on the currently selected instrument mode.
MEASure:SENSor?	Report the currently-selected sensor measurement.
OUTPut[1][:STATe] <bool>	Set output state of currently selected instrument.
OUTPut[1][:STATe]?	Reports output state of currently selected instrument mode.
OUTPut2[:STATe] <bool>	Enable or disable external fan control.
OUTPut2[:STATe]?	Report external fan output state.
SENSor <string>	Set the temperature sensor type. See Command Reference below for more information.
SENSor?	Report the currently selected temperature sensor type. See Command Reference below for more information.
SOURce[1]:AM[:STATE] <integer>	Enable or disable LDI modulation.
SOURce[1]:AM[:STATE]?	Report currently selected LDI modulation state.
SOURce[1]:CURRent:LIMit:HIGH <nrf>	Set upper TEC current limit.
SOURce[1]:CURRent:LIMit:HIGH?	Report upper TEC current limit.
SOURce[1]:CURRent:LIMit:LOW <nrf>	Set lower TEC current limit.
SOURce[1]:CURRent:LIMit:LOW?	Report lower TEC current limit.
SOURce[1]:CURRent:LIMit[:AMPLitude] <nrf>	Set laser current limit.
SOURce[1]:CURRent:LIMit[:AMPLitude]?	Report laser current limit.
SOURce[1]:CURRent:RANGe <nrf>	Set range of laser current source.
SOURce[1]:CURRent:RANGe?	Report currently selected laser current source range.
SOURce[1]:CURRent[:LEVel][:IMMediate] <nrf>	Set control setpoint for LDI or ITE, depending on the currently selected instrument mode.
SOURce[1]:CURRent[:LEVel][:IMMediate]?	Report control setpoint for LDI or ITE, depending on the currently selected instrument mode.
SOURce[1]:FUNCtion:[:MODE] <string>	Set the operating mode for the currently selected instrument mode. See Command Reference below for more information.
SOURce[1]:FUNCtion[:MODE]?	Report the operating mode for the currently selected instrument mode. See Command Reference below for more information.
SOURce[1]:POWer:LIMit <nrf>	Set the photodiode power limit.
SOURce[1]:POWer:LIMit?	Report the photodiode power limit setpoint.
SOURce[1]:POWer[:LEVel][:IMMediate] <nrf>	Set the laser diode power setpoint.
SOURce[1]:POWer[:LEVel][:IMMediate]?	Report the laser diode power setpoint.

SOURce[1]:RESistance:LCONstants:DERivative <nrf>	Set the “D” term for the TEC controller PID control loop.
SOURce[1]:RESistance:LCONstants:DERivative?	Report the “D” term for the TEC controller PID control loop.
SOURce[1]:RESistance:LCONstants:INTegral <nrf>	Set the “I” term for the TEC controller PID control loop.
SOURce[1]:RESistance:LCONstants:INTegral?	Report the “I” term for the TEC controller PID control loop.
SOURce[1]:RESistance:LCONstants[:GAIN] <nrf>	Set the “P” term for the TEC controller PID control loop.
SOURce[1]:RESistance:LCONstants[:GAIN]?	Report the “P” term for the TEC controller PID control loop.
SOURce[1]:RESistance:PROTection:LOW <nrf>	Set the TE controller resistance lower limit.
SOURce[1]:RESistance:PROTection:LOW?	Report the TE controller resistance lower limit.
SOURce[1]:RESistance:PROTection[:HIGH] <nrf>	Set the TE controller resistance upper limit.
SOURce[1]:RESistance:PROTection[:HIGH]?	Report the TE controller resistance upper limit.
SOURce[1]:RESistance:SPOint <nrf>	Set the TE controller resistance setpoint.
SOURce[1]:RESistance:SPOint?	Report the TE controller resistance setpoint.
SOURce:RESistance:TOLerance <nrf>	Set the TEC resistance tolerance. See status section: “out of tolerance” bit in condition reg.
SOURce:RESistance:TOLerance?	Report the TEC resistance tolerance setting.
SOURce[1]:TEMPerature:AM[:STATE] <integer>	Enable or disable TE controller analog temperature modulation.
SOURce[1]:TEMPerature:AM[:STATE]?	Report analog temperature modulation state.
SOURce[1]:TEMPerature:LCONstants:DERivative <nrf>	Set the “D” term for the TEC controller PID control loop.
SOURce[1]:TEMPerature:LCONstants:DERivative?	Report the “D” term for the TEC controller PID control loop.
SOURce[1]:TEMPerature:LCONstants:INTegral <nrf>	Set the “I” term for the TEC controller PID control loop.
SOURce[1]:TEMPerature:LCONstants:INTegral?	Report the “I” term for the TEC controller PID control loop.
SOURce[1]:TEMPerature:LCONstants[:GAIN] <nrf>	Set the “P” term for the TEC controller PID control loop.
SOURce[1]:TEMPerature:LCONstants[:GAIN]?	Report the “P” term for the TEC controller PID control loop.
SOURce[1]:TEMPerature:PROTection:LOW <nrf>	Set TE controller low temperature limit.
SOURce[1]:TEMPerature:PROTection:LOW?	Report TE controller low temperature limit.
SOURce[1]:TEMPerature:PROTection[:HIGH] <nrf>	Set TE controller high temperature limit.
SOURce[1]:TEMPerature:PROTection:HIGH?	Report TE controller high temperature limit.

SOURce[1]:TEMPerature:SPOint <nrf>	Set TE controller temperature setpoint.
SOURce[1]:TEMPerature:SPOint?	Report TE controller temperature setpoint.
SOURce[1]:TEMPerature:TOLerance <nrf>	Set TEC temperature tolerance.
SOURce[1]:TEMPerature:TOLerance?	Report TEC temperature tolerance.
SOURce[1]:VOLTage:LIMit <nrf>	Set laser diode voltage limit.
SOURce[1]:VOLTage:LIMit?	Report laser diode voltage limit.
SOURce[2]:VOLTage[:LEVel] <nrf>	Set external fan voltage setpoint.
SOURce[2]:VOLTage[:LEVel]?	Report external fan voltage setpoint.
SYST:ERRor:ALL?	Report all errors in error queue.
SYSTem:ERRor:CODE:ALL?	Report all error codes in error queue.
SYSTem:ERRor:CODE[:NEXT]?	Report next error code from error queue.
SYSTem:ERRor:COUNt?	Report the number of errors in the error queue.
SYSTem:ERRor[:NEXT]?	Report next error from error queue.
SYSTem:PREset	Purge error queue, reset laser controller and TE controller to default settings.
SYSTem:VERSion?	Report currently installed firmware version.

Command Reference

The following pages contain a reference for common commands of the LDC-3736 Quantum Cascade Laser Controller.

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*CLS

Clear Status

Description Clears all status event registers, the event filter, the status register, SRQ bit, the OPC bit, and the error queue

Notes Useful to clear registers before enabling service requests (SRQ)

Examples *CLS

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*ESE <integer>

Standard Event Status Enable

Description Sets the bits in the standard event status enable register.

Parameters The value must be between 0 and 255.

Notes The integer sent as a parameter is expressed in binary form when an event occurs in the standard event status register that matches the corresponding bit in the standard event status enable register; bit 5 will be enabled in the status byte register

See *ESR? for a description of each bit in the status register along with a diagram of the reporting structure.

Examples "*ESE 40" Sets the standard event status enable register to enable bit 5 of the status byte register if a device-dependent error or a command error occurs ($40 = 2^3 + 2^5$)

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*ESE?

Event Status Enable Query

Description Determine the contents of the standard event status enable register

Parameters None

Notes The response is a value between 0 and 255, representing the bits of the standard event status enable register when expressed in base 2 binary format

See *ESR? for a description of each bit in the status register along with a diagram of the reporting structure

Examples "*ESE?" A response of 68 means the user request and query error bits have been enabled in the standard event status enable register ($68 = 2^2 + 2^6$)

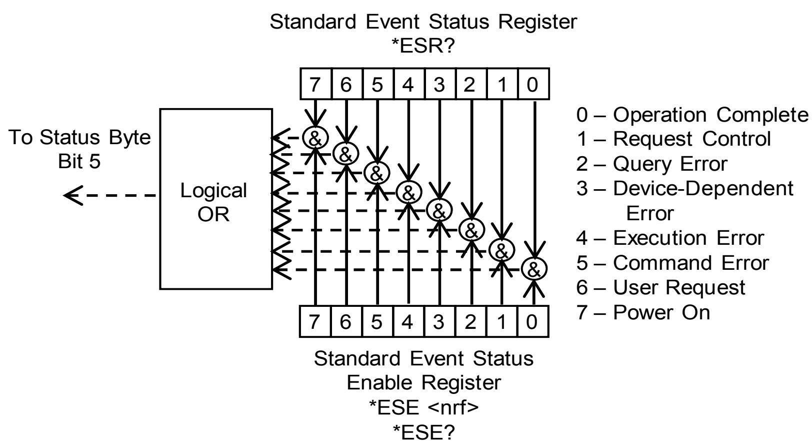
*ESR?
Standard Event Status Register Query

Description Determine the contents of the standard event status register

Parameters None

Notes Reading this register clears the contents. The response is a value between 0 and 255, representing the bits of the standard event status register when expressed in base 2 binary format.

The event bit is set when a specific event occurs:



Bit 0	Operation Complete is set when all pending device operations have been finished after *OPC common command has been executed
1	Unused and always reports 0
2	Query Error means that data in the output has been lost or that none was available
3	Device-Specific Error is an error has occurred that is neither a command query or execution error
4	Execution Error means a parameter was evaluated to be outside the legal input range or capability
5	Command Error means a command could not be interpreted by the parser
6	Unused and always reports "0"
Bit 7	Power On indicates that an off-to-on transition has occurred in the power supply
	*CLS will clear this register

Examples "*ESR?" A response of 32 means a command error has occurred

*IDN?
Instrument Identification

Description Requests the instrument to identify itself

Parameters None

Notes Returns a string of instrument identification information. The string contains a comma separated list of manufacturer, model number, serial number, and firmware revision.

Examples "*IDN?" Responds with "ILX Lightwave,LDC-3706,37061111,1.00-1.00"

*OPC
Operation Complete

Description Sets the operation complete bit (bit 0) in the standard event status register when all pending overlapped commands have been completed

Parameters None

Notes This command does not hold off subsequent operations. You can determine when the overlapped commands have completed either by polling the standard event status register (*ESR?) or by setting up the status system such that a service request is asserted when bit 0 is set in the standard event status register.

Examples OUTPUT ON;*OPC Will set bit 0 in the standard event status register when the output is on

*OPC?
Operation Complete Query

Description Places an ASCII character 1 into the instrument's output queue when all pending operations have been finished

Parameters None

Notes This command is a sequential command that holds off all subsequent commands until the "1" is returned. Make sure you have set the timeouts appropriately for using this command when you expect long delays.

Examples *OPC? A response of "1" means that all overlapped commands are complete

*RCL <bin>
Recall

Description Recalls a stored setup configuration from memory

Parameters A value from 0 – 10

Notes Bin 0 is the factory-set default configuration

The *SAV function is used to save configurations for convenient recall

The current setup is automatically stored and recalled at the next power-on

Examples "*RCL 0" –response: instrument is reconfigured to factory-default settings

*RST
Reset

Description Performs a device reset

Parameters None

Notes

1. Clears *OPC or *OPC? device requirements
2. Stops operation of overlapped commands
3. Sets all device specific function to a known state (*RST Value)

The reset command does NOT affect the following:

1. Output Queue
2. Enable Registers
3. Event Registers
4. *PSC state
5. Memory contents associated with *SAV

*SAV <bin>
Save

Description Saves the current instrument configuration to non-volatile memory

Parameters A value from 1 – 10

Notes The *SAV operation saves the contents of everything affected by the *RST command. It is not necessary to save the current setup for next power-on. The current setup is automatically stored and recall at next power-on.

Use *RCL <bin> to restore the saved configuration

Examples "*SAV 3" The current instrument configuration is stored in memory bin 3

*SRE <integer>
Service Request Enable Command

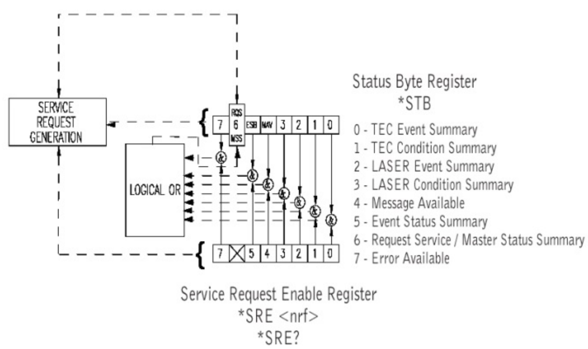
Description Sets the service request enable register bits

Parameters A value in the range of 0 to 255

Notes The integer sent as a parameter when expressed in binary format, each bit represents a bit in the service request enable register. A bit value of one indicates an enabled condition. A bit value of zero indicates a disabled condition. Bit 6 will be ignored.

Setting the service request enable register allows the programmer to select which summary messages in the status byte register may cause service requests. Each bit in the service request enable register corresponds to a bit in the status byte register.

A service request is generated when a bit in either the service request enable register or the status byte register transitions from zero to one and the corresponding bit in the other register is either set to one or transitions from zero to one at the same time.



Examples "*SRE 16" Enables the service request enable register to generate a service request when a query generating message is available to read from the output queue.

*SRE?
Service Request Enable Query

Description Returns the enabled bits in the service request enable register

Parameters None

Notes The response is a value between 0 and 255, representing the bits of the standard event status enable register when expressed in base 2 binary format

Examples "*SRE?" A response of 16 signifies that the message available summary bit is enabled

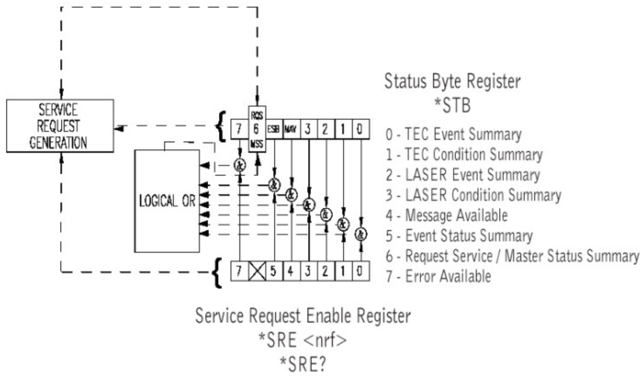
*STB?

Status Byte Query

Description Returns the value of the status byte register

Parameters None

Notes The response is the sum of the enabled bits and must be a value between 0 and 255



Examples "*STB?" A response of 129 specifies that the TEC event summary and the error available bits are set.

---

*TST?

Self Test

Description Performs an internal self-test and then reports results

Parameters None

Notes Response 0 = test completed with no errors
Response 1 = test completed with errors

This is a synchronous command and will block other commands from execution until it has completed

Examples "*TST?" A response of 0 means tests completed without errors

---

*WAI

Wait to Continue

Description Prevents the instrument from executing any further commands until all pending operations are complete

Parameters None

Notes This command can be used to make the instrument wait until an operation is complete before continuing

Care should be taken to set the time-out appropriately for use with the *WAI command. After this command is sent, the instrument may block subsequent commands waiting for the input queue to empty.

Examples ":OUTPUT ON;*WAI;:MEAS:T?" The temperature measurement will occur after the output is on

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The following pages contain a reference for device-dependent commands of the LDC-3736 Quantum Cascade Laser Controller.

CALCulate:TRANsform:POWer:RESPonsivity <nrf>
CALCulate:TRANsform:POWer:RESPonsivity?

Description Sets/Reports photodiode responsivity.

Parameters μA/mW – 0.0 to 1000.0 representing photodiode responsivity

Reset Value 0.0

CALCulate:TRANsform:TEMPerature:CVDusen:A <nrf>
CALCulate:TRANsform:TEMPerature:CVDusen:A?

Description Sets/Reports coefficient A (CVD A) for the Callender-Van Dusen RTD resistance-to-temperature equation.

Parameters CVD A - -9.999 to 9.999 representing the first coefficient of the Callendar-Van Dusen equation multiplied by 10^{-3} $°C^{-1}$

Notes The Callendar-Van Dusen equation:
$R_T = R_0[1 + AT + BT^2 + CT^3(T - 100)]$ (T < 0 °C)
$R_T = R_0[1 + AT + BT^2]$ (T ≥ 0 °C)
Where R_T is the resistance at temperature T.

Reset Value 3.908

CALCulate:TRANsform:TEMPerature:CVDusen:B <nrf>
CALCulate:TRANsform:TEMPerature:CVDusen:B?

Description Sets/Reports coefficient B (CVD B) for the Callender-Van Dusen RTD resistance-to-temperature equation.

Parameters CVD B - -9.999 to 9.999 representing the second coefficient of the Callendar-Van Dusen equation multiplied by 10^{-7} $°C^{-2}$

Notes The Callendar-Van Dusen equation:
$R_T = R_0[1 + AT + BT^2 + CT^3(T - 100)]$ (T < 0 °C)
$R_T = R_0[1 + AT + BT^2]$ (T ≥ 0 °C)
Where R_T is the resistance at temperature T.

Reset Value -5.775

CALCulate:TRANsform:TEMPerature:CVDusen:C <nrf>
CALCulate:TRANsform:TEMPerature:CVDusen:C?

Description Sets/Reports coefficient C (CVD C) for the Callender-Van Dusen RTD resistance-to-temperature equation.

Parameters CVD C - -9.999 to 9.999 representing the third coefficient of the Callendar-Van Dusen equation multiplied by 10^{-12} $°C^{-3}$

Notes The Callendar-Van Dusen equation:
$R_T = R_0[1 + AT + BT^2 + CT^3(T - 100)]$ (T < 0 °C)
$R_T = R_0[1 + AT + BT^2]$ (T ≥ 0 °C)
Where R_T is the resistance at temperature T.

Reset Value -4.183

CALCulate:TRANsform:TEMPerature:CVDusen:R <nrf>
CALCulate:TRANsform:TEMPerature:CVDusen:R?

Description Sets/Reports coefficient R0 (CVD R0) for the Callender-Van Dusen RTD resistance-to-temperature equation.

Parameters CVD R0 - The resistance of the transducer at 0 °C, adjustable from 0 to 9999.9 Ohm

Notes The Callendar-Van Dusen equation:
$R_T = R_0[1 + AT + BT^2 + CT^3(T - 100)]$ (T < 0 °C)
$R_T = R_0[1 + AT + BT^2]$ (T ≥ 0 °C)
Where R_T is the resistance at temperature T.

Reset Value 100

CALCulate:TRANsform:TEMPerature:ICI:OFFSet <nrf>
CALCulate:TRANsform:TEMPerature:ICI:OFFSet?

Description Sets/Reports offset compensation for a temperature to current transducer.

Parameters offset – -9.999 to 9.999 representing the sensor offset in μA

Reset Value 0

CALCulate:TRANsform:TEMPerature:ICI[:GAIN] <nrf>
CALCulate:TRANsform:TEMPerature:ICI[:GAIN]?

Description Sets/Reports slope compensation for a temperature to current transducer.

Parameters slope – 0 to 9.999 representing the slope in μA/**K.**

Reset Value 1

CALCulate:TRANsform:TEMPerature:ICV:OFFSet <nrf>
CALCulate:TRANsform:TEMPerature:ICV:OFFSet?

Description Sets/Reports offset compensation for a temperature to voltage transducer.

Parameters offset – -99.99 to 99.99 representing the sensor offset in mV.

Reset Value 0

CALCulate:TRANsform:TEMPerature:ICV[:GAIN] <nrf>
CALCulate:TRANsform:TEMPerature:ICV[:GAIN]?

Description Sets/Reports slope compensation for a temperature to voltage transducer.

Parameters offset – 0 to 99.99 representing the slope in mV/K.

Reset Value 10

CALCulate:TRANsform:TEMPerature:SHHart:A <nrf>
CALCulate:TRANsform:TEMPerature:SHHart:A?

Description Sets/Returns Steinhart-Hart parameter C1 for a thermistor temperature transducer.

Parameters C1 - -9.9999 to 9.9999 representing the first parameter of the Steinhart-Hart equation multiplied by 10^{-3}.

Notes The Steinhart-Hart equation:
$\frac{1}{T} = C1 - C2 \cdot \ln(\mathrm{R}) + \mathrm{C3} \cdot \ln^3(\mathrm{R})$
Where R is the resistance at temperature T.

Reset Value 1.125

CALCulate:TRANsform:TEMPerature:SHHart:B <nrf>
CALCulate:TRANsform:TEMPerature:SHHart:B?

Description Sets/Returns Steinhart-Hart parameter C2 for a thermistor temperature transducer.

Parameters C2 - -9.9999 to 9.9999 representing the second parameter of the Steinhart-Hart equation multiplied by 10^{-4}.

Notes The Steinhart-Hart equation:
$\frac{1}{T} = C1 - C2 \cdot \ln(\mathrm{R}) + \mathrm{C3} \cdot \ln^3(\mathrm{R})$
Where R is the resistance at temperature T.

Reset Value 2.347

CALCulate:TRANsform:TEMPerature:SHHart:C <nrf>
CALCulate:TRANsform:TEMPerature:SHHart:C?

Description Sets/Returns Steinhart-Hart parameters C3 for a thermistor temperature transducer.

Parameters C3 - -9.9999 to 9.9999 representing the third parameter of the Steinhart-Hart equation multiplied by 10^{-7}.

Notes The Steinhart-Hart equation:
$\frac{1}{T} = C1 - C2 \cdot \ln(\mathrm{R}) + \mathrm{C3} \cdot \ln^3(\mathrm{R})$
Where R is the resistance at temperature T.

Reset Value 0.855

CALibrate:CURR100UA:STARt
CALibrate:CURR100UA[:DATA] <nrf>

Description Begins/Takes data for the 100 µA thermistor calibration procedure.

Parameters DATA – a number representing the measured current in Amps

CALibrate:CURR10UA:STARt
CALibrate:CURR10UA[:DATA] <nrf>

Description Begins/Takes data for the 10 µA thermistor calibration procedure.

Parameters DATA – a number representing the measured current in Amps

CALibrate:CURRent:STARt
CALibrate:CURRent[:DATA]] <nrf>

Description Begins/Takes data for the laser current calibration procedure if the laser diode mode is selected or for the TEC current output calibration procedure if the TEC controller mode is selected (see the INSTrument[:SELect] command).

Parameters DATA – a number representing the measured current in Amps

CALibrate:DATE <nrf>,<nrf>,<nrf>
CALibrate:DATE?

Description Sets/Reports the calibration date information for the instrument.

Parameters Month, Day, Year – the month, day, and year that represent the last calibration date

CALibrate:MDI:STARt
CALibrate:MDI[:DATA] <nrf>

Description Begins/Takes data for the monitor photodiode current calibration procedure.

Parameters DATA – a number representing the measured current in Amps

CALibrate:PDI:STARt
CALibrate:PDI[:DATA] <nrf>

Description Begins/Takes data for the monitor photodiode current calibration procedure.

Parameters DATA – a number representing the measured current in Amps

Notes This is the same as CALibrate:MDI:STARt and CALibrate:MDI[:DATA] above; there are two versions for user flexibility

CALibrate:RTD1000UA:STARt
CALibrate:RTD1000UA[:DATA] <nrf>

Description Begins/Takes data for the 1 mA RTD resistance calibration procedure.

Parameters DATA – a number representing the measured resistance in Ohms

CALibrate:RTD2500UA:STARt
CALibrate:RTD2500UA[:DATA] <nrf>

Description Begins/Takes data for the 2.5 mA RTD resistance calibration procedure.

Parameters DATA – a number representing the measured resistance in Ohms

CALibrate:SENSORV:STARt
CALibrate:SENSORV[:DATA] <nrf>

Description Begins/Takes data for the TE ICV sensor voltage calibration procedure.

Parameters DATA – a number representing the measured voltage in Volts

CALibrate:VALues <string>,<nrf>,<nrf>
CALibrate:VALues? <string>

Description Sets/Reports calibration constants for various instrument measurements and sepoints.

Parameters value to set – string representing what measurement or setpoint to be set, see notes for acceptable inputs

slope – the second parameter is the slope constant to be set

offset – the third parameter is the offset constant to be set

Notes Acceptable strings for first parameter:

"CURRent[1]:SETPoint:LOW:BYPass"
"CURRent[1]:SETPoint:LOW"
"CURRent[1]:SETPoint:MEDium:BYPass"
"CURRent[1]:SETPoint:MEDium"
"CURRent[1]:SETPoint:HIGH:BYPass"
"CURRent[1]:SETPoint:HIGH"
"CURRent[1]:LIMit:LOW"
"CURRent[1]:LIMit:MEDium"
"CURRent[1]:LIMit:HIGH"
"VOLTage:LIMit"
"POWer:LIMit"
"CURRent[1]:MEASure:LOW"
"CURRent[1]:MEASure:MEDium"
"CURRent[1]:MEASure:HIGH"
"VOLTage:MEASure"
"CURRent2:MEASure"
"CURRent2"
"CURRent:SETPoint"
"CURRent:MEASure"
"SENSor:VOLTage"
"SENSor:CURRent:THERM10UA"
"SENSor:CURRent:THERM100UA"
"SENSor:CURRent:RTD1MA"
"SENSor:CURRent:RTD2_5MA"
"SENSor:RESistance:COUNts"
"ALL"

CALibrate:VALues:ERASe <string>

Description Resets calibration constants for various instrument measurements and sepoints to default settings.

Parameters value to reset – string representing what measurement or setpoint to be reset, see notes for acceptable inputs

Notes Acceptable strings for first parameter:

"CURRent[1]:SETPoint:LOW:BYPass"
"CURRent[1]:SETPoint:LOW"
"CURRent[1]:SETPoint:MEDium:BYPass"
"CURRent[1]:SETPoint:MEDium"
"CURRent[1]:SETPoint:HIGH:BYPass"
"CURRent[1]:SETPoint:HIGH"
"CURRent[1]:LIMit:LOW"
"CURRent[1]:LIMit:MEDium"
"CURRent[1]:LIMit:HIGH"
"VOLTage:LIMit"
"POWer:LIMit"
"CURRent[1]:MEASure:LOW"
"CURRent[1]:MEASure:MEDium"
"CURRent[1]:MEASure:HIGH"
"VOLTage:MEASure"
"CURRent2:MEASure"
"CURRent2"
"CURRent:SETPoint"
"CURRent:MEASure"
"SENSor:VOLTage"
"SENSor:CURRent:THERM10UA"
"SENSor:CURRent:THERM100UA"
"SENSor:CURRent:RTD1MA"
"SENSor:CURRent:RTD2_5MA"
"SENSor:RESistance:COUNts"
"ALL"

CALibrate:VMEAS:STARt
CALibrate:VMEAS[:DATA] <nrf>

Description Begins/Takes data for the laser voltage calibration procedure if the laser diode mode is selected or for the TEC voltage calibration procedure if the TEC controller mode is selected (see the INSTrument[:SELect] command).

Parameters DATA – a number representing the measured voltage in Volts

CALibrate:SENSORI:STARt

Description Begins the TE ICI sensor voltage calibration procedure.

CONDition?

Description Reports the selected instrument's Condition status register. See section 3, Status Reporting.

Example INST las; Condition? A response of 1025 (bits 10 and 0 set) indicates the output is on and the laser is in current limit.

DISPlay:BRIGhtness <nrf>
DISPlay:BRIGhtness?

Description Sets/Reports brightness setting of the front panel displays.

Parameters brightness – an integer from 0 – 10 representing the level of brightness desired (1 = minimum brightness, 10 = full brightness)

DISPlay[:ENABle] <nrf>
DISPlay[:ENABle]?

Description Sets/Reports on/off state of the front panel displays.

Parameters on state – 0 for off, 1 for on

ENABle:CONDition <nrf>
ENABle:CONDition?

Description Sets or reports the selected instrument's Condition Enable status register. See section 3, Status Reporting.

Parameter A number containing the bit-encoded value to set in the register.

Example INST LAS; Enable:Condition 16. Only bit 4 is set; when an interlock error occurs the Laser Condition Summary bit will be set in the Status Byte.

EVEnt?

Description Reports the selected instrument's Event status register. See section 3, Status Reporting. This query will report the event status register, then clear the register.

Example INST LAS; Event? A response of 8 (bit 3 set) indicates that a Power Limit condition occurred since the last read of the Event register.

ENABle:EVEnt <nrf>
ENABle:EVEnt?

Description Sets or reports the selected instrument's Event Enable status register. See section 3, Status Reporting.

Parameter A number containing the bit-encoded value to set in the register.

Example INST LAS; Enable:Event 2. Bit 1 is set, so a voltage-limit event will cause the Laser Event Summary bit to be set in the Status Byte.

INPut:BIAS:VOLTage <nrf>
INPut:BIAS:VOLTage?

Description Sets/Reports photodiode bias voltage value.

Parameters PD bias – 0.000 – 5.000 - the desired PD bias voltage in volts

Reset Value 2.500 V

INPut:FILTer:[LPASs][:STATe] <bool>
INPut:FILTer:[LPASs][:STATe]?

Description Enables/Reports state of laser current filter.

Parameters Boolean values: 0, 1, ON, OFF.

Reset Value OFF

INSTrument:CATalog?

Description Reports the possible instrument mode selections for the LDC-3706.

Response Responds with the string "LAS, TEC", the two possible operating modes for the LDC-3706.

INSTrument:NSELect <nrf>

INSTrument:NSELect?

Description Sets/Reports the instrument operating mode.

Parameters instrument mode – 1 or 2 – 1 for laser driver mode and 2 for TEC controller mode

INSTrument[:SELect] <string>
INSTrument[:SELect]?

Description Sets/Reports the instrument operating mode.

Parameters instrument mode – “LAS” or “TEC” – “LAS for laser driver mode and “TEC” for TEC controller mode

MEASure[:SCALar]:[F]RESistance?

Description Reports the TE sensor resistance in Ohms.

MEASure[:SCALar]:CURRent[1]?

Description Reports the laser diode output current in Amps in laser driver mode or the TEC controller output current in Amps in TEC controller mode.

MEASure[:SCALar]:CURRent2?

Description Reports photodiode current measurement in milliamps.

MEASure[:SCALar]:POWer?

Description Reports photodiode power measurement in milliwatts.

MEASure[:SCALar]:TEMPerature?

Description Reports TE temperature measurement in ˚C.

MEASure[:SCALar]:VOLTage?

Description Reports the laser diode output voltage in Volts in laser driver mode or the TEC controller output voltage in Volts in TEC controller mode.

MEASure:SENSor?

Description Reports the currently selected sensor’s native quantity. For a resistive sensor, response value is in ohms. For ICI, response is in uA. For ICV, response is in mV.

OUTPut[1][:STATe] <bool>
OUTPut[1][:STATe]?

Description Sets/reports laser output state in laser driver mode or TEC output state in TEC controller mode.

Parameter state – 0 or 1 – 0 for off, 1 for on. Also “ON” or “OFF”.

OUTPut2[:STATe] <bool>
OUTPut2[:STATe]?

Description Sets/reports external fan output state.

Parameter state – 0 or 1 – 0 for off, 1 for on

SENSor <string>
SENSor?

Description Sets/reports sensor type for TEC controller.

Parameters sensor type – string representing what type of sensor will be used

Notes Acceptable strings for first parameter:

THERM100uA

THERM10uA

RTD1MA

RTD2_5MA

ICI

ICV

THERM_AUTO

RTD_AUTO

DEFault (default is the same as THERM-AUTO)

SOURce[1]:AM[:STATe] <nrf>
SOURce[1]:AM[:STATe]?

Description Sets/reports enabled state of laser driver analog modulation.

Parameters state – 0 or 1 – 0 for off, 1 for on

SOURce[1]:CURRent:LIMit:HIGH <nrf>
SOURce[1]:CURRent:LIMit:HIGH?

Description Sets/reports upper TEC current limit.

Parameters upper limit – 0.00 – 8.00 – upper current limit in Amps

Reset Value 8.00

SOURce[1]:CURRent:LIMit:LOW <nrf>
SOURce[1]:CURRent:LIMit:LOW?

Description Sets/reports lower TEC current limit.

Parameters lower limit – -8.00 – 0.00 – lower current limit in Amps

Reset Value -8.00

SOURce[1]:CURRent:LIMit[:AMPLitude] <nrf>
SOURce[1]:CURRent:LIMit[:AMPLitude]?

Description Sets/reports laser driver current limit.

Parameters limit – 0.00 – 4.040 –current limit in Amps

Reset Value 0.500 Amp (500 mA)

SOURce[1]:CURRent:RANGe <nrf>
SOURce[1]:CURRent:RANGe?

Description Sets/reports laser driver current range.

Parameters range – 1, 2, or 4 –1 for 1 Amp range, 2 for 2 Amp range, and 4 for 4 Amp range

SOURce[1]:CURRent[:LEVel][:IMMediate] <nrf>
SOURce[1]:CURRent[:LEVel][:IMMediate]?

Description Sets/reports laser driver current setpoint in laser driver mode or TEC current setpoint in TEC controller mode.

Parameters setpoint - -8.000 to +8.000 – current setpoint in Amps

SOURce[1]:FUNCtion[:MODE] <string>
SOURce[1]:FUNCtion[:MODE]?

Description Sets/reports laser driver operating mode in laser driver mode or TEC operating mode in TEC controller mode.

Parameters mode – string representing operation mode, see notes

Notes Acceptable strings for first parameter:

"POWer" (laser driver mode only)
"CURRent"
"TEMPerature" (TEC controller mode only)
"RESistance" (TEC controller mode only)

SOURce[1]:POWer:LIMit <nrf>
SOURce[1]:POWer:LIMit?

Description Sets/reports laser driver photodiode power limit.

Parameters limit – power limit in Watts.

Note Maximum value depends on responsivity: limited by maximum IPD of 10 mA for 3736.
See Calculate:Transform:Power:Responsivity command.

Reset Value 0.001 Watt (10.0 mW)

SOURce[1]:POWer[:LEVel][:IMMediate] <nrf>
SOURce[1]:POWer[:LEVel][:IMMediate]?

Description Sets/reports laser driver photodiode power setpoint.

Parameters setpoint – power setpoint in Watts. Maximum value depends on responsivity.

Reset Value 0.0 Watts

SOURce[1]:RESistance:LCONstants:DERivative <nrf>
SOURce[1]:RESistance:LCONstants:DERivative?

Description Sets/reports "D" term for TEC controller PID loop, in Sensor mode.

Parameters setpoint – 0.000000 – 10.000000 – D value setting

Reset Value 0.05

SOURce[1]:RESistance:LCONstants:INTegral <nrf>
SOURce[1]:RESistance:LCONstants:INTegral?

Description Sets/reports "I" term for TEC controller PID loop, in Sensor mode.

Parameters setpoint – 0.000000 – 10.000000 – I value setting

Reset Value 0.1

SOURce[1]:RESistance:LCONstants[:GAIN] <nrf>
SOURce[1]:RESistance:LCONstants[:GAIN]?

Description Sets/reports "P" term for TEC controller PID loop, in Sensor mode.

Parameters setpoint – 0.000000 – 100.000000 – P value setting

Reset Value 15.0

SOURce[1]:RESistance:PROTection:LOW <nrf>
SOURce[1]:RESistance:PROTection:LOW?

Description Sets/reports TE sensor resistance low limit.

Parameters low limit – 0.00 – 500000.0 – limit in Ω

Reset Value 0.00

SOURce[1]:RESistance:PROTection[:HIGH] <nrf>
SOURce[1]:RESistance:PROTection[:HIGH]?

Description Sets/reports TE sensor resistance high limit.

Parameters high limit – 0.00 – 500000.0 – limit in Ω

Reset Value 500000.0

SOURce[1]:RESistance:SPOint <nrf>
SOURce[1]:RESistance:SPOint?

Description Sets/reports TE controller resistance setpoint.

Parameters setpoint – 0.00 – 500000.0 – setpoint in Ω

SOURce[1]:RESistance:TOLerance <nrf>
SOURce[1]:RESistance:TOLerance?

Description Sets/reports TE controller resistance tolerance. This setting is used in status reporting (see section 3). When the measured resistance is more than this amount over the setpoint, the “Out of Tolerance” bit will be set in the condition register. The bit will also be set if the measured resistance is less than this amount below the setpoint.

Parameters The tolerance value in Ω.

SOURce[1]:TEMPerature:AM[:STATe] <nrf>
SOURce[1]:TEMPerature:AM[:STATe]?

Description Sets/reports TE analog modulation enabled state.

Parameters state – 0 or 1 – 0 is disabled, 1 in enabled

SOURce[1]:TEMPerature:LCONstants:DERivative <nrf>
SOURce[1]:TEMPerature:LCONstants:DERivative?

Description Sets/reports “D” term for TEC controller PID loop, in Temperature mode.

Parameters setpoint – 0.000000 – 10.000000 – D value setting

Reset Value 0.0

SOURce[1]:TEMPerature:LCONstants:INTegral <nrf>
SOURce[1]:TEMPerature:LCONstants:INTegral?

Description Sets/reports “I” term for TEC controller PID loop, in Temperature mode.

Parameters setpoint – 0.000000 – 10.000000 – I value setting

Reset Value 1.0

SOURce[1]:TEMPerature:LCONstants[:GAIN] <nrf>

SOURce[1]:TEMPerature:LCONstants[:GAIN]?

Description Sets/reports "P" term for TEC controller PID loop, in Temperature mode.

Parameters setpoint – 0.000000 – 100.000000 – P value setting

Reset Value 0.5

SOURce[1]:TEMPerature:PROTection:LOW <nrf>
SOURce[1]:TEMPerature:PROTection:LOW?

Description Sets/reports low limit for temperature.

Parameters limit – -100.00 – 200.00 – low temperature in ˚C

Reset Value -100.00

SOURce[1]:TEMPerature:PROTection[:HIGH] <nrf>
SOURce[1]:TEMPerature:PROTection[:HIGH]?

Description Sets/reports high limit for temperature.

Parameters limit – -100.00 – 200.00 – high temperature in ˚C

Reset Value 200.00

SOURce[1]:TEMPerature:SPOint <nrf>
SOURce[1]:TEMPerature:SPOint?

Description Sets/reports temperature setpoint.

Parameters setpoint – -100.00 – 200.00 – temperature setpoint in ˚C

SOURce[1]:TEMPerature:TOLerance <nrf>
SOURce[1]: TEMPerature:TOLerance?

Description Sets/reports TE controller temperature tolerance. This setting is used in status reporting (see section 3). When the measured tempeature is more than this amount over the setpoint, the "Out of Tolerance" bit will be set in the condition register. The bit will also be set if the measured temperature is less than this amount below the setpoint.

Parameters The tolerance value in degrees C.

SOURce[1]:VOLTage:LIMit <nrf>
SOURce[1]:VOLTage:LIMit?

Description Sets/reports laser diode voltage maximum setpoint.

Parameters maximum voltage – 0.000 – 18.000 – maximum voltage in Volts

Reset Value 9.000

SOURce2:VOLTage[:LEVel] <nrf>
SOURce2:VOLTage[:LEVel]?

Description Sets/reports external fan voltage setpoint.

Parameters fan voltage – 0 – 12 – external fan voltage in Volts

Reset Value 12

SYSTem:ERRor:ALL?

Description Reports all errors in error queue.

SYSTem:ERRor:CODE:ALL?

Description Reports all error codes in error queue.

SYSTem:ERRor:CODE[:NEXT]?

Description Reports next error code from error queue.

SYSTem:ERRor:COUNt?

Description Reports the number of errors in the error queue.

SYSTem:ERRor[:NEXT]?

Description Reports the next error from the error queue.

SYSTem:PRESet

Description Purges error queue and resets laser controller and TE controller to default settings.

SYSTem:VERSion?

Description Reports currently installed firmware version.

Chapter 5: Troubleshooting and Calibration

This chapter will help you resolve any problems you may experience with your LDC-3736 Quantum Cascade Laser Controller quickly. If you need additional help, please contact ILX Lightwave Customer Service. See page ix for contact information.

ILX Lightwave Corporation provides in-house calibration services for ILX instruments. International customers may contact our service centers for regional calibration support. Most ILX instruments, including the LDC-3736 requires 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-around times are normally five business days or less. Please contact ILX Customer Support (see Comments, Suggestions, and Problems on page ix for contact information) for additional calibration information.

For further assistance with technical solutions and troubleshooting, visit www.newport.com/ilxlightwave.

Troubleshooting Guide

This section lists some common problems and corrective actions. In the event that the corrective action does not resolve problem; please contact ILX Lightwave.

For a comprehensive list of frequently asked questions, see the ILX Lightwave website or contact ILX Lightwave Customer Service (see Comments, Suggestions, and Problems on page viii for contact information).

SYMPTOM	CORRECTIVE ACTION
GENERAL	
The instrument does not power up	Check the power cord to make sure that it is securely connected and check the wall outlet by connecting to a known operational device. There are no user-serviceable fuses on this device, but there are several internal fuses. Contact customer support at ILX Lightwave.
The instrument reads "Internal Communication Error"	Error code 516 is the internal communication error indication that the LDC-3736 is not functioning correctly. The instrument must be returned to ILX Lightwave if this error occurs.
Slow or unexpected response to remote commands	Check that no two devices are set to the same GPIB address. Make sure that there are less than 15 devices on the bus. Check the configuration of your GPIB controller card or COM port. Specifically note the information regarding the terminating character. Check that total GPIB cable length is less than 20 meters (65 feet). Remove all other instruments from the bus to isolate the LDC-3736. If this corrects the problem, re-connect one instrument at a time until the problem returns. Then check the other instrument for address conflicts and proper GPIB function.
The LDC-3736 is not responding to all ANSI/IEEE 488.2 commands	The LDC-3736 is not fully IEEE 488.2 compliant.
The LDC-3736 is not being recognized by USB	Check the USB cable connection between the LDC-3736 instrument and the computer.

No response from a remote command and the RMT indicator is off	Check that a GPIB or USB A/B cable, from the system controller, is connected to the LDC-3736 instrument. If you are using GPIB, the cable should be less than 3 meters (10 feet) long. Press **LOCAL** until the GPIB address is displayed. If it is not correct, change it by using the ADJUST knob until you see the correct address. Check that your controlling software is sending commands to the correct GPIB address and using the correct terminating character. Check that no two devices are set to the same GPIB address. Make sure that there are less than 15 devices on the bus. Check that total GPIB cable length is less than 20 meters (65 feet). Check the configuration of your GPIB controller card or COM port. Specifically note the information regarding the terminating character. Remove all other instruments from the GPIB bus to isolate the LDC-3706 Series instrument. If this corrects the problem, re-connect one instrument at a time until the problem returns. Then check the other instrument for address conflicts and proper GPIB function. Read the error queue remotely (**SYST:ERR?**). The command syntax or command structure may be in error. Read the status byte (***STB?**) for possible device problems.

LASER CONTROLLER	
Power on, but no current output	Check the interlock pins on the LASER input connector on the instrument rear panel. These pins must be shorted either directly or through a switch. If an “Open Circuit Error” is shown on the display, check the load connections and then try again. Check the OUTPUT ON switch, the corresponding LED should be lit.
Output current at limit, cannot be lowered	If POWER mode is used, check the monitor diode (feedback) connections. Try reversing the polarity of the monitor photodiode. Check the photodiode bias adjustment in the LASER (PARAMETER) menu. If in constant current mode, check the current set point and I LIMIT setting. Setting the output below the limit may require several turns of the adjust knob if the set point is much greater than the desired limit setting.
Output goes off intermittently	Check the interlock circuit. An intermittent interlock will turn the output off. Check that the AC power cord connection is secure. Power-line drop-outs may reset the unit and when power is restored, the output will be off.
Unable to adjust output	Check the LASER (ADJUST) indicator, the indicator must be lit for any LASER adjustments to be made. Check the I LIMIT parameter for the output range in use and that it is set above 0 mA.
Power Mode operation has high output current, but little or no power is measured	Check the PD BIAS setting. If it is set too low, the power control mode may act as an open feedback loop. If in doubt, set the PD BIAS to mid-range (2.5 V). Ensure that the current limit is set correctly according to laser manufacturer’s datasheet.
Output exceeds Power Limit	The "Power Limit" is not a hardware limit. It only serves as a warning that the power measurement has exceeded the limit set point. Ensure that the current limit is set correctly according to laser manufacturer’s datasheet.
Open Circuit Error occurs during calibration	Check load connections. Check that measuring meter does not auto-range (use non-auto-ranging modes).
Calibration is aborted unintentionally	Calibration modes will be aborted if an open circuit is detected.
VOLTAGE LIMIT indicator blinks	This indicates a voltage limit error. Check laser connections. A high impedance may cause this condition.
Open circuit error E503 or Voltage Limit error E505 prevents output from reaching desired value.	The LDC-3736 has an adjustable laser compliance voltage. Check to see if the LASER voltage limit setting is too low (see Chapter 2). Check laser connections.

TEMPERATURE CONTROLLER	
The instrument reads “Sensor Open”	Confirm the appropriate sensor has been selected under the PARAM menu. Check the cable connections to the sensor. If the problem persists, contact customer support at ILX Lightwave.
Power on, but temperature is not controlled or is unstable.	If there is a SENSOR OPEN indication (Error code 505), check the sensor connections (pins 14,15). Check that the proper sensor current range is selected. Check that the appropriate coefficients have been set for your sensor. Refer to the *Sensor Options* section under *General Operating* Procedures 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. If the problem persists, contact customer support at ILX Lightwave.
IC-Current sensor value is not changing on the LDC-3736	Insure the 4-wire sensor voltage measurement (pins 1 and 2) are not connected to the sensor.
Inaccurate sensor, TEC voltage, or TEC current measurement on the LDC-3736	Insure the 4-wire TEC sensor connections (pins 7 and 8) are connected. For thermistor or RTD sensors insure the 4-wire sensor connections (pins 1 and 2) are connected.

Error Messages

Error messages may appear on the LDC-3736 display when error conditions occur in the instrument. In remote operation, use SYST:ERR:ALL? to read the current error list. The SYST:ERR? query returns a string containing the next error message that is in the error message queue.

Error Code Tables

The error codes are classified and placed in tables corresponding to their classification. The classifications are Command Errors, Execution Errors, Device Errors, Query Errors and Instrument Specific Errors.

Table 5.1 – Error Code Classifications

Error Code Range	Area of Operation
E-001 – E-099	Internal Program Errors
E-100 – E-199	Parser Errors
E-200 – E-299	Execution Control Errors
E-300 – E-399	Device Specific Errors
E-400 – E-499	TEC Control Errors
E-500 – E-599	Laser Control Errors

Note: Error codes not listed are reserved for future design use.

Table 5.2 – Error Messages

Error Code	Explanation
E-100	General command parsing error.
E-101	Invalid character.
E-102	Syntax error.
E-103	Invalid separator.
E-104	Data type error.
E-108	Invalid parameter for command.
E-109	Command is missing a parameter.
E-110	Command header error.
E-111	Command header separator error.
E-112	Program mnemonic is too long.
E-113	Undefined command header.
E-114	Header suffix is out of range.
E-115	Unexpected number of parameters received.
E-120	General numeric data error.
E-121	Invalid character included in numeric data.

Error Code	Explanation
E-123	Exponent too large in numeric data.
E-124	Too many digits in numeric data.
E-128	Numeric data not allowed.
E-130	General suffix error.
E-131	Invalid suffix received.
E-134	Suffix too long.
E-100	General command parsing error.
E-101	Invalid character.
E-102	Syntax error.
E-103	Invalid separator.
E-104	Data type error.
E-108	Invalid parameter for command.
E-109	Command is missing a parameter.
E-110	Command header error.
E-111	Command header separator error.
E-112	Program mnemonic is too long.
E-113	Undefined command header.
E-114	Header suffix is out of range.
E-115	Unexpected number of parameters received.
E-120	General numeric data error.
E-121	Invalid character included in numeric data.
E-123	Exponent too large in numeric data.
E-124	Too many digits in numeric data.
E-128	Numeric data not allowed.
E-130	General suffix error.
E-131	Invalid suffix received.
E-134	Suffix too long.
E-138	Suffix not allowed.
E-140	General character data error.
E-141	Invalid character data received.
E-144	Character data too long.
E-148	Character data not allowed.
E-150	General string data error.

Error Code	Explanation
E-151	Invalid string data received.
E-158	String data not allowed.
E-160	General block data error.
E-161	Invalid block data received.
E-168	Block data not allowed.
E-170	Command expression error.
E-171	Invalid expression received.
E-178	Expression data not allowed.
E-180	General command macro error.
E-200	General execution error.
E-201	Invalid command when in local mode.
E-202	Settings have been lost.
E-203	Command is protected and cannot be called.
E-220	Error with parameter during execution.
E-221	A settings conflict has occurred.
E-222	Data out of range.
E-223	Too much data received.
E-224	Illegal parameter value received.
E-225	Execution ran out of memory.
E-226	List received are not of the same length.
E-230	Data received is corrupt or stale.
E-231	Data received is in a questionable state.
E-232	Data received is in an invalid format.
E-233	Data received is in an invalid version.
E-240	A hardware error has occurred during execution.
E-241	The hardware is missing.
E-250	A mass storage error has occurred during execution.
E-251	The mass storage is missing.
E-252	The media is missing.
E-253	The media is corrupt.
E-254	The media is full.
E-255	The directory is full.
E-256	File name not found.
E-257	File name error.
E-258	The media is protected.

Error Code	Explanation
E-260	Executable expression error.
E-261	Math error in executable expression.
E-270	General executable macro error.
E-271	A macro syntax error has occurred during execution.
E-272	A macro error has occurred during execution.
E-273	Illegal macro label.
E-274	Executable macro parameter error.
E-275	Macro definition is too long.
E-276	A macro recursion error has occurred.
E-277	Attempted macro redefinition is not allowed.
E-278	Macro header was not found.
E-280	A general program error has occurred.
E-281	Cannot create program.
E-282	Illegal program name.
E-283	Illegal variable name.
E-284	Program is currently running.
E-285	A program syntax error has occurred.
E-286	A program runtime error has occurred.
E-290	A memory use error has occurred.
E-291	The executable has run out of memory.
E-292	The referenced name does not exist.
E-293	The referenced name already exists.
E-294	An incompatible data type error has occurred.
E-300	General device-specific error.
E-310	General device-specific system error.
E-311	General device-specific memory error.
E-312	System memory has been lost.
E-313	Calibration memory has been lost.
E-314	Save/Recall memory has been lost.
E-315	Configuration memory has been lost.
E-320	A storage fault has occurred.
E-321	The device is out of memory.
E-330	The device self-test has failed.
E-340	The calibration procedure has failed.
E-341	The calibration data entered is invalid.
E-342	The measurement calibration has failed.
E-343	The limit calibration has failed.
E-344	A calibration memory write error has occurred.
E-345	A calibration memory read error has occurred.
E-350	A queue overflow has occurred.
E-360	General communications error.
E-361	A parity check error has occurred in the program.

Error Code	Explanation
E-362	A framing error has occurred in the program.
E-363	An input buffer overrun has occurred.
E-365	A time out error has occurred.
E-366	Invalid storage location selected.
E-402	Temperature sensor open error.
E-403	TEC open circuit error.
E-404	TEC current limit error.
E-405	TEC voltage limit error.
E-407	TEC temperature limit error.
E-409	TEC sensor type change detected.
E-410	TEC out of tolerance value detected.
E-411	General TEC control error.
E-412	General TEC programming error.
E-413	General TEC communications error.
E-501	Laser interlock error.
E-503	Laser open circuit error.
E-504	Laser over current error.
E-509	Laser temperature out of range error.
E-520	Digital board EEPROM error.
E-532	General laser communications error.
E-533	Laser disabled due to TEC error (when TEC Error mode is enabled)
E-596	Unknown laser board detected.

Calibration Overview

The LDC-3736 Quantum Cascade Laser Controller should be calibrated every 12 months or whenever performance verification indicates that calibration is necessary.

All calibrations can be done with the case closed. The instrument is calibrated by changing the internally stored digital calibration constants.

WARNING

Lasers and TECs should never be connected to the output of the LDC-3736 during calibration procedures. All calibration routines have to potential to surpass protection limits and can result in damage to lasers and TECs.

Recommended Equipment

Recommended test equipment for calibrating the LDC-3736 is listed in Table 5.1. Equipment other than that shown in the table may be used if the specifications meet or exceed those listed.

Table 5.1 Recommended calibration equipment

DESCRIPTION	SPECIFICATION
DMM	8 1/2 Digit
Metal Film Resistors	5 kΩ (for all temperature sensors) 100 Ω (for MDI) 1.2 kΩ and 300 Ω (for 1 mA RTD) 60 Ω and 240 Ω (for 2.5 mA RTD)
High Power Resistors	1 Ω 25 W (for MDI) 2 Ω 150 W (for ITE and VTE) 4.5 Ω 100 W (for LDI and LDV)
Optocoupler	0 to 10 mA for photodiode feedback > 40 mA maximum input diode current, < 20 mA maximum collector current (for MDI)

Environmental Conditions

ILX Lightwave recommends calibration at 23 °C ± 1.0 °C. When necessary, however, the LDC-3736 may be calibrated at its intended use temperature if this is within the specified operating temperature range of 10 to 40 °C.

Warm-up

The LDC-3736 should be allowed to warm-up for at least 1 hour before calibration unless otherwise specified.

Calibration Adjustments

There are sixteen calibrations that need to be completed for proper operation of the LDC-3736 Quantum Cascade Laser Controller. These calibrations pertain to temperature sensor measurement, the ITE current measurement, the TEC voltage measurement, the laser source current measurement, the laser source voltage measurement, and the photodiode current measurement.

If a problem arises during calibration which prevents normal completion, calibration may be aborted by allowing the calibration procedure to time out by not pressing any front panel buttons, turning any knobs, or sending any remote commands. This prevents alteration of stored calibration values due to the fact that new values are not saved to non-volatile memory until the last step of each calibration procedure is complete.

Thermistor Calibration

The following procedure calibrates the 100 µA or 10 µA constant current sources so that thermistor resistance measurements will be accurate. This procedure does not calculate C1, C2, and C3. For information on calibrating the thermistor sensor, see Application Note #4 Thermistor Calibration and the Steinhart-Hart Equation.

The first part of the calibration is to determine an accurate value for the sensor current (10 µA or 100 µA). Thermistor resistance measurements require that the IC-V calibration procedure has been performed. The order in which the procedures are performed is not important.

1. Connect a DC ammeter to the sensor pins of the 15-pin output connector of the LDC-3726/3746 (pins 7 and 8) or the 25-pin output connector of the LDC-3736/37620 (pins 14 and 15). (Note: the current from the sensor pins should be less than 120 µA.)
2. Enter the sensor calibration mode by navigating to the “100 µA Cal” or “10 µA Cal” selection in the Sensor Cal area of the Calibration submenu of TEC parameter menu tree. Press the **SET** button to select the calibration, and then press the **TEC** button to start it.
3. Turn the ADJUST knob until the display indicates the same current measured by the DC ammeter.
4. Press the **TEC** button and wait for the 7-segment display to exit the calibration mode. Once the calibration is completed, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

IC-I (AD590 or equivalent) Sensor Calibration

The following procedure calibrates the IC-I sensor measurement so that the temperature measurement will be accurate. This procedure does not calibrate C1 and C2. For information on calibrating the IC-I sensor, see Appendix A.

This procedure uses internal components for its calibration. No external components are required. Accurate IC-I measurements require that the IC-V, the 100 µA thermistor, and the IC-I calibration procedures have been performed. The order in which these three procedures are performed is not important.

WARNING

For IC-Current sensors used with the LDC-3736 the 4-wire sensor measurements (pins 7 and 8) should not be connected. The use of the 4-wire sensor will cause inaccurate sensor measurements.

1. Enter the sensor calibration mode by navigating to the “ICI Cal” selection in the Sensor Cal area of the Calibration submenu of TEC parameter menu tree.
2. Select the “ICI Cal” selection by pressing the **SET** button, and then press the **TEC** button in order to enable the TEC output. This will initiate an auto-calibration.

3. Wait for the 7-segment display to exit the calibration mode. Once the calibration is completed, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

IC-V (LM335 or Equivalent) Sensor Calibration

The following procedure calibrates the IC-V sensor measurement so that the temperature measurement will be accurate. This procedure does not calibrate C1 and C2. For information on calibrating the IC-V sensor, see Appendix A.
This procedure is also required for the other sensor measurements. It only needs to be done once.

1. Connect a 5 kΩ (± 5%) metal film resistor and a precision voltmeter in parallel at the sensor feedback pins of the 15-pin output connector of the LDC-3726/3746 (pins 7 and 8) or the 25-pin output connector of the LDC-3736/37620 (pins 14 and 15).
2. Enter the sensor calibration mode by navigating to the “ICV Cal” selection in the Sensor Cal area of the Calibration submenu of TEC parameter menu tree.
3. Select “ICV Cal” by pressing the **SET** button, and then press the **TEC** button in order to enable the first sensor current.
4. Turn the ADJUST knob until the display indicates the same voltage as shown on the precision voltmeter.
5. Press the **TEC** button in order to enable the second sensor current.
6. Turn the ADJUST knob until the display indicates the same voltage as shown on the precision voltmeter.
7. Press the **TEC** button and wait for the 7-segment display to exit the calibration mode and reflect the entered sensor resistance setpoint. Once the calibration is completed, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

RTD Sensor Calibration

The following procedure calibrates the 1 mA and 2.5 mA RTD temperature sensors so that the resistance measurements will be accurate. This procedure does not calculate R_0, A, B and C. For information on calibrating the RTD sensor itself, see Application Note #4 Thermistor Calibration and the Steinhart-Hart Equation.

1 mA RTD

1. Measure and record the exact resistance of a 300 Ω and 1200 Ω metal film resistor. A 4-point probe resistance measurement is recommended.
2. Connect the 300 Ω resistor to the sensor pins of the 15-pin output connector of the LDC-3726/3746 (pins 7 and 8) or the 25-pin output connector of the LDC-3736/37620 (pins 14 and 15).
3. Enter the sensor calibration mode by navigating to the “RTD1mACal” selection in the Sensor Cal area of the Calibration submenu of TEC parameter menu tree.
4. Select the appropriate RTD calibration selection by pressing the **SET** button when the title for that calibration procedure is shown on the display, then press the **TEC** button in order to enable the sensor current.
5. Turn the ADJUST knob until the display indicates the same resistance you recorded for the 300 Ω resistor. Press the **TEC** button.
6. Connect the 1200 Ω resistor to the sensor pins.
7. Turn the ADJUST knob until the display indicates the same resistance you recorded for the 1200 Ω resistor. Press the **TEC** button.

8. Wait for the 7-segment display to exit the calibration mode and reflect the entered sensor resistance setpoint. Once the calibration is completed, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

2.5 mA RTD

1. Measure and record the exact resistance of a 60 Ω and 240 Ω metal film resistor. A 4-point probe resistance measurement is recommended.
2. Connect the 60 Ω resistor to the sensor pins of the 15-pin output connector of the LDC-3726/3746 (pins 7 and 8) or the 25-pin output connector of the LDC-3736/37620(pins 14 and 15).
3. Enter the sensor calibration mode by navigating to the “RTD2mACal” selection in the Sensor Cal area of the Calibration submenu of TEC parameter menu tree.
4. Select the appropriate RTD calibration selection by pressing the **SET** button when the title for that calibration procedure is shown on the display, then press the **TEC** button in order to enable the sensor current.
5. Turn the ADJUST knob until the display indicates the same resistance you recorded for the 60 Ω resistor. Press the **TEC** button.
6. Connect the 1200 Ω resistor to the sensor pins.
7. Turn the ADJUST knob until the display indicates the same resistance you recorded for the 240 Ω resistor. Press the **TEC** button.
8. Wait for the 7-segment display to exit the calibration mode and reflect the entered sensor resistance setpoint. Once the calibration is completed, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

ITE Current Calibration

The following procedure calibrates the ITE constant current source for both polarities of current. During this procedure the ITE current is driven to two pre-determined values. When each of these values is reached and is stable, the user enters the actual value of the current, as measured by an external DMM. The LDC-3736 Quantum Cascade Laser Controller then automatically calibrates the TEC current source and limits.

1. Measure and record the exact resistance of a 2 Ω, 150 W resistor. A 4-point probe resistance measurement is recommended.
2. Connect the 2 Ω, 150 W resistor across the TEC output terminals of the LDC-3726/3746 (pins 1 and 3) of the 15-pin connector or the LDC-3736/37620 (pins {9, 10, 21, 22} and {12, 13, 24, 25}) of the 25-pin connector.
3. Navigate to the “Ite Cal” selection in the Calibration submenu of TEC parameter menu tree.
4. Select the ITE calibration mode by pressing the **SET** button while the “Ite Cal” selection is displayed. Then, press the **TEC** button to start the calibration procedure. Calculate the actual current output by using Ohm's Law:

   $$I = V / R$$

   Where V is the accurately measured voltage across the resistor with a precision multimeter and R is the accurately measured load resistance. The first current should be approximately 1 or 2 A (positive).
5. Turn the ADJUST knob until the display shows the value of the ITE measurement as calculated from step 4. Then press the **TEC** button.
6. The instrument will apply a second current (approximately negative 1 or 2 A) after a short time. Repeat step 5 for the newly calculated current at this setpoint.
7. Wait for the 7-segment display to exit the calibration mode. Once the self-calibration is completed, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

TEC Voltage Measurement Calibration

The following procedure calibrates the TEC voltage measurement.

1. Calibrate the ITE current as described in the section above.
2. With the output off, connect a 2 Ω, 150 W resistor across the TEC output terminals of the LDC-3726/3746 (pins 1 and 3) of the 15-pin connector or the LDC-3736/37620 (pins {9, 10, 21, 22} and {12, 13, 24, 25}) of the 25-pin connector.
3. Connect a calibrated DMM across the load resistor. Navigate to the “Vte Cal” selection in the Calibration submenu of TEC parameter menu tree.
4. Enter the calibration mode by pressing the **SET** button while the “Vte Cal” selection is shown on the display. Then, press the **TEC** button to start the calibration process.
5. Measure the voltage using the DMM. Adjust the voltage shown on the lower display to match your measured voltage by turning the ADJUST knob. Then press the **TEC** button.
6. The instrument will apply a second current after a short time. Repeat step 6 for the new voltage measurement.
7. Wait for the 7-segment display to exit the calibration mode. Once the self-calibration is completed and calibration mode is exited, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

Laser Driver Current Calibration

The following procedure calibrates the laser constant current source for a single range and modulation state. This procedure will need to be performed for each combination of laser driver current range and modulation state. Since modulation state can be on or off, and there are three laser current ranges, this procedure may need to be performed up to 6 times to completely calibrate the system. If you do not intend to use any of the ranges or modulation states, you may calibrate only the combinations you intend to use. For example, if you do not intend to use modulation, you will only need to calibrate the three current ranges, 1 Amp, 2 Amp, and 4 Amp, once each. During the calibration procedure the current is driven to two pre-determined values. When each of these values is reached and is stable, the user enters the actual value of the current, as measured by an external DMM. The LDC-3736 then automatically calibrates the laser diode current source and limits.

1. Measure and record the exact resistance of a 1 Ω, 25 W resistor. A 4-point probe resistance measurement is recommended.
2. Connect the 1 Ω, 25 W resistor across the laser output terminals of the LDC-3736 instrument (pins {4, 5} and {8, 9}) on the 9-pin connector.
3. Navigate to the “LDI” selection in the Laser Calibration submenu of the laser parameter menu tree.
4. Select the LDI calibration mode by pressing the **SET** button while the “LDI” selection is displayed. Then, press the **LAS** button to start the calibration procedure. Calculate the actual current output by using Ohm's Law:

   $$I = V / R$$

   Where V is the accurately measured voltage across the resistor with a precision multimeter and R is the accurately measured load resistance.
5. Turn the ADJUST knob until the display shows the value of the laser current measurement as calculated from step 4. Then press the **LAS** button.
6. The instrument will apply a new current after a short time. Repeat step 5 for the second current.
7. Wait for the 7-segment display to exit the calibration mode. Once the self-calibration is completed, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

Laser Voltage Measurement Calibration

The following procedure calibrates the Laser voltage measurement. It only needs to be done once: the range and modulation selections are not important to the voltage calibration.

1. Calibrate the laser current as described in the section above.
2. Connect the 4.5 Ω, 100 W resistor across the laser output terminals of the LDC-3736 instrument (pins {4, 5} and {8, 9}) on the 9-pin connector.
3. Connect a calibrated DMM across the load resistor. Navigate to the “LDV” selection in the Laser Calibration submenu of laser parameter menu tree.
4. Enter the calibration mode by pressing the **SET** button while the “LDV” selection is shown on the display. Then, press the **LAS** button to start the calibration process.
5. Measure the voltage using the DMM. Adjust the voltage shown on the lower display to the match your measured voltage by turning the ADJUST knob. Then press the **LAS** button.
6. The instrument will apply a second current after a short time. Repeat step 5 for the second current.

7. Once the self-calibration is completed and calibration mode is exited, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

Photodiode Current Calibration

1. Setup an optocoupler with a forward emitter current of 40 mA or greater and a maximum collector output current of 10 mA or less in a current divider circuit, with the emitter in series with a 100 Ω resistor and with a 1 Ω, 25 W resistor in parallel across the 100 Ω resistor and optocoupler.
2. Connect this circuit across the laser output terminals of the LDC-3736 instrument (pins {4, 5} and {8, 9}) on the 9-pin connector.
3. Measure and record the exact resistance of a 1 Ω metal film resistor. A 4-point probe resistance measurement is recommended
4. Connect the 1 Ohm metal film resistor to the emitter of the optocoupler detector and connect the photodiode cathode and anode input terminals of the LDC-3736 instrument (pins 6 and 7 of the 9-pin connector) to the free end of the 1 Ohm metal film resistor and to the collector of the optocoupler detector, respectively. Connect a calibrated DMM in parallel across the 1 Ohm metal film resistor to measure the voltage across this resistor.
5. Select constant-power mode operation. Set the Power Limit to its maximum.
6. Navigate to the “MDI” selection in the Laser Calibration submenu of laser parameter menu tree.
7. Select the MDI calibration mode by pressing the **SET** button while the “MDI” selection is displayed. Then, press the **LAS** button to start the calibration procedure. Wait for the photodiode current to ramp up and settle, then calculate the actual photodiode current output by using Ohm's Law:

   $$I = V / R$$

   Where V is the accurately measured voltage across the resistor with a precision multimeter and R is the accurately measured load resistance.
8. Turn the ADJUST knob until the display shows the value of the photodiode current measurement as calculated from step 6. Then press the **LAS** button.
9. The instrument will ramp to a new setpoint. Repeat step 7 for the newly calculated photodiode current at this setpoint.
10. Wait for the 7-segment display to exit the calibration mode. Once the self-calibration is completed, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

Appendix A:
AD590 and LM335 Sensor Calibration

The LDC-3736 Quantum Cascade Laser Controller uses two constants (slope and offset) for calibrating linear IC thermal sensing devices, such as the AD590, and the LM335. Offset is used as the linear or zero offset value, and the slope is used as the slope or gain adjustment. Therefore, when accuracy is not critical, offset should be set to a nominal value of 0, and slope should be set to a nominal value of 1 when the selected sensor is an IC-I or set to a nominal value of 10 when the selected sensor is an IC-V.

In order to calibrate an IC sensor device, the sensor must be operated at an accurately known, stable temperature. For example, the sensor may be calibrated at 0 °C if the sensor is placed in ice water until its temperature is stable. A highly accurate temperature probe, thermometer, environmental chamber, etc., may also be used to determine the known temperature for calibration. This appendix contains one and two point calibration methods for IC sensor devices. These methods will work for either type of device.

AD590 Sensor

The AD590 is a linear IC thermal sensor which acts as a constant current regulator. It produces a current, I, which is directly proportional to absolute temperature, over its useful range (-50 °C to +150 °C). This nominal value can be expressed as:

$I = 1\ \mu A / K$

Where I is the nominal current produced by the AD590, and K is the temperature in Kelvin.

The LDC-3736 uses current to determine the nominal temperature, T_n, by the formula:

$T_n = (I / (1\ \mu A / K)) - 273.15$

Where T_n is in °C.

The temperature, T_d, which is displayed by the LDC-3736 instrument, is first calibrated as follows:

$T_d = C1 + (C2 * T_n)$

Where offset and slope are the constants stored by the user in the LDC-3736 Series instrument for the AD590.

The AD590 measurement is calibrated, at the factory, with C2 = 1 and C1 = 0 (nominal values). The AD590 grades of tolerance vary, but typically this means that without adjusting C1 or C2, the temperature accuracy is ±1 °C over its rated operating range. If C1 and C2 are also calibrated, the temperature accuracy is ±0.2 °C over its rated operating range. However, the AD590 is not perfectly linear, and even with C1 accurately known there is a non-linear absolute temperature error associated with the device. This non-linearity is shown in Figure A.1, reprinted from Analog Devices specifications, where the error associated with C1 is assumed to be zero.

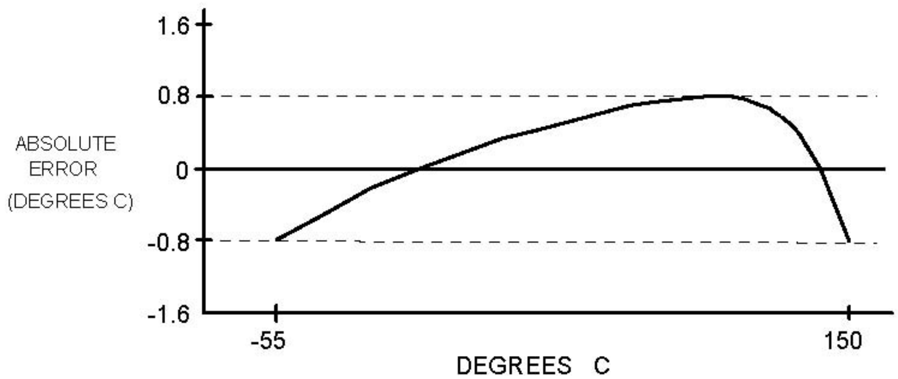

Figure A.1 – Non Linearity Graph

If a maximum absolute error of 0.8 °C is tolerable (over the entire temperature range), the one point calibration of C1 should be used. If C1 is calibrated at 25 °C, and the intended operating range is 0 to 50 °C, a maximum error of about ±0.2°C may be expected over that operating range. If a greater accuracy is desired, the two point method of determining C1 and C2 should be used. Note however, the absolute error curve is non-linear; therefore, the constant C2 will vary over different temperature ranges.

LM335 Sensor

The LM335 is a linear thermal sensor which acts as a constant voltage regulator. It produces a voltage, V, which is directly proportional to absolute temperature, over its useful range (-40 °C to +100 °C). This nominal value can be expressed as:

V = 10 mV / K

Where V is the nominal voltage produced by the LM335 and K is the temperature in Kelvin.

The LDC-3706 Series instruments use V to determine the nominal temperature, T_n, by the formula: $T_n = (V / (10mV / K)) - 273.15$

Where T_n is measured in °C.

The temperature, T_d, which is displayed by the LDC-3736 instrument, is first calibrated as follows: $T_d = C1 + (C2 / 10.0 * T_n)$

Where C1 and C2 are the constants stored by the user in the LDC-3736 instrument for the LM335.

When the LDC-3736 instrument is shipped from the factory, the LM335 measurement system is calibrated, but the sensor (C1 and C2) is not. Nominally, C1 = 0, and C2 = 10. In that case, the temperature accuracy is typically ±1 °C over the rated operating range. With C1 and C2 calibrated also, the temperature accuracy is typically ±0.3 °C over the rated operating range. The temperature accuracy may be improved over a narrow temperature range by a two-point calibration of C1 and C2. However, the LM335 is not perfectly linear, and even with C1 accurately known (and C2 uncalibrated) there is a non-linear absolute temperature error associated with the device. This non-linearity caused error is typically ±0.3 °C, with the error associated with C1 assumed to be zero.

If a maximum absolute error of ±1 °C is tolerable, no calibration of C1 or C2 is required, just set C1 = 0, C2 = 1. If a maximum absolute error of ±0.5 °C is tolerable, the one point calibration of C1 may be used (see page C-5). If a greater accuracy is desired, the two point method of determining C1 and C2 should be used (see page C-6). Note however, the absolute error associated with the constant C2 may vary over different temperature ranges.

One Point Calibration Method

This procedure will work for any linear IC temperature sensor. The accuracy of this procedure depends on the accuracy of the known temperature, externally measured. It is used to determine the zero offset of the device, and it assumes that the gain offset (slope) is known and is correct.

1. Allow the LDC-3736 to warm-up for at least one hour. Set the sensor to the desired sensor type, and RECALL the constants for the particular device to be calibrated.

2. Select the C1 parameter. Read and record the value of C1.

3. Place the sensor at an accurately known and stable temperature, Ta. Connect the sensor to pins 14 and 15 of the LDC-3736 25-pin connector. Set the LDC-3736 for normal constant temperature (T mode) operation. Allow the LDC-3736 to stabilize at the known temperature, Ta and read the displayed temperature, Td.

4. Determine the new value of the offset, offset-new, from the formula:

   Offset – New = Previous Offset Value + Ta – Td

   and replace the previous offset value with the newly calculated value by selecting the offset parameter and entering the offset-new value.

Two Point Calibration Method

This procedure will work for any linear IC temperature sensor. The accuracy of this procedure depends on the accuracy of the known temperatures, externally measured. It is used to determine the zero offset of the device and the gain offset (slope).

1. Allow the LDC-3736 to warm-up for at least one hour. Set the sensor to the desired sensor type, and RECALL the constants for the particular device to be calibrated.

2. Select the C1 parameter. Read and record the value of C1. Select the C2 parameter. Read and record the value of C2.

3. Place the sensor at an accurately known and stable temperature, Ta1. Connect the sensor to pins 7 and 8 of the LDC-3726/3746 15-pin connector or to pins 14 and 15 of the LDC-3736/37620 25-pin connector. Set the LDC-3706 Series instrument for normal constant temperature (T mode) operation. Allow the LDC-3706 Series instrument to stabilize at the known temperature, Ta1 and read the displayed temperature, T_{d1}. Record these values.

4. Repeat Step 3 for another known temperature, T_{a2}, and the corresponding displayed temperature, T_{d2}. The two known temperatures should at the bounds of the intended operating range. The smaller of the two is intended operating range, the better the calibration over that same range.

5. Determine the new value of C1 ($C1_n$) and C2 ($C2_n$) from the following calculations. First determine the intermediate values U and V, where $V = (T_{a1} - T_{a2}) / (T_{d1} - T_{d2})$, and $U = T_{a1} - (T_{d1} * V)$

   Then $C1_n$ and $C2_n$ can be determined by the following:

   $C1_n = U + (V * C1)$ and $C2_n = V * C2$

6. Replace C1 with $C1_n$ by selecting the C1 parameter and entering the new $C1_n$ value. Replace C2 with $C2_n$ by selecting the C2 parameter and entering the new $C2_n$ value.

Appendix B: Auto-Tune Method

The LDC-3736 Quantum Cascade Laser Controller currently uses a single auto-tune method. The auto-tune algorithm will calculate a thermal system's appropriate PID coefficients through a mathematical PID analysis process. The figure and text below describe the tuning process.

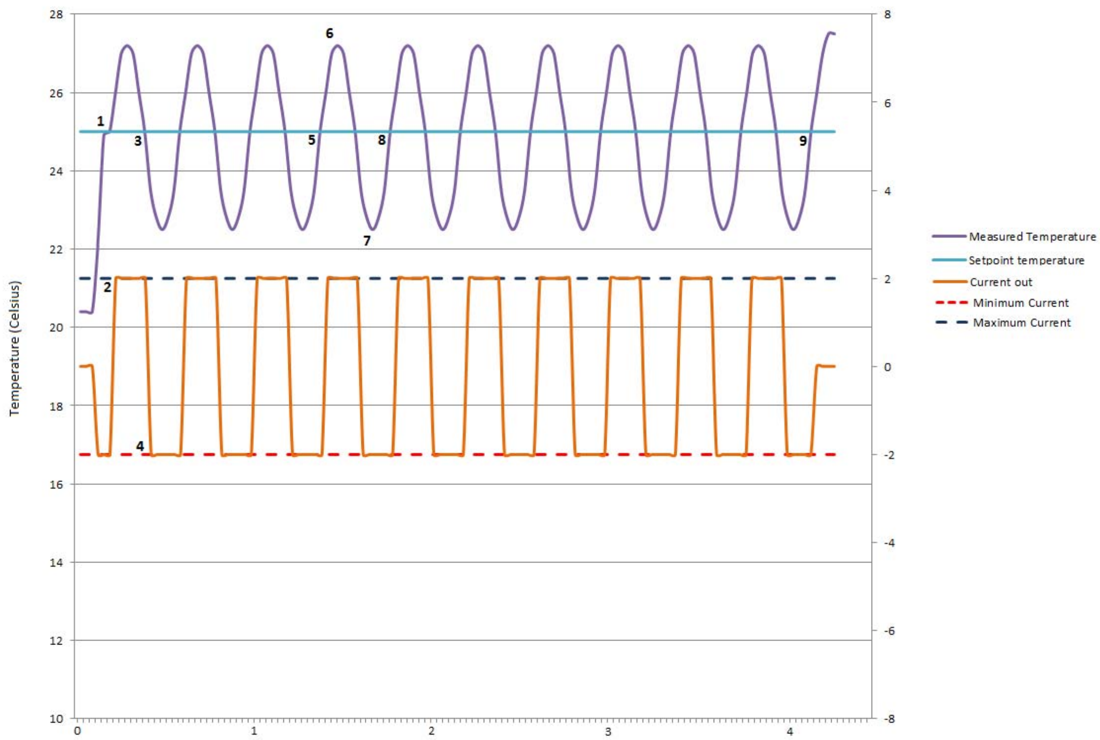

Figure B.1 – Tuning Process

The autotune procedure requires a temperature or resistance setpoint, a maximum TEC current, and a minimum TEC current value to be entered in order to begin. The setpoint is set using the front panel adjust section to set the TEC setpoint to the desired value. The maximum and minimum TEC current are set by setting the I+ and I- values through the limits submenu of the TEC parameter menu. In the example shown, a temperature setpoint above ambient is entered, and maximum and minimum TEC current values are set to +2.0 and -2.0 Amps, respectively. When autotune is started by the user, the instrument will set the current to the minimum TEC current level, which causes the maximum possible rate of heating. When the instrument detects that the temperature has reached the temperature setpoint value (Point 1 on graph), the PID calculation procedure begins.

During autotune, anytime the actual temperature exceeds the setpoint temperature, the current is set to the maximum TEC current value, which causes the maximum possible rate of cooling. This is seen on the graph at point 1 and point 2. When the temperature exceeds the setpoint temperature at point1, the current immediately switches to the maximum value, as seen at point 2. Eventually, the temperature setpoint will fall below the setpoint temperature, and the current will be set to the minimum current value, which causes the maximum possible rate of heating. This is seen on the graph at point 3 and point 4. When the temperature falls below the setpoint temperature at point 3, the current immediately switches to the minimum value, as seen at point 4. This cycling of current from heating to cooling occurs 10 times during an autotune procedure. This is why there are 10 cycles shown between point1 and point 9 on the graph.

After the first three cycles have been completed (point 5 on the graph), the autotune procedure begins to record the information needed to determine the PID values. The information needed is the time it takes for a heating and cooling cycle to complete, the maximum temperature reached during a cycle, and the minimum temperature reached during a cycle. For the fourth cycle in the graph above, shown between point 5 and point 8, the time from point 5 to point 8 will be recorded to get a cycle period measurement. The maximum temperature (point 6 on the graph) and minimum temperature (point 7 on the graph) will also be recorded. These three values will be recorded for the last 7 cycles of the procedure. After 10 total cycles are completed (point 9 on the graph), the output is disabled and the PID values are calculated.

To calculate the PID values, first the measured amplitude of the cycle is calculated by taking the maximum measured temperature minus the minimum measured temperature for each cycle. Then, the average of the seven measured amplitudes and the seven measured cycle periods will be calculated. Using these averages and the maximum and minimum TEC current settings, the PID values are calculated as follows:

Driving Amplitude = (maximum TEC current – minimum TEC current)
Amplitude Ratio = (4 * Driving Amplitude) / (π * Average Measured Amplitude)
P = 0.6 * Amplitude Ratio
I = 1.0 / (Average Period / 2.0)
D = Average Period / 32.0

The PID values are then saved into the manual PID values and the instrument is ready to control to the given setpoint. The PID tuning process typically takes 5 to 10 minutes. The PID values will be appropriate to control to set points near the setpoint used during the procedure under similar conditions to those that occurred during the autotune procedure. These values can be altered through the manual PID setting section of the front panel or through remote commands to fine tune performance or to adjust for different set points and operating conditions.