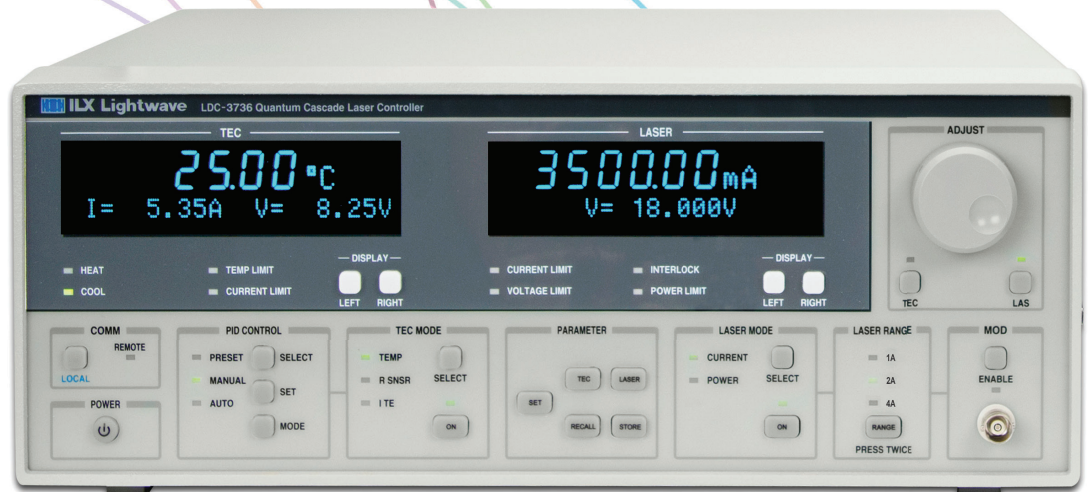


# User's Guide

## Laser Diode Controller LDC-3706 Series



**Newport Corporation**  
31950 Frontage Road Bozeman, MT, USA

PHONE: 1-800-459-9459 1-406-556-2481 FAX: 1-406-586-9405 EMAIL: sales@ixlightwave.com  
Complete listings for all global office locations are available online at [www.newport.com/contact](http://www.newport.com/contact)

[www.newport.com](http://www.newport.com)

Newport Corporation, Irvine and Santa Clara, California and Franklin, Massachusetts; Evry and Beaune-La-Rolande, France; Stahnsdorf, Germany and Wuxi, China have all been certified compliant with ISO 9001 by the British Standards Institution.



# Table of Contents

Safety Information and the Manual.....	v
General Safety Considerations.....	v
Safety Symbols.....	vi
Safety Marking Symbols.....	vii
Warranty.....	vii
Limitations.....	vii
Returning an Instrument.....	viii
Claims for Shipping Damage.....	viii
Comments, Suggestions, and Problems.....	ix
Chapter 1: Introduction and Specifications.....	1
Safety Considerations.....	1
Initial Inspection.....	1
Shipping Kit.....	1
Product Overview.....	2
Options and Accessories.....	5
LDC-3706 Specifications.....	6
Chapter 2: General Operation.....	11
Grounding Requirements.....	11
AC Line Power Requirements.....	11
The Power Up Sequence.....	12
Firmware Upgradeability.....	12
GPIB Communication.....	13
USB Communication.....	13
Tilt Foot Adjustment.....	13
Rack Mounting.....	13
Connections.....	14
Connecting to the Laser Controller.....	17
Front Panel Operation.....	19
Power On / Off.....	19

Adjust Knob and Enable Button .....	19
Parameters Setup.....	20
PID Temperature Control .....	21
Temperature Control Mode .....	23
Laser Current Source Setup.....	23
Current Control Mode.....	25
Display .....	25
Error Indicators .....	26
<b>General Operating Procedures.....</b>	<b>26</b>
Warm-Up and Environmental Considerations.....	26
<b>Operating the Laser Current Source from the Front Panel .....</b>	<b>27</b>
Using the LDC-3706 Controller's Trigger Output Function .....	30
<b>Operating the Temperature Controller from the Front Panel .....</b>	<b>31</b>
General Guidelines for Sensor Selection and Safety Limits .....	31
Sensor Options.....	31
Safety Limits .....	35
<b>Constant Temperature Mode Operation .....</b>	<b>36</b>
<b>Constant Sensor Mode Operation .....</b>	<b>37</b>
<b>Constant Current Mode Operation.....</b>	<b>38</b>
<b>Resistive Heater Mode Operation.....</b>	<b>39</b>
<b>Chapter 3: Remote Operation .....</b>	<b>41</b>
<b>GPIB Address.....</b>	<b>41</b>
<b>Basic GPIB Concepts .....</b>	<b>41</b>
Data and Interface Messages .....	41
Talkers, Listeners, and Controllers.....	42
GPIB Cable Connections .....	42
The GPIB Connector .....	43
Reading the GPIB Address .....	44
Changing the GPIB Address .....	44
<b>Basic USB Concepts .....</b>	<b>44</b>
<b>Changing Between Local and Remote Operation.....</b>	<b>45</b>
<b>GPIB vs. USB Communication .....</b>	<b>45</b>
<b>Command Syntax .....</b>	<b>45</b>
Letters.....	45
White Space .....	46
Terminators .....	46
Command Separators .....	46
Parameters .....	46

Syntax Summary .....	48
IEEE 488.2 Common Commands.....	49
Command Timing .....	50
Sequential / Overlapped Commands.....	51
Query Response Timing.....	51
<b>Chapter 4: Command Reference .....</b>	<b>53</b>
Remote Command Reference Summary.....	53
Command Reference .....	63
<b>Chapter 5: Troubleshooting and Calibration .....</b>	<b>90</b>
Troubleshooting Guide .....	91
Error Messages .....	95
Error Code Tables .....	95
Calibration Overview .....	97
Recommended Equipment.....	97
Environmental Conditions .....	97
Warm-up.....	98
Calibration Adjustments .....	98
Thermistor Calibration .....	98
IC-I (AD590 or equivalent) Sensor Calibration.....	99
IC-V (LM335 or Equivalent) Sensor Calibration .....	99
RTD Sensor Calibration .....	100
ITE Current Calibration.....	101
TEC Voltage Measurement Calibration.....	101
Laser Driver Current Calibration.....	102
Laser Voltage Measurement Calibration .....	103
Photodiode Current Calibration .....	104
<b>Appendix A: AD590 and LM335 Sensor Calibration .....</b>	<b>107</b>
AD590 Sensor .....	107
LM335 Sensor .....	108
One Point Calibration Method.....	109
Two Point Calibration Method.....	1100
<b>Appendix B: Auto-Tune Method.....</b>	<b>111</b>

# List of Figures

Figure 1.1 – LDC-3726 Front Panel.....	2
Figure 1.2 – LDC-3726 Rear Panel .....	2
Figure 1.3 – LDC-3736 Front Panel.....	3
Figure 1.4 – LDC-3736 Rear Panel .....	3
Figure 1.5 – LDC-37620 Front Panel.....	4
Figure 1.6 – LDC-37620 Rear Panel .....	4
Figure 2.1 - Laser Diode Connection Configurations.....	17
Figure 2.2 – Front Panel Display .....	19
Figure 2.3a – The Setpoint Current .....	25
Figure 2.3b – The Measured Current.....	25
Figure 2.4 - Example Thermistor Resistance vs. Temperature .....	32
Figure 3.1 – GPIB Cable Connection.....	42
Figure 3.2 – GPIB Connector.....	43
Figure 3.3 – Common Command Diagrams .....	49
Figure 3.4 – Status Reporting Scheme .....	50
Figure 5.1 – I <sub>PD</sub> Calibration Circuit .....	104
Figure A.1 – Non Linearity Graph .....	108
Figure B.1 – Tuning Process.....	111

# Safety and Warranty Information

---

- ✓ Details about cautionary symbols
- ✓ Safety markings used on the instrument
- ✓ Information about the warranty
- ✓ Customer service contact information

## Safety Information and the Manual

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



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



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

## 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 an 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  $\pm 10\%$  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  $10\text{ }^{\circ}\text{C}$  to  $40\text{ }^{\circ}\text{C}$
- Storage and transportation temperature of  $-40\text{ }^{\circ}\text{C}$  to  $70\text{ }^{\circ}\text{C}$
- 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.



Caution, refer to manual



Earth ground Terminal



Alternating current



Visible and/or invisible laser radiation



Caution, risk of electric shock



Protective Conductor Terminal



Caution, hot surface



Frame or chassis terminal

## 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 the shipment be insured.
- If the original shipping container is not available, place the 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 the instrument is received, 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 a quotation for estimated costs of repair. The user must negotiate and settle with the carrier for the amount of damage.

## Comments, Suggestions, and Problems

To ensure that the user gets the most out of ILX Lightwave products, ILX Lightwave asks that any product operation or service related questions or comments be directed to ILX Lightwave Customer Support.

ILX Lightwave may be contacted in whatever way is most convenient:

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

Fax (406) 586-9405

E-mail [sales@newport.com](mailto:sales@newport.com)

Or mail to:

MKS / Newport

31950 East Frontage Road

Bozeman, Montana, U.S.A 59715

[www.newport.com/b/ilx-lightwave](http://www.newport.com/b/ilx-lightwave)

When contacting ILX Lightwave, 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, a Return Merchandise Authorization (RMA) number will be issued. Please mark this number on the outside of the shipping box.

The user or the user's shipping service is responsible for any shipping damage when returning the instrument to ILX Lightwave; ILX recommends the shipment be insured. If the original shipping container is not available, place the 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-3706 Laser Controllers and contains unpacking information, instructions on how to install and apply power, maintenance information, specifications and listings of the LDC-3706 instrument 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-3706 from service. Do not use the LDC-3706 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-3706 instrument to ILX Lightwave for service and repair to ensure that safety features are maintained.**

## Initial Inspection

When the LDC-3706 Laser Controller is received, verify that the following items were shipped with the instrument:

- Power Cord
- Shipping Kit
- LNF-320 Low Noise Filter (LDC-3736 only)
- 50-Ohm BNC terminator (LDC-37620 only)

## Shipping Kit

The shipping kit for the LDC-3706 instrument includes a USB A/B cable and a USB Flash Drive containing the ILX Lightwave USB Driver, and product manual.

## Product Overview

The LDC-3706 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-3706 instrument'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-3726 Front Panel



Figure 1.2 – LDC-3726 Rear Panel



Figure 1.3 – LDC-3736 Front Panel



Figure 1.4 – LDC-3736 Rear Panel



Figure 1.5 – LDC-37620 Front Panel



Figure 1.6 – LDC-37620 Rear Panel



## Options and Accessories

Options and accessories available for LDC-3706 Laser Controllers include the following:

	DESCRIPTION	MODEL / PART NUMBER	COMPATABLE WITH		
			LDC-3726	LDC-3736	LDC-37620
	Single Rack Mount Kit, 37X6	RM-146	✓	✓	✓
	Calibrated 10kΩ Thermistor	TS-510	✓	✓	✓
Cables	Current Source to Laser Mount Cable, 6 Amp, 7W2 to DB9	CC-305H	✓	✓	
	Current Source to Laser Mount Cable, 5 Amp, DB9 to DB9	CC-305S	✓	✓	
	Current Source Cable, 5 Amp, DB9 to Bare Wire	CC-306S	✓	✓	
	Current Source to Laser Mount Cable, 20 Amp, 9W4 to 7W2	CC-308H			✓
	Current Source to Laser Mount Cable, 40 Amp, 9W4 to 7W2	CC-320			✓
	Laser Current Source Cable, 40 Amp, 9W4 to Copper/Crown	CC-340			✓
	TEC Controller to Laser Mount Cable, 6 Amp, DB15 to 7W2	CC-501HT	✓		
	TEC Controller to Laser Mount Cable, 5 Amp, DB15 to DB9	CC-505S	✓		
	TEC Controller Cable, Fan Wires, 10 Amp, DB25 to Unterminated	CC-594H		✓	✓
	TEC Controller to Laser Mount Cable, 5 Amp, DB25 to DB9	CC-595S		✓	
	TEC Controller to Laser Mount Interconnect, 10 Amp, DB25 to 7W2	CC-596H		✓	✓
	Temperature Controller Cable, 300B Series, DB15 Male to DB15 Female	500-04	✓		
	Laser Diode Driver Cable, DB9 Male to DB9 Female	300-04	✓		
	<b>Laser Diode Mounting Fixtures</b>				
QCL	Mounting Fixture, C-mount <sup>1</sup>	LDM-487201	✓	✓	
	Mounting Fixture, Alpes COC <sup>1</sup> Mount	LDM-487202	✓	✓	
Low Power	TO-Can Laser Diode Mount	LDM-4405	✓	✓	
	TO-Can Laser Diode Mount (Compact)	LDM-4990	✓	✓	
	DIL Laser Diode Mount	LDM-4982	✓	✓	
	13-Pin Butterfly Laser Diode Mount	LDM-4983	✓	✓	
	14-Pin Butterfly Laser Diode Mount	LDM-4984	✓	✓	
	Connectorized Flanged TO Can Mount	LDM-4986	✓	✓	
	26-Pin Butterfly Laser Diode Mount	LDM-4989	✓	✓	
	Laser Diode Mount, TO-9, TO-56, Pigtailed	710	✓		
High Power	C-Mount Laser Diode Mount	LDM-4409	✓	✓	✓
	CS Bar Laser Diode Mount	LDM-4415			
	Laser Diode, TO-3 and HHL Mount	LDM-4442	✓		
	Butterfly Laser Diode Mount	LDM-49840	✓	✓	✓
	2-Pin Module Laser Diode Mount	LDM-49860	✓	✓	✓

1. See Chapter 2, TEC Connections.

# LDC-3706 Specifications

## LASER CURRENT SOURCE

### LDC-3726

#### DRIVE CURRENT OUTPUT <sup>1</sup>

Output Current Range:	0–100mA	0–200mA	0–500mA
Setpoint Resolution (Display):	0.001mA	0.01mA	0.01mA
Setpoint Resolution (Remote): <sup>12</sup>	2µA	4µA	10µA
Setpoint Accuracy (Unmodulated): <sup>14</sup> (Modulated 3726 Only):	±(0.025% of SP ± 0.01% of FS) ±(0.19% FS - 0.155% SP)	±(0.025% of SP ± 0.01% of FS) ±(0.19% FS - 0.155% SP)	±(0.025% of SP ± 0.01% of FS) ±(0.19% FS - 0.155% SP)

Compliance Voltage:	0–10V adjustable	0–10V adjustable	0–10V adjustable
Temperature Coefficient:	<50ppm/°C	<50ppm/°C	<50ppm/°C
Short-Term Stability (one-hour): <sup>2</sup>	<20ppm	<20ppm	<20ppm
Long-Term Stability (24-hour): <sup>3</sup>	<40ppm	<40ppm	<40ppm
Noise and Ripple (rms) <sup>4</sup>			
High Bandwidth Mode (rms):	10µA	10µA	10µA
Low Bandwidth Mode (with LNF-320):	1.5µA	2µA	2µA
Transients			
Operational: <sup>5</sup>	<2mA	<3mA	<3mA
1 kV EFT/Surge: <sup>6</sup>	<20mA/<30mA	<20mA/<30mA	<20mA/<30mA

#### COMPLIANCE VOLTAGE LIMIT ADJUST

Range:	0–11V	0–11V	0–11V
Setpoint Resolution (Display):	0.1V	0.1V	0.1V
Setpoint Resolution (Remote):	50mV	50mV	50mV
Accuracy:	±0.1% FS	±0.1% FS	±0.1% FS

#### DRIVE CURRENT LIMIT SETTINGS

Range:	1–101mA	1–202mA	1–505mA
Resolution:	0.5mA	1mA	2.5mA
Accuracy:	±(0.3% of SP + 0.25 mA)	±(0.3% of SP + 0.25 mA)	±(0.3% of SP + 0.25 mA)

#### PHOTODIODE FEEDBACK

Type:	Differential	Differential	Differential
Photodiode Reverse Bias:	0–5V adjustable	0–5V adjustable	0–5V adjustable
Photodiode Current Range:	5 to 5000µA	5 to 5000µA	5–5000µA
Output Stability: <sup>7</sup>	±0.02% of SP	±0.02% of SP	±0.02% of SP
Setpoint Accuracy:	±1.5µA	±1.5µA	±1.5µA

#### EXTERNAL ANALOG MODULATION

Input:	0–10V, 1 kΩ	0–10V, 1 kΩ	0–10V, 1 kΩ
Transfer Function:	10mA/V	20mA/V	50mA/V
Bandwidth (3dB)			
High Bandwidth: <sup>8,13</sup>	DC to 1MHz	DC to 1MHz	DC to 1MHz
Low Bandwidth: <sup>9</sup>	DC to 15kHz	DC to 15kHz	DC to 15kHz

#### TRIGGER OUTPUT

Type:	TTL	TTL	TTL
Pulse Width:	13 µs	13 µs	13 µs
Delay:	12 ms	12 ms	12 ms

#### MEASUREMENT (DISPLAY)

Output Current			
Range:	0–100.0mA	0–200.0mA	0–500mA
Resolution:	0.002mA	0.01mA	0.01mA
Accuracy:	±0.05% FS	±0.05% FS	±0.05% FS
Photodiode Current			
Range:	0–5000µA	0–5000µA	0–5000µA
Resolution:	1µA	1µA	1µA
Accuracy:	±2µA	±2µA	±2µA
Photodiode Responsivity <sup>10</sup>			
Range (µA/mW):	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):	0.00–100.00	0.00–500.00	0.00–500.00
Resolution:	0.01mW	0.01mW	0.01mW
Forward Voltage			
Range:	0.000–10.000V	0.000–10.000V	0.000–10.000V
Resolution:	1mV	1mV	1mV
Accuracy: <sup>11</sup>	±2mV	±2mV	±2mV

## GENERAL

I/O Connectors	Female, 15-pin, D-sub
TEC I/O:	BNC
Analog Input:	BNC
Remote Interface:	GPIO IEEE 488.1; USB 2.0 (B-Type)
Power Requirements <sup>A</sup>	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:	22.8 lbs.; 10.34 kg.
Operating Temperature:	10°C to 40°C
Storage Temperature:	-30°C to 70°C
Humidity:	<85% relative, non-condensing
Compliance:	CE

A Output De-Rating = 3.7 mA/V below 103VAC to 90 VAC

## CURRENT SOURCE NOTES

- <sup>1</sup> All values relate to a one-hour warm-up period.
- <sup>2</sup> Over any one-hour period, half-scale output.
- <sup>3</sup> Over any 24-hour period, half-scale output.
- <sup>4</sup> Measured electrically with a frequency range of 100Hz to 340kHz (High Bandwidth), 100Hz to 17kHz (Low Bandwidth).
- <sup>5</sup> 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 condition it is recommend setting both the current and voltage limit just above typical operating conditions and enabling the TEC output prior to the laser current output.
- <sup>6</sup> Maximum output current transient resulting from a 1000V power line transient spike. Tested to ILX Technical Standard #LDC-00196; request ILX App Note #13.
- <sup>7</sup> Maximum monitor photodiode current drift over any 30 minute period. Assumes zero drift in responsivity of photodiode.
- <sup>8</sup> 50% modulation at mid-scale output. Higher bandwidth is possible with smaller modulation signal.
- <sup>9</sup> Small signal specification is for typical 10% modulation depth. Large signal specification assumes 50% modulation depth at mid-scale output.
- <sup>10</sup> Responsivity value is user-defined and is used to calculate the optical power.
- <sup>11</sup> Four wire voltage measurement at the load. Voltage measurement accuracy while driving calibration load. Accuracy is dependent upon load and cable used.
- <sup>12</sup> Based on resolution of digital to analog converters used in circuit.
- <sup>13</sup> 3726 high bandwidth achieved with load impedances less than 4 ohms.
- <sup>14</sup> Under factory testing conditions. Single resistance test load.

# LASER CURRENT SOURCE

## LDC-3736

## LDC-37620

### DRIVE CURRENT OUTPUT <sup>1</sup>

Output Current Range:	0–1000mA	0–2000mA	0–4000mA	0–10A	0–20A
Setpoint Resolution (Display):	0.1mA	0.1mA	0.1mA	1mA	1mA
Setpoint Resolution (Remote): <sup>12</sup>	20µA	40µA	80µA	1mA	1mA
Setpoint Accuracy (% of FS):	±0.15% of SP ± 1mA	±0.15% of SP ± 1mA	±0.15% of SP ± 1mA	±0.1% ± 10mA	±0.1% ± 10mA
Compliance Voltage:	0–18V adjustable	0–18V adjustable	0–18V adjustable	0 – 4V adjustable	0 – 4V adjustable
Temperature Coefficient:	<50ppm/°C	<50ppm/°C	<50ppm/°C	<50ppm/°C	<50ppm/°C
Short-Term Stability (one-hour): <sup>2</sup>	<20ppm	<20ppm	<20ppm	<50ppm	<50ppm
Long-Term Stability (24-hour): <sup>3</sup>	<40ppm	<40ppm	<40ppm	<100ppm	<100ppm
Noise and Ripple (rms) <sup>4</sup>					
High Bandwidth Mode (rms):	30µA	60µA	100µA	<5mA	<7mA
Low Bandwidth Mode (rms):	30µA	50µA	90µA	<5mA	<7mA
Low Bandwidth Mode (with LNF-320):	10µA	15µA	50µA	N/A	N/A
Transients					
Operational: <sup>5</sup>	<4mA	<4mA	<4mA	<25mA	<25mA
1 kV EFT/Surge: <sup>6</sup>	<15mA/<8mA	<15mA/<8mA	<15mA/<8mA	<80mA / <150 mA	<80mA / <150 mA

### COMPLIANCE VOLTAGE LIMIT ADJUST

Range:	0–19.8V	0–19.8V	0–19.8V	0 – 4.4V	0 – 4.4V
Setpoint Resolution (Display):	0.1V	0.1V	0.1V	0.1V	0.1V
Setpoint Resolution (Remote):	60mV	60mV	60mV	15mV	15mV
Accuracy:	±2.5% FS	±2.5% FS	±2.5% FS	±2.5% FS	±2.5% FS

### DRIVE CURRENT LIMIT SETTINGS

Range:	1–1010mA	1–2020mA	1–4040mA	0 - 10.1A	0 - 20.2A
Resolution:	5mA	10mA	20mA	100mA	100mA
Accuracy:	±10mA	±20mA	±40mA	±101mA	±202mA

### PHOTODIODE FEEDBACK

Type:	Differential	Differential	Differential	Differential	Differential
Photodiode Reverse Bias:	0–5V adjustable	0–5V adjustable	0–5V adjustable	0 – 5V adjustable	0 – 5V adjustable
Photodiode Current Range:	5 to 10000µA	5 to 10000µA	5–10000µA	5 to 10000µA	5 to 10000µA
Output Stability: <sup>7</sup>	0.02% of SP	0.02% of SP	0.02% of SP	0.02% of SP	0.02% of SP
Setpoint Accuracy:	±0.05% of FS	±0.05% of FS	±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	0 – 10V, 1 kΩ	0 – 10V, 1 kΩ
Transfer Function:	100mA/V	200mA/V	400mA/V	1A/V	2A/V
Bandwidth (3dB)					
High Bandwidth: <sup>8</sup>	DC to 250 kHz	DC to 250 kHz	DC to 250 kHz	DC to 100kHz	DC to 100kHz
Low Bandwidth: <sup>9</sup>	DC to 17 kHz	DC to 17 kHz	DC to 17 kHz	DC to 10kHz	DC to 10kHz

### TRIGGER OUTPUT

Type:	TTL	TTL	TTL	TTL	TTL
Pulse Width:	10 µs	10 µs	10 µs	13 µs	13 µs
Delay:	2.5 mS	2.5 mS	2.5 mS	2.5 mS	2.5 mS

### MEASUREMENT (DISPLAY)

Output Current					
Range:	0–1000.0mA	0–2000.0mA	0–4000mA	0 – 10.000A	0 – 20.000A
Resolution:	0.1mA	0.1mA	0.1mA	0.001A	0.001A
Accuracy:	±0.1% FS	±0.1% FS	±0.1% FS	±0.1% FS + 10mA	±0.1% FS + 10mA
Photodiode Current					
Range:	0–10000µA	0–10000µA	0–10000µA	0 – 10000µA	0 – 10000µA
Resolution:	1µA	1µA	1µA	1µA	1µA
Accuracy:	±4µA	±4µA	±4µA	±4µA	±4µA
Photodiode Responsivity <sup>10</sup>					
Range (µA/mW):	0.00–1000.00	0.00–1000.00	0.00–1000.00	0.00 – 1000.00	0.00 – 1000.00
Resolution:	0.01µA/mW	0.01µA/mW	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	0.00 – 20000.0	0.00 – 20000.0
Resolution:	0.1mW	0.1mW	0.1mW	0.1mW	0.1mW
Forward Voltage					
Range:	0.000–18.000V	0.000–18.000V	0.000–18.000V	0.000 – 4.000V	0.000 – 4.000V
Resolution:	1mV	1mV	1mV	1mV	1mV
Accuracy: <sup>11</sup>	±2mV	±2mV	±2mV	±2mV	±2mV

## GENERAL

I/O Connectors	Female, 25-pin, D-sub
TEC I/O:	BNC
Analog Input:	BNC
Remote Interface:	GPIO IEEE 488.1; USB 2.0 (B-Type)
Power Requirements <sup>14</sup>	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

A Output De-Rating (3736) = 0.3V and 0.04A per input Volt AC below 100 VAC to a minimum of 90 VAC

## CURRENT SOURCE NOTES

- All values relate to a one-hour warm-up period.
- Over any one-hour period, half-scale output.
- Over any 24-hour period, half-scale output.
- Measured electrically with a frequency range of 100Hz to 340kHz (High Bandwidth), 100Hz to 17kHz (Low Bandwidth).
- 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). In the LDC-37620 there is a potential for up to 100mA operational transient when the laser is enabled and then the TEC output is enabled. To protect the laser in all condition it is recommended setting both the current and voltage limit just above typical operating conditions and enabling the TEC output prior to the laser current output.
- Maximum output current transient resulting from a 1000V power line transient spike. Tested to ILX Technical Standard #LDC-00196; request ILX App Note #13.
- Maximum monitor photodiode current drift over any 30 minute period. Assumes zero drift in responsivity of photodiode.
- 50% modulation at mid-scale output. Higher bandwidth is possible with smaller modulation signal.
- Small signal specification is for typical 10% modulation depth. Large signal specification assumes 50% modulation depth at mid-scale output.
- Responsivity value is user-defined and is used to calculate the optical power.
- Four wire voltage measurement at the load. Voltage measurement accuracy while driving calibration load. Accuracy is dependent upon load and cable used.
- Based on resolution of digital to analog converters used in circuit.
- 3726 high bandwidth achieved with load impedances less than 4 ohms.
- Under factory testing conditions. Single resistance test load.

# TEMPERATURE CONTROL<sup>1</sup>

## LDC-3726

Temperature Control Range: <sup>2</sup>	
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: <sup>3</sup>	
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: <sup>4</sup>	
1 Hour:	±0.001°C
24 Hours: <sup>4</sup>	±0.002°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): <sup>6</sup>	0.01 kΩ
Accuracy:	±180 Ω

100 µA Bias Setting	
Range:	0 to 45 kΩ
Resolution (Display): <sup>6</sup>	0.001 kΩ
Accuracy:	±18 Ω

IC-V Sensor Voltage	
Nominal Bias:	1 mA
Range:	0 to 6V
Resolution (Display): <sup>6</sup>	0.0001 V
Accuracy:	±2 mV

IC-I Sensor Current	
Nominal Bias:	5 to 15 V
Range:	0 to 600 µA
Resolution (Display): <sup>6</sup>	0.001 µA
Accuracy:	±0.18 µA

RTD Sensor Resistance	
1 mA Bias Setting	
Range:	0 to 1500 Ω
Resolution (Display): <sup>6</sup>	0.01 Ω
Accuracy:	±0.8 Ω

2.5 mA Bias Setting	
Range:	0 to 200 Ω
Resolution (Display): <sup>6</sup>	0.001 Ω
Accuracy:	±0.1 Ω

User Sensor Calibration	
Thermistor:	Steinhart-Hart, 3 constants
IC Sensors:	Slope, Offset
RTD	R <sub>p</sub> , A, B, C

## TEC OUTPUT

Output Type:	Bi-directional, linear
Isolation:	Floating with respect to earth ground
Current Setpoint	
Range:	-4.00A to +4.00A
Resolution (Display): <sup>6</sup>	0.01A
Accuracy:	±0.025A
Current Limit	
Range:	-4.05A to +4.05A
Accuracy:	±0.025A
Voltage Measurement <sup>7</sup>	
Range:	-8.00V to +8.00V
Resolution (Display): <sup>6</sup>	0.01V
Accuracy:	±0.01V
Compliance Voltage:	±8V
Maximum Output Power:	32W
Current Noise and Ripple: <sup>5</sup>	<1.0 mA rms

## AUXILIARY I/O SPECIFICATIONS

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

# TEMPERATURE CONTROL<sup>1</sup>

## LDC-3736 / 37620

Temperature Control Range: <sup>2</sup>	
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: <sup>3</sup>	
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: <sup>4</sup>	
1 Hour:	±0.002°C
24 Hours: <sup>4</sup>	±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): <sup>6</sup>	0.01 kΩ
Accuracy:	±180 Ω

100 µA Bias Setting	
Range:	0 to 45 kΩ
Resolution (Display): <sup>6</sup>	0.001 kΩ
Accuracy:	±18 Ω

IC-V Sensor Voltage	
Nominal Bias:	1 mA
Range:	0 to 6V
Resolution (Display): <sup>6</sup>	0.0001 V
Accuracy:	±2 mV

IC-I Sensor Current	
Nominal Bias:	5 to 15 V
Range:	0 to 600 µA
Resolution (Display): <sup>6</sup>	0.001 µA
Accuracy:	±0.18 µA

RTD Sensor Resistance	
1 mA Bias Setting	
Range:	0 to 1500 Ω
Resolution (Display): <sup>6</sup>	0.01 Ω
Accuracy:	±0.8 Ω

2.5 mA Bias Setting	
Range:	0 to 200 Ω
Resolution (Display): <sup>6</sup>	0.001 Ω
Accuracy:	±0.1 Ω

User Sensor Calibration	
Thermistor:	Steinhart-Hart, 3 constants
IC Sensors:	Slope, Offset
RTD:	R <sub>0</sub> , A, B, C

## TEC OUTPUT

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

## AUXILIARY I/O SPECIFICATIONS

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

## TEMPERATURE CONTROL NOTES

- <sup>1</sup> All values are specified for an ambient temperature of 23±5°C after a 1 hour warm up unless otherwise specified.
- <sup>2</sup> Software limits of range. Actual range depends on the physical load, sensor type, and TEC module used.
- <sup>3</sup> 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.
- <sup>4</sup> 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 ±(T<sub>max</sub>-T<sub>min</sub>)/2 over the measurement period.
- <sup>5</sup> Measured over the full DC current range into a 1 Ω load.
- <sup>6</sup> 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.
- <sup>7</sup> Measured at the output connector. Users may enter in cable resistance to provide an accurate voltage measurement at the load.
- <sup>8</sup> Unregulated output and requires a minimum of a 120mA current draw.



# Chapter 2:

## General Operation

---

This chapter is an overview of the operation of the LDC-3706 Laser Controllers. It offers instructions for connecting the laser to the current source and temperature controller and describes powering up the instrument. This chapter also contains step by step procedures that teach the user how to operate the controller in Constant Current Mode, Constant Power Mode, and to operate the temperature controller in Constant Temperature Mode. ILX recommends that the contents of this chapter are reviewed at a minimum before operating the new controller.

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

### Grounding Requirements

The LDC-3706 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-3706 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  $\pm 10\%$  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.



**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-3706 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”
- 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-3706 instrument performs a self-test to ensure that the internal hardware and software are communicating properly. If the LDC-3706 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-3706 instrument configuration is set to the same state as when the power was last turned off.

To quickly set a different configuration the recall function can be used. 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-3706 instrument can be reinstalled or upgraded via USB. Contact ILX Lightwave technical support for information on upgrading the software of the LDC-3706 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 USB Flash Drive 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-3706 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-3706 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 LDC-3726 and LDC-3736. A 9W4 connector is located on the rear panel of the LDC-37620. The connections for these connectors are shown below.

LDC-3726 & 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 (+)

LDC-37620	
PIN NUMBER	CONNECTION
A1	Laser Anode (+)
A2	Laser Anode (+)
A3	Laser Cathode (-)
A4	Laser Cathode (-)
1	Photodiode Anode (+)
2	Photodiode Cathode (-)
3	Laser Anode Voltage Sense (+)
4	Chassis Ground
5	Laser Cathode Voltage Sense (-)

**Interlock Connections:** For the LDC-3726 and LDC-3736, a short must exist between the Interlock pins (pins 1 and 2) of the current source output connector in order for the laser output to be enabled. 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.

For the LDC-37620, a short must exist on the rear BNC interlock connector in order for the laser diode output to be enabled. The short can be made using the 50  $\Omega$  BNC terminator included in the shipping kit or can be 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.

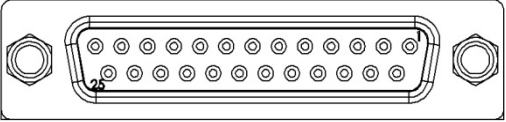
### CAUTION

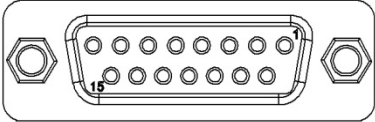
The interlock terminals on the LASER connector, pins 1 and 2, must be kept isolated from all other connections including earth ground.

### WARNING

The Current Source output terminals of the LDC-3706 Laser Controller (Laser Anode and Laser Cathode) should never be shorted together or loaded with less than 0.1  $\Omega$ . Doing so may result in damage to the instrument.

**Temperature Control Output:** A 15-pin D-sub connector is located on the back panel of the LDC-3726. A 25-pin D-sub connector is located on the back panel of the LDC-3736 and LDC-37620. The connections are shown below.

LDC-3736 & LDC-37620	
	
PIN NUMBER	CONNECTION
1	Sensor (+) Sense Terminal
2	Sensor (-) Sense Terminal
3	Fan (+)
4	Analog Ground
5	Analog Ground
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 (-)

LDC-3726	
	
PIN NUMBER	CONNECTION
1	TE Module (+)
2	TE Module (+)
3	TE Module (-)
4	TE Module (-)
5	TE Module Shield
6	Temp. Sensor Shield
7	Sensor (+)
8	Sensor (-)
9	Analog Ground
10	N/C
11	N/C
12	N/C
13	N/C
14	Fan (+)*
15	Fan (-)*

\*Pins 14 and 15 are Fan (+) and Fan (-), respectively, for only CC501S.

If you choose to assemble custom interconnect cables, 18AWG wire is recommended to minimize voltage drop at high current. Note that the DB-25 connector pins are rated for  $I_{\text{nominal}} = 2.5\text{A}$ , therefore all four TEC+ pins (9, 10, 21, 22) must be used if 8 A is to be delivered to a load as well as all 4 TEC- pins (12, 13, 24, 25) for the return.

Cable ID pin configurations will determine the maximum output current for the TEC and is only applicable to products with the 25-pin D-sub connector.

MAX Output Current	Cable ID1	Cable ID2
	Pin 17 (LDC-3736 & LDC-37620)	Pin 18 (LDC-3736 & LDC-37620)
8A	Pin 17 to Analog Ground	Pins 18 to Analog Ground
5A	Pin 17 to Analog Ground	Pin 18 N/C
1A	Pin 17 N/C	Pin 18 N/C

**TEC Grounding Considerations:** The TEC output connections of the LDC-3706 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-3706 Laser Controller (TE Module (+) and TE Module (-)) should never be shorted together or loaded with less than 0.1  $\Omega$ . 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-3706 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 k $\Omega$ . 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 the GPIB or USB remote interfaces.

**Analog Temperature Control Input:** An isolated BNC connector is located on the rear panel of the LDC-3706 that provides the capability to adjust the temperature setpoint by applying a voltage signal. The LDC-3706 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 the GPIB or USB remote interfaces.

**External Fan Control:** The LDC-3706 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-3706 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-3706, 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 the laser or any other sensitive devices to the LDC-3706 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-3706 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.

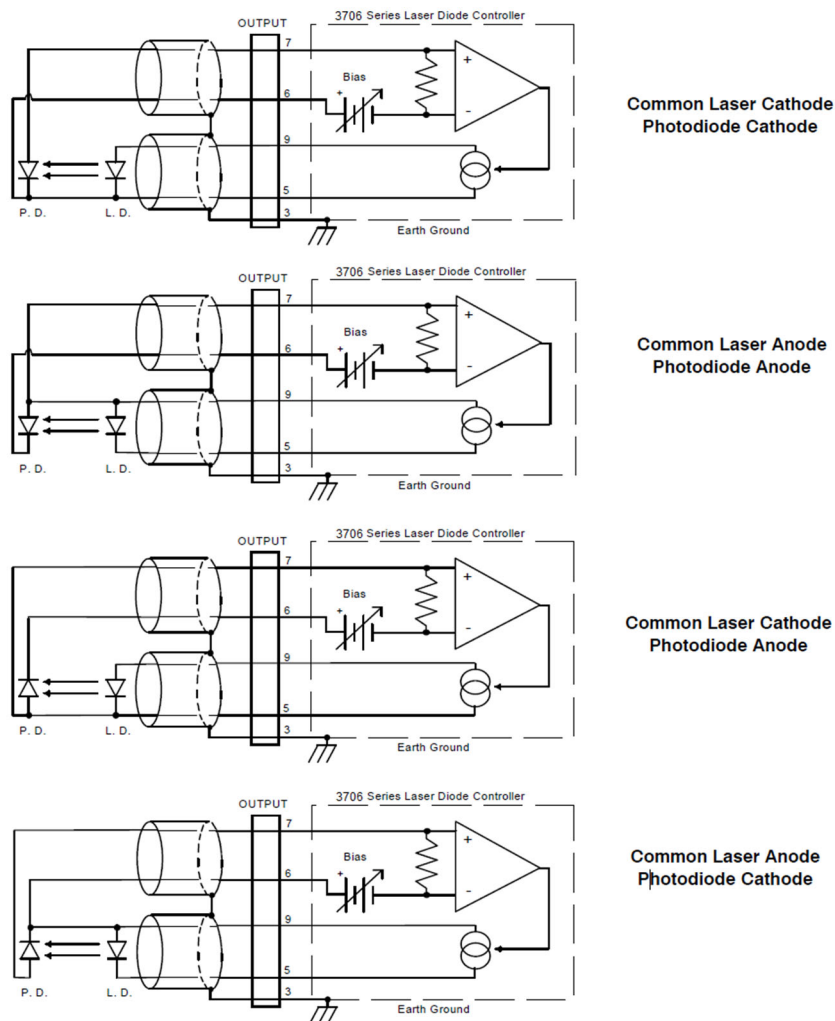


Figure 2.1 - Laser Diode Connection Configurations

**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-3706 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 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. It is recommended that the laser and photodiode remain isolated when possible.

## Front Panel Operation

**General Operation:** This section describes the fundamentals of operation for the LDC-3706 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 toggles between power on and standby power (off).

### 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-3706 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).

## Parameters 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 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  $\mu$ A, 10  $\mu$ A, 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  $\mu$ A thermistor, 100  $\mu$ A 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-3706 will set the PID values, sensor type, and current limits.

<b>Models</b>	<b>Presets</b>
<b>All LDC-3706 Models</b>	GAIN1, GAIN3, GAIN10, GAIN 30, GAIN100, GAIN300
<b>LDC-3726 Only</b>	LDM4405, LDM4980, LDM4990, 710
<b>LDC-3736 Only</b>	LDM4872
<b>LDC-37620 Only</b>	LDM49840, LDM49860

**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-3706 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. 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 illuminated LED above the ON button (left). A disabled output is indicated by an unlit LED above the ON button (left).

- TEMPERATURE – Sets the LDC-3706 temperature controller to maintain a constant temperature
- SENSOR – Controls the LDC-3706 temperature controller to a constant sensor value
- TE CURRENT – Sets the LDC-3706 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-3706 has exceeded the user defined temperature limits
- CURRENT LIMIT (Left) – Illuminated if the LDC-3706 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:



**For the best laser diode protection it is recommend to set the current limit slightly above the 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 for the Laser Current source are divided into three different limits which are accessible at the top of the laser menu:

- Laser Current Limit
- Laser Voltage Limit
- Laser Power Limit

**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  $\mu\text{A}/\text{mW}$  for the laser system currently being controlled is set here. The default value is 0.0  $\mu\text{A}$ ; end user is required to enter a value for laser power conversion.

**Photodiode Bias Voltage:** The LDC-3706 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. The default value is 0.0V; end user is required to enter a value for photodiode current readings.

**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-3706 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 illuminated 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-3706 instruments.

	<b>LDC-3726</b>	<b>LDC-3736</b>	<b>LDC-37620</b>
Range 1	0 - 100 mA	0 - 1 A	0 - 10 A
Range 2	0 - 200 mA	0 - 2 A	0 - 20 A
Range 3	0 - 500 mA	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 units 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 2.3a, and the measured values are indicated by an equal sign, as in Figure 2.3b.



Figure 2.3a – Setpoint Current



Figure 2.3b – 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-3706 will provide the maximum resolution allowed.

## **Error Indicators**

The LDC-3706 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-3706 instrument should never be shorted together or loaded with less than 0.1  $\Omega$ . Doing so may result in damage to the instrument.

### **CAUTION**

Temperature control must be enabled prior to the laser output to protect against thermal runaway of the laser device. In addition, a potential 0.1A operational transient is present in the LDC-37620 10A/20A High Power Laser Diode Controller if the laser output is enabled and then the temperature control output is enabled.

## **Warm-Up and Environmental Considerations**

To achieve the rated accuracy, allow the LDC-3706 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 the LDC-3706 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-3706 into an appropriate AC power source supplying the correct mains voltage and frequency for the instrument (refer to the rear panel for the correct ratings)
2. Turn on the LDC-3706. 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 the laser by pressing the **RANGE** soft button under **LASER RANGE**. For best performance select the lowest range that allows the laser to be run at the maximum desired output current.
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, if available.*

7. Under the **ADJUST** section press the **LASER** soft button and use the knob to adjust the output current to the 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 the 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-3706 into an appropriate AC power source supplying the correct mains voltage and frequency for the instrument (refer to the rear panel for the correct ratings)
2. Turn on the LDC-3706. 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 the laser by pressing the **RANGE** soft button under **LASER RANGE**. For best performance select the lowest range that allows the laser to be run at the maximum desired output current.
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 the 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 the laser in all operating modes.



**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 the 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 the 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-3706 Laser Controller allows operation of 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-3706 instrument into an appropriate AC power source supplying the correct mains voltage and frequency for the instrument (refer to the rear panel for the correct ratings)
2. Turn on the LDC-3706. 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 the laser by pressing the **RANGE** soft button under **LASER RANGE**. For best performance select the lowest range that allows the laser to be run at the maximum desired output current.
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-3706 or a calibrated current meter. The calibrated PD responsivity is calculated by dividing the photodiode current by the output power ( $\mu\text{A} / \text{mW}$ ).

The default responsivity value is  $0.0 \mu\text{A}$ ; the end user is required to enter in the appropriate calculated value for the LDC-3706 instrument to display the laser power in mW. Otherwise, the Constant Power Mode will only be configurable in  $\mu\text{A}$  photodiode current units. Furthermore, a proper photodiode bias voltage must also be set for current reading to be provided, as this default value is  $0.0\text{V}$ .

7. Under the **ADJUST** section press the **LASER** soft button and use the knob to adjust the output power to the 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 the 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-3706 Controller's Trigger Output Function

For applications where initiating synchronous measurements is required for a remote instrument with the LDC-3706, 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-3706 Laser Controller is available for connecting any standard BNC terminated cable and connecting to equipment that can accept the levels produced by the LDC-3706 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 an application.

### Sensor Options

The LDC-3706 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-3706 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  $\mu\text{A}$  or 10  $\mu\text{A}$ ) through the thermistor which results in a voltage across the thermistor. This voltage is used as a feedback signal by the LDC-3706 digital control loops to maintain a constant temperature. The thermistor should be connected across the Sensor+ and Sensor- pins (LDC-3736 & LDC-37620: Pins 1 & 2, LDC-3726: Pins 7 & 8 of the TEC output connector).

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-3706 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  $C_1$ ,  $C_2$ , and  $C_3$  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, a calibrated sensor must be used. For example, when using a thermistor, enter its Steinhart-Hart coefficients  $C_1$ ,  $C_2$ , and  $C_3$  into the temperature controller. If the exact temperature is not crucial (within  $\pm 1.5^\circ\text{C}$ ) and a 10 k $\Omega$  thermistor is being used, use the default constants provided by the LDC-3706.

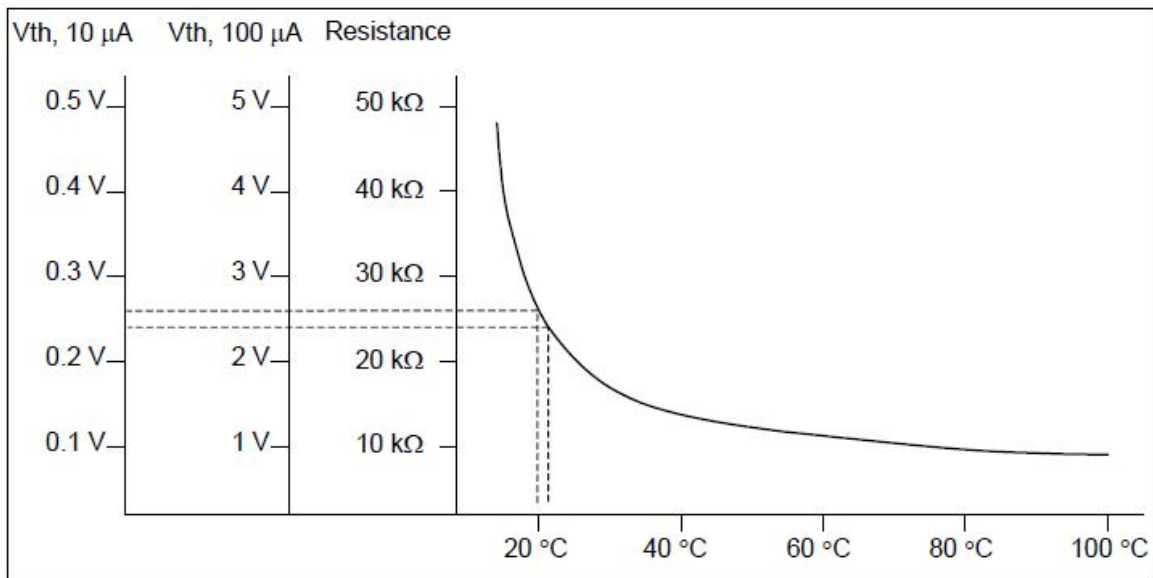
Thermistor resistance changes with temperature. The LDC-3706 supplies a constant current, either 10  $\mu\text{A}$  or 100  $\mu\text{A}$ , through the thermistor so that a temperature change results in a voltage change across the thermistor. This voltage change is sensed by the instrument and fed back to the control loop. The supply current selection depends on the thermistor operating temperature range and the required temperature resolution. A general rule of thumb for a 100 k $\Omega$  thermistor is to use the 10  $\mu\text{A}$  range for temperatures between  $-30^\circ\text{C}$  and  $+30^\circ\text{C}$  and for 10 k $\Omega$  thermistor the 100  $\mu\text{A}$  range for temperatures between  $10^\circ\text{C}$  to  $70^\circ\text{C}$ . Select the thermistor sense current of 10  $\mu\text{A}$  or 100  $\mu\text{A}$  in the front panel TEC parameter menu. Using 10  $\mu\text{A}$  as the thermistor current allows a maximum thermistor resistance of 450 k $\Omega$  to be used. The 100  $\mu\text{A}$  setting allows a 45 k $\Omega$  maximum.

The LDC-3706 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  $\mu\text{A}$  and 100  $\mu\text{A}$  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 4.5 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 k $\Omega$  at 20 $^{\circ}\text{C}$ . Deviations of one degree at 20  $^{\circ}\text{C}$  cause a resistance variation of about 2 k $\Omega$ . If using the 10  $\mu\text{A}$  setting, there is 20 mV of feedback to the control circuit. Using the 100  $\mu\text{A}$  setting provides 200 mV of feedback. The larger feedback signal means that the temperature is more precisely controlled. Notice also that the lower slope of the curve at the higher temperatures results in a smaller feedback signal. If higher temperatures are being controlled, it may be necessary 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-3706 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  $\mu\text{A}/\text{K}$  or approximately 298  $\mu\text{A}$  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  $\mu\text{A}/\text{K}$  and the offset is nominally 0  $\mu\text{A}$  but both can be adjusted to calibrate a 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-3706 has a sensor current limit of 600  $\mu\text{A}$ , which is approximately 325°C.



**For IC-Current sensors used with the LDC-3706 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-3706 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 a 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-3706 instrument has a sensor voltage limit of 6 V, which is approximately 325°C.

**RTD SENSORS** – When an RTD sensor is selected, the LDC-3706 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.

$$\begin{aligned}
 R_T &= R_0(1 + AT + BT^2 + 100CT^3 - CT^4) && \text{For } T \leq 0^\circ\text{C} \\
 R_T &= R_0(1 + AT + BT^2) && \text{For } T > 0^\circ\text{C}
 \end{aligned}$$

where:

$$\begin{aligned}
 R_0 &= \text{Resistance } (\Omega) \text{ at temperature } 0\text{C} \\
 R_T &= \text{Resistance } (\Omega) \text{ at temperature } T^\circ\text{C} \\
 T &= \text{Temperature in } ^\circ\text{C}
 \end{aligned}$$

The IEC 60751 Callendar-Van Dusen constants are listed below and are used as default values in the LDC-3706 Laser Diode Controller.

$$\begin{aligned}
 A &= +3.908 * 10^{-3} \\
 B &= -5.775 * 10^{-7} \\
 C &= -4.183 * 10^{-12}
 \end{aligned}$$

For optimal accuracy and stability, the 1 mA current source should be selected for RTD sensors with resistance of 200  $\Omega$  to 1500  $\Omega$  and the 2.5 mA range should be used with resistance of 1  $\Omega$  to 200  $\Omega$ . In general, the change in resistance per change in temperature is much lower for a typical 100  $\Omega$  RTD than that of a typical 10 k $\Omega$  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-3706 provides a current limit feature that allows the user 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 laser to become damaged.

To help avoid damage caused by thermal runaway, the LDC-3706's temperature controller provides a high-temperature limit setting. When the load temperature exceeds the temperature limit, the LDC-3706'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. Additionally, setting the positive current limit to a lower value will reduce the likelihood of thermal runaway.

## Constant Temperature Mode Operation

1. Plug the LDC-3706 Instrument into an appropriate AC power source supplying the correct mains voltage and frequency for the instrument (refer to the rear panel for the correct ratings)
2. Turn on the LDC-3706; 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-3706 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-3706 Laser Controller into an AC power source supplying the correct mains voltage and frequency for the instrument (refer to the rear panel for the correct ratings)
2. Turn on the LDC-3706; 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 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 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-3706 instrument into an AC power source supplying the correct mains voltage and frequency for instrument (refer to the rear panel for the correct ratings)
2. Turn on the LDC-3706; 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 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-3706 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-3706 Controller into an AC power source supplying the correct mains voltage and frequency for the instrument (refer to the rear panel for the correct ratings)
2. Turn on the LDC-3706; 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 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-3706 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-3706 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. 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-3706 Laser Controller remotely through either the GPIB or USB computer interface.

### **GPIB Address**

The talk and listen addresses on the LDC-3706 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. The LDC-3706 instrument's GPIB address can be changed 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-3706 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.

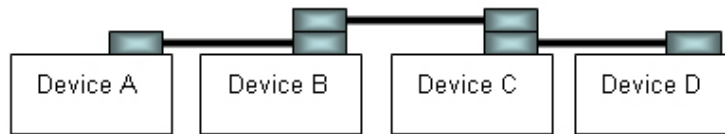
## Talkers, Listeners, and Controllers

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.

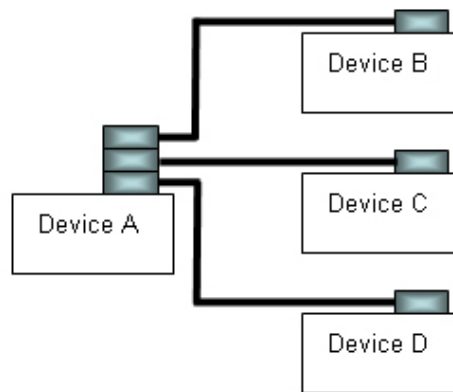
If there is more than one controller, only one can be the Controller in Charge (CIC). Control can be passed from one computer to another. In a multiple-controller system, there can be one “System Controller” capable of asserting control (becoming CIC).

## GPIB Cable Connections

Standard GPIB connectors can be connected together (stacked) allowing the system to be configured linearly, or in a star configuration. Up to 15 devices may be connected to the bus. The maximum length of cable used should be limited to 20m. Caution should be taken if individual cable lengths exceed 4m.



**Linear Configuration**



**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.

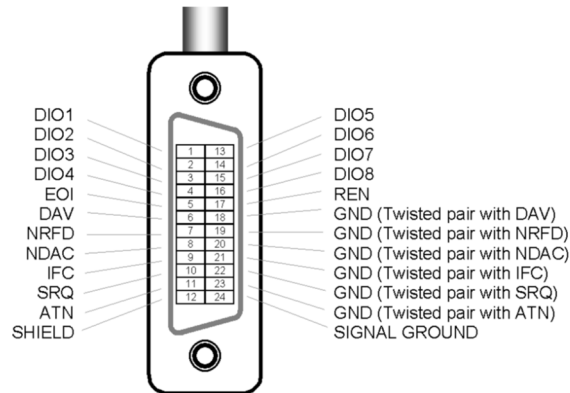


Figure 3.2 – GPIB Connector

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 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.

## 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 LDC-3706 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 device in turn, 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, VISA Write can be used 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, Left display, and Right display buttons. Pressing the Local button returns the instrument to Local control mode.

## GPIB vs. USB Communication

The USB interface uses the same command set as the GPIB interface. Command syntax does not vary between communication protocols.

## 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 termination sequences:

- <^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, and therefore has no effect on the message.

The LDC-3706 instrument terminates its GPIB responses with <NL><^END>.

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

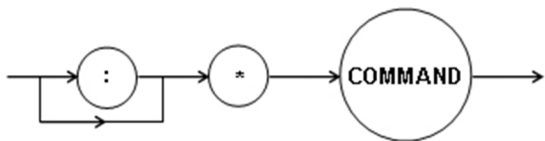
The following are examples of invalid syntax command strings that will produce errors:

**Table 3.6** – Invalid Syntax Command Strings

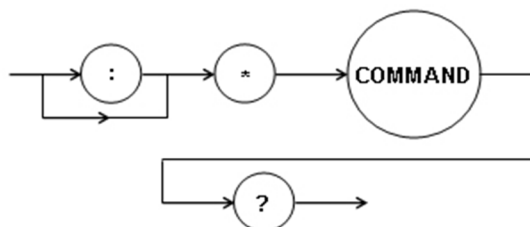
COMMAND	COMMENT
SOURCE:CURR:LIM HIGH?	Missing colon between “LIM” and “HIGH”.
OUTPUT ON SYST:VERS?	Missing semicolon; “SYST:VERS” command causes an error.
DISPLAY ?	Space not allowed before question mark.
SOURCE:POW:LIM1.2	Space missing between “LIM” command and the parameter value 1.2.

## IEEE 488.2 Common Commands

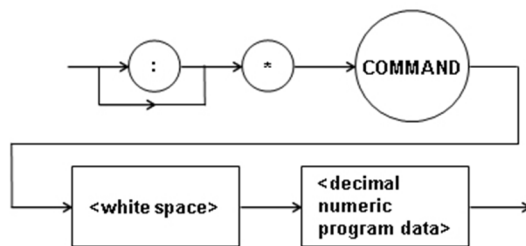
The IEEE 488.2 Common Commands and Queries are distinguished by the “\*” which begins each mnemonic. The diagrams below show the syntax structure for common commands, common command queries, and common commands with numeric data required.



Common Command



Common Command Query



Common Command with Numeric Data

Figure 3.3 – Common Command Diagrams

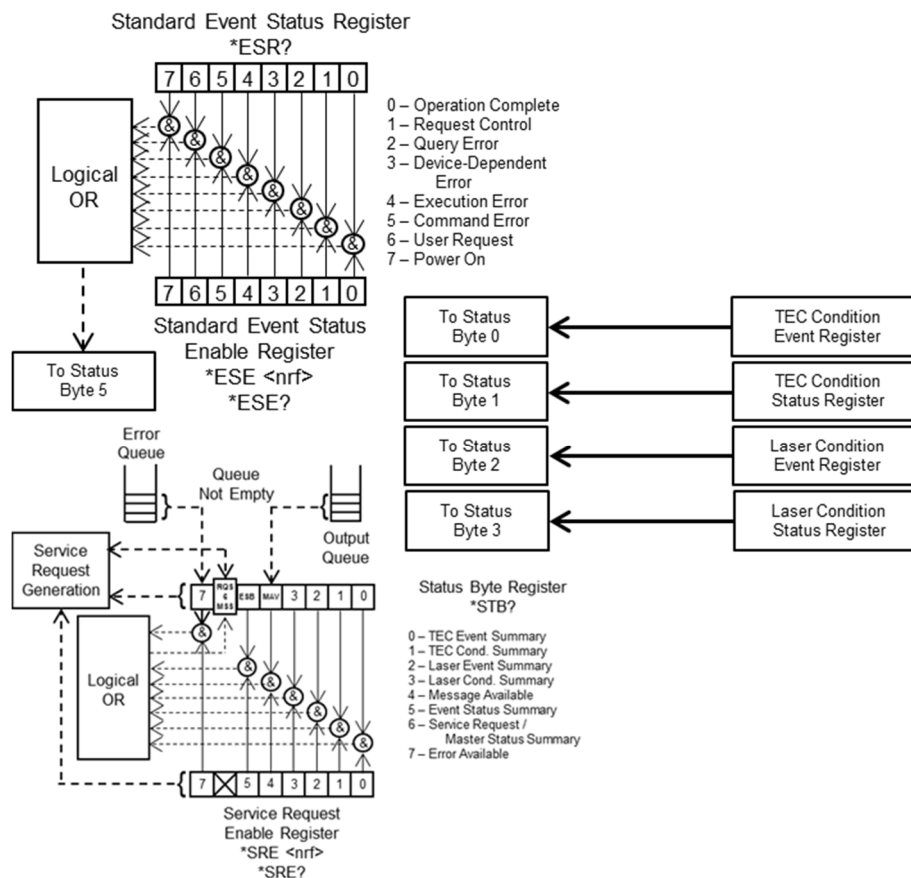
Numeric data is required with \*RCL (0 – 10, see front panel RECALL function), \*SAV (1 – 10, see front panel STORE function), and \*ESE (0 – 255, see Figure 3.4 – Status Reporting Scheme).

All the IEEE 488.2 Common Commands supported by the LDC-3706 are listed in Table 3.7:

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

*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-3706. See EVENT? and CONDition? commands for details for LASER and TEC condition and event registers.



**Figure 3.4 – 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 in chapter 4 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-3706 Laser Controller. This chapter is divided into three parts.

- ✓ Overview of the remote commands
- ✓ List of remote commands in alphabetical order
- ✓ LDC-3706 Compatible Commands

### CAUTION

**Running any remote calibration constant commands will overwrite the factory calibration data stored on the instrument. It is recommended that the user contacts ILX Lightwave for assistance prior to self-calibration. ILX Lightwave recommends an annual calibration cycle at the factory. Contact your local sales representative for more information.**

### Remote Command Reference Summary

This section contains all of the commands for the LDC-3706, 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.

The LDC-3706 controller uses SCPI standard commands. In order to maintain compatibility with standalone temperature controllers and current sources, the LDC-3706 implements two logical instruments. The commands preceded by INSTRUMENT allow selection of either the TEC (temperature controller) or LAS (current source) logical instruments. Ensure that the correct instrument is selected by sending “INSTRUMENT LAS” or “INSTRUMENT TEC”. Some commands listed in Table 4.2 operate on only one logic instrument while some operate on both as identified by the column on the right.

**Table 4.1 – Remote Command Summary of IEEE 488.1 Common Commands**

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

NAME	FUNCTION	INSTrument
CALCulate:TRANSform:TEMPerature:SHHart:B?	Report coefficient B in Steinhart-Hart resistance to temperature equation for thermistors.	TEC
CALCulate:TRANSform:TEMPerature:SHHart:C <nrf>	Set coefficient B in Steinhart-Hart resistance to temperature equation for thermistors.	TEC
CALCulate:TRANSform:TEMPerature:SHHart:C?	Report coefficient B in Steinhart-Hart resistance to temperature equation for thermistors.	TEC
CALibrate:CUR100UA:START	Initiate calibration of 100 $\mu$ A thermistor current source.	TEC
CALibrate:CUR100UA:DATA <nrf>	Send measured current to 100 $\mu$ A calibration procedure.	TEC
CALibrate:CUR10UA:START	Initiate calibration of 10 $\mu$ A thermistor current source.	TEC
CALibrate:CUR10UA:DATA <nrf>	Send measured current to 10 $\mu$ A calibration procedure.	TEC
CALibrate:CURRent:START	Initiate calibration of current procedure.	LAS, TEC
CALibrate:CURRent:DATA <nrf>	Sends measured current data to current calibration procedure.	LAS, TEC
CALibrate:DATE <nrf>, <nrf>, <nrf>	Update calibration date of instrument (LAS/TEC). Parameters are month, date, year.	LAS, TEC
CALibrate:DATE?	Report calibration date of instrument.	LAS, TEC
CALibrate:MDI:START	Initiate photodiode current measurement calibration.	LAS
CALibrate:MDI:DATA <nrf>	Send measured photocurrent to MDI calibration procedure.	LAS
CALibrate:PDI:START	Initiate photodiode current measurement calibration. This is the same procedure as CALibrate:MDI:START	LAS
CALibrate:PDI:DATA <nrf>	Send measured photocurrent to PDI calibration procedure.	LAS
CALibrate:RTD1000UA:START	Initiate 1 mA RTD calibration.	TEC
CALibrate:RTD1000UA:DATA <nrf>	Send measured RTD resistance to 1 mA RTD calibration procedure.	TEC
CALibrate:RTD2500UA:START	Initiate 2.5 mA RTD calibration.	TEC
CALibrate:RTD2500UA:DATA <nrf>	Send measured RTD resistance to 2.5 mA RTD calibration procedure.	TEC
CALibrate:SENSORI:START	Execute ICI sensor current calibration procedure.	TEC
CALibrate:SENSORV:START	Perform ICV sensor voltage measurement calibration.	TEC
CALibrate:SENSORV:DATA <nrf>	Send measured ICV sensor voltage to sensor voltage calibration procedure.	TEC

NAME	FUNCTION	INSTRUMENT
CALibrate:VMEAS:START <nrf>	Initiate LDV or VTE measurement calibration, based on which instrument mode is currently selected.	LAS, TEC
CALibrate:VMEAS:DATA <nrf>	Send measured LDV or VTE voltage to VMEAS calibration procedure.	LAS, TEC
DISPlay:BRIGhtness <nrf>	Set display brightness.	N/A
DISPlay:BRIGhtness?	Report display brightness setting.	N/A
DISPlay[:ENABle] <nrf>	Turn display on or off.	N/A
DISPlay[:ENABle]?	Reports display on or off condition.	N/A
CONDition?	Report selected instrument's Condition status register.	LAS, TEC
ENABle:CONDition <nrf>	Set value of selected instrument's Condition Enable register.	LAS, TEC
ENABle:CONDition?	Report value of selected instrument's Condition Enable register.	LAS, TEC
EVEnt?	Report selected instrument's Event status register.	LAS, TEC
ENABle:EVEnt <nrf>	Set value of selected instrument's Event Enable register.	LAS, TEC
ENABle:EVEnt?	Report value of selected instrument's Event Enable register.	LAS, TEC
FORMat:SREGister <string>	Set format of values sent to/read from common registers ESE, ESR, SRE, and STB.	N/A
FORMat:SREGister?	Reports current format.	N/A
INPut:BIAS:VOLTage <nrf>	Set photodiode bias voltage.	LAS
INPut:BIAS:VOLTage?	Report photodiode bias voltage.	LAS
INPut:FILTer:[LPASs]:[:STATe] <nrf>	Enable or disable laser current low-pass filter.	LAS
INPut:FILTer:[LPASs]:[:STATe]?	Report state of low-pass filter.	LAS
INSTRument:CATalog?	Reports the possible instrument type settings available.	N/A
INSTRument:NSElect <nrf>	Selects between Laser current source or TE controller instrument operating modes.	N/A
INSTRument:NSElect?	Reports currently selected instrument operating mode.	N/A
INSTRument[:SElect] <string>	Selects between Laser current source or TE controller instrument operating modes.	N/A
INSTRument[:SElect]?	Reports currently selected instrument operating mode.	N/A

NAME	FUNCTION	INSTRUMENT
LIV:STABLELDI <nrf>	Set stable current for LIV.	LAS
LIV:STABLELDI?	Report stable current for LIV.	LAS
LIV:STARTLDI <nrf>	Set starting current for LIV.	LAS
LIV:STARTLDI?	Report starting current for LIV.	LAS
LIV:ENDLDI <nrf>	Set ending current for LIV.	LAS
LIV:ENDLDI?	Report ending current for LIV.	LAS
LIV:STEPLDI <nrf>	Set current step size for LIV.	LAS
LIV:STEPLDI?	Report current step size for LIV.	LAS
LIV:STEPTIME <nrf>	Set step size for LIV.	LAS
LIV:STEPTIME?	Report step size for LIV.	LAS
LIV:POINTS?	Report number of points for LIV.	LAS
LIV:BEGIN	Start LIV sampling.	LAS
LIV:INPROGRESS?	Report if LIV sampling in process.	LAS
LIV:READCOUNT <nrf>	Set number of data points to read out when processing an LIV:DATA? query.	LAS
LIV:READCOUNT?	Report number of data points to read out when processing an LIV:DATA? query.	LAS
LIV:DATA? <nrf>	Report LIV data.	LAS
LIV:TEMPERature:INFO?	Reports temperature data for LIV measurements.	LAS
LIV:IGNORETEMPSTAB <nrf>	Sets if LIV ignores temperature stability during measurement.	LAS
LIV:IGNORETEMPSTAB?	Reports if LIV ignores temperature stability during measurement.	LAS
MEASure[:SCALar]:[F]RESistance?	Report TE sensor resistance measurement.	TEC
MEASure[:SCALar]:CURRent[1]?	Report LDI or ITE, depending on currently selected instrument mode.	LAS, TEC
MEASure[:SCALar]:CURRent2?	Report photodiode current measurement.	LAS
MEASure[:SCALar]:POWER?	Report photodiode power measurement.	LAS
MEASure[:SCALar]:TEMPERature?	Report temperature measurement.	TEC
MEASure[:SCALar]:VOLTage?	Report LDV or VTE, depending on the currently selected instrument mode.	LAS, TEC
MEASure:SENSor?	Report the currently-selected sensor measurement.	TEC

NAME	FUNCTION	INSTrument
OUTPut[1][:STATE] <nrf>	Set output state of currently selected instrument.	LAS, TEC
OUTPut[1][:STATE]?	Reports output state of currently selected instrument mode.	LAS, TEC
OUTPut2[:STATE] <nrf>	Enable or disable external fan control.	TEC
OUTPut2[:STATE]?	Report external fan output state.	TEC
PID:AUTOtune	Starts or stops the auto-tune process.	TEC
PID:AUTOtune?	Report if auto-tune is in process.	TEC
PID:PRESET <string>	Sets a PID preset for a mount.	TEC
PID:PRESET:LIST?	Report list of PID presets.	TEC
SENSor <string>	Set the temperature sensor type.	TEC
SENSor?	Report the currently selected temperature sensor type.	TEC
SENSor:ICI:SETPoint <nrf>	Set current setpoint for IC sensor.	TEC
SENSor:ICI:SETPoint?	Report current setpoint for IC sensor.	TEC
SENSor:ICI:LIMit:LOW <nrf>	Set low current limit for IC sensor.	TEC
SENSor:ICI:LIMit:LOW?	Report low current limit for IC sensor.	TEC
SENSor:ICI:LIMit:HIGH <nrf>	Set high current limit for IC sensor.	TEC
SENSor:ICI:LIMit:HIGH?	Report high current limit for IC sensor.	TEC
SENSor:ICV:SETPoint <nrf>	Set voltage setpoint for IC sensor.	TEC
SENSor:ICV:SETPoint?	Report voltage setpoint for IC sensor.	TEC
SENSor:ICV:LIMit:LOW <nrf>	Set low voltage limit for IC sensor.	TEC
SENSor:ICV:LIMit:LOW?	Report low voltage limit for IC sensor.	TEC
SENSor:ICV:LIMit:HIGH <nrf>	Set high voltage limit for IC sensor.	TEC
SENSor:ICV:LIMit:HIGH?	Report high voltage limit for IC sensor.	TEC
SOURce[1]:AM[:STATE] <nrf>	Enable or disable LDI modulation.	LAS
SOURce[1]:AM[:STATE]?	Report currently selected LDI modulation state.	LAS
SOURce[1]:CURRent:LIMit:HIGH <nrf>	Set upper TEC current limit.	TEC
SOURce[1]:CURRent:LIMit:HIGH?	Report upper TEC current limit.	TEC

NAME	FUNCTION	INSTrument
SOURce[1]:CURRent:LIMit:LOW <nrf>	Set lower TEC current limit.	TEC
SOURce[1]:CURRent:LIMit:LOW?	Report lower TEC current limit.	TEC
SOURce[1]:CURRent:LIMit[:AMPLitude] <nrf>	Set laser current limit.	LAS
SOURce[1]:CURRent:LIMit[:AMPLitude]?	Report laser current limit.	LAS
SOURce[1]:CURRent:RANGe <nrf>	Set range of laser current source.	LAS
SOURce[1]:CURRent:RANGe?	Report currently selected laser current source range.	LAS
SOURce[1]:CURRent[:LEVel][:IMMediate] <nrf>	Set control setpoint for LDI or ITE, depending on the currently selected instrument mode.	LAS, TEC
SOURce[1]:CURRent[:LEVel][:IMMediate]?	Report control setpoint for LDI or ITE, depending on the currently selected instrument mode.	LAS, TEC
SOURce[1]:FUNctioN[:MODE] <string>	Set the operating mode for the currently selected instrument mode.	LAS, TEC
SOURce[1]:FUNctioN[:MODE]?	Report the operating mode for the currently selected instrument mode.	LAS, TEC
SOURce[1]:POWer:LIMit <nrf>	Set the photodiode power limit.	LAS
SOURce[1]:POWer:LIMit?	Report the photodiode power limit setpoint.	LAS
SOURce[1]:POWer[:LEVel][:IMMediate] <nrf>	Set the laser diode power setpoint.	LAS
SOURce[1]:POWer[:LEVel][:IMMediate]?	Report the laser diode power setpoint.	LAS
SOURce[1]:RESistance:LCONstants:DERivative <nrf>	Set the "D" term for the TEC controller PID control loop.	TEC
SOURce[1]:RESistance:LCONstants:DERivative?	Report the "D" term for the TEC controller PID control loop.	TEC
SOURce[1]:RESistance:LCONstants:INTegral <nrf>	Set the "I" term for the TEC controller PID control loop.	TEC
SOURce[1]:RESistance:LCONstants:INTegral?	Report the "I" term for the TEC controller PID control loop.	TEC
SOURce[1]:RESistance:LCONstants[:GAIN] <nrf>	Set the "P" term for the TEC controller PID control loop.	TEC
SOURce[1]:RESistance:LCONstants[:GAIN]?	Report the "P" term for the TEC controller PID control loop.	TEC
SOURce[1]:RESistance:PROTection:LOW <nrf>	Set the TE controller resistance lower limit.	TEC
SOURce[1]:RESistance:PROTection:LOW?	Report the TE controller resistance lower limit.	TEC
SOURce[1]:RESistance:PROTection[:HIGH] <nrf>	Set the TE controller resistance upper limit.	TEC
SOURce[1]:RESistance:PROTection[:HIGH]?	Report the TE controller resistance upper limit.	TEC
SOURce[1]:RESistance:SPOint <nrf>	Set the TE controller resistance	TEC



NAME	FUNCTION	INSTrument
	setpoint.	
SOURce[1]:RESistance:SPOint?	Report the TE controller resistance setpoint.	TEC
SOURce:RESistance:TOLerance <nrf>	Set the TEC resistance tolerance. See status section: "out of tolerance" bit in condition reg.	TEC
SOURce:RESistance:TOLerance?	Report the TEC resistance tolerance setting.	TEC
SOURce[1]:TEMPerature:AM[:STATE] <nrf>	Enable or disable TE controller analog temperature modulation.	TEC
SOURce[1]:TEMPerature:AM[:STATE]?	Report analog temperature modulation state.	TEC
SOURce[1]:TEMPerature:LCONstants:DERivative <nrf>	Set the "D" term for the TEC controller PID control loop.	TEC
SOURce[1]:TEMPerature:LCONstants:DERivative?	Report the "D" term for the TEC controller PID control loop.	TEC
SOURce[1]:TEMPerature:LCONstants:INTEgral <nrf>	Set the "I" term for the TEC controller PID control loop.	TEC
SOURce[1]:TEMPerature:LCONstants:INTEgral?	Report the "I" term for the TEC controller PID control loop.	TEC
SOURce[1]:TEMPerature:LCONstants[:GAIN] <nrf>	Set the "P" term for the TEC controller PID control loop.	TEC
SOURce[1]:TEMPerature:LCONstants[:GAIN]?	Report the "P" term for the TEC controller PID control loop.	TEC
SOURce[1]:TEMPerature:PROTection:LOW <nrf>	Set TE controller low temperature limit.	TEC
SOURce[1]:TEMPerature:PROTection:LOW?	Report TE controller low temperature limit.	TEC
SOURce[1]:TEMPerature:PROTection[:HIGH] <nrf>	Set TE controller high temperature limit.	TEC
SOURce[1]:TEMPerature:PROTection:HIGH?	Report TE controller high temperature limit.	TEC
SOURce[1]:TEMPerature:SPOint <nrf>	Set TE controller temperature setpoint.	TEC
SOURce[1]:TEMPerature:SPOint?	Report TE controller temperature setpoint.	TEC
SOURce[1]:TEMPerature:TOLerance <nrf>	Set TEC temperature tolerance.	TEC
SOURce[1]:TEMPerature:TOLerance?	Report TEC temperature tolerance.	TEC
SOURce[1]:TOLerance:TIME <nrf>	Set duration for temperature to be stable.	TEC
SOURce[1]:TOLerance:TIME?	Report duration for temperature to be stable.	TEC
SOURce[1]:STABLE?	Report if temperature has settled to user-specified temperature and time window.	TEC

NAME	FUNCTION	INSTrument
SOURce[1]:VOLTage:LIMit <nrf>	Set laser diode voltage limit.	LAS
SOURce[1]:VOLTage:LIMit?	Report laser diode voltage limit.	LAS
SOURce[2]:VOLTage[:LEVel] <nrf>	Set external fan voltage setpoint.	TEC
SOURce[2]:VOLTage[:LEVel]?	Report external fan voltage setpoint.	TEC
SYSTem:BEEPer:ENABLe <bool>	Sets the audio indicators on the system on or off.	N/A
SYSTem:BEEPer:ENABLe?	Reports the on/off state for audio indicators.	N/A
SYST:ERRor:ALL?	Report all errors in error queue.	N/A
SYSTem:ERRor:CODE:ALL?	Report all error codes in error queue.	N/A
SYSTem:ERRor:CODE[:NEXT]?	Report next error code from error queue.	N/A
SYSTem:ERRor:COUnT?	Report the number of errors in the error queue.	N/A
SYSTem:ERRor[:NEXT]?	Report next error from error queue.	N/A
SYSTem:PREset	Purge error queue, reset laser controller and TE controller to default settings.	N/A
SYSTem:VERSIon?	Report currently installed firmware version.	N/A

## Command Reference

The following pages contain a reference for common commands of the LDC-3706 Laser Controller.

---

### \*CLS

#### Clear Status

<b>Description</b>	Clears all status event registers, the event filter, the status register, SRQ bit, the OPC bit, and the error queue
<b>Parameters</b>	None
<b>Notes</b>	Useful to clear registers before enabling service requests (SRQ)
<b>Examples</b>	*CLS

---

### \*ESE <integer>

#### Standard Event Status Enable

<b>Description</b>	Sets the bits in the standard event status enable register.
<b>Parameters</b>	The value must be between 0 and 255.
<b>Notes</b>	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.
<b>Examples</b>	*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 ( $40 = 2^3 + 2^5$ )

---

### \*ESE?

#### Event Status Enable Query

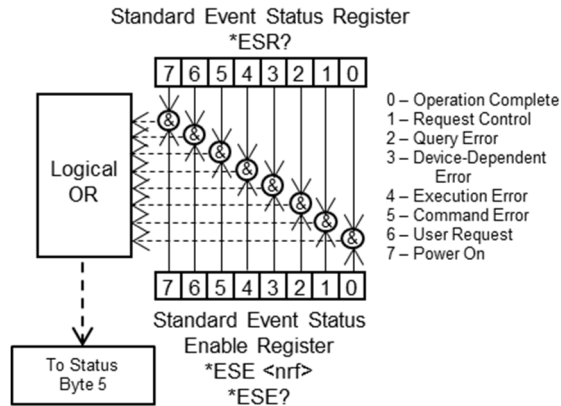
<b>Description</b>	Determine the contents of the standard event status enable register
<b>Notes</b>	The response is a value between 0 and 255, representing the bits of the standard event status enable register when expressed in base 2 binary format  See *ESR? for a description of each bit in the status register along with a diagram of the reporting structure
<b>Examples</b>	*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

**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
- Bit 1 Unused and always reports 0
- Bit 2 Query Error means that data in the output has been lost or that none was available
- Bit 3 Device-Specific Error is an error has occurred that is neither a command query or execution error
- Bit 4 Execution Error means a parameter was evaluated to be outside the legal input range or capability
- Bit 5 Command Error means a command could not be interpreted by the parser
- Bit 6 Unused and always reports "0" Bit
- 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

**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**

<b>Description</b>	Sets the operation complete bit (bit 0) in the standard event status register when all pending overlapped commands have been completed
<b>Parameters</b>	None
<b>Notes</b>	This command does not hold off subsequent operations. Determining when 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.
<b>Examples</b>	OUTPUT ON;*OPC Will set bit 0 in the standard event status register when the output is on

---

## **\*OPC?**

### **Operation Complete Query**

<b>Description</b>	Places an ASCII character 1 into the instrument's output queue when all pending operations have been finished
<b>Notes</b>	This command is a sequential command that holds off all subsequent commands until the "1" is returned. Make sure to set the timeouts appropriately when using this command when long delays are expected.
<b>Examples</b>	*OPC? A response of "1" means that all overlapped commands are complete

---

## **\*RCL <bin>**

### **Recall**

<b>Description</b>	Recalls a stored setup configuration from memory
<b>Parameters</b>	A value from 0 – 10
<b>Notes</b>	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
<b>Examples</b>	**RCL 0" –response: instrument is reconfigured to factory-default settings

---

## **\*RST**

### **Reset**

<b>Description</b>	Performs a device reset
<b>Parameters</b>	None
<b>Notes</b>	<ol style="list-style-type: none"><li>1. Clears *OPC or *OPC? device requirements</li><li>2. Stops operation of overlapped commands</li><li>3. Sets all device specific function to a known state (*RST Value)</li></ol> <p>The reset command does NOT affect the following:</p> <ol style="list-style-type: none"><li>1. Output Queue</li><li>2. Enable Registers</li><li>3. Event Registers</li><li>4. *PSC state</li><li>5. Memory contents associated with *SAV</li></ol>

## \*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

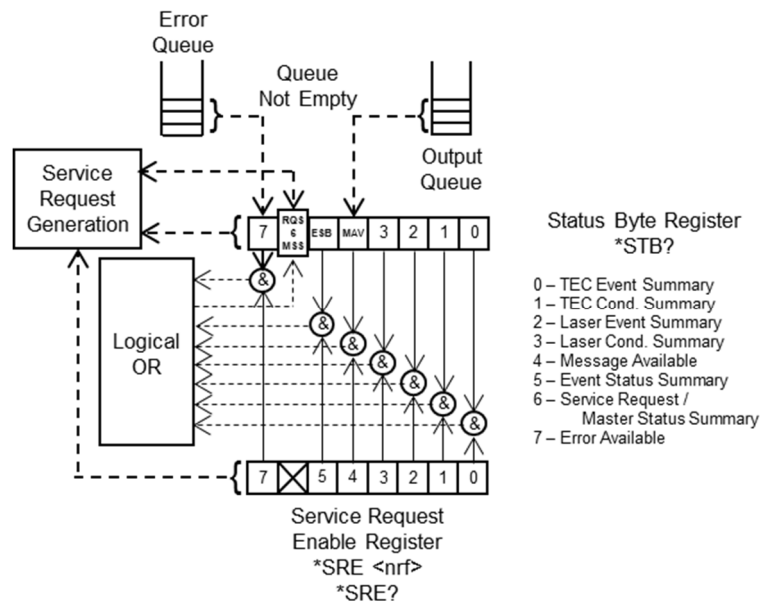
**Description** Sets the service request enable register bits

**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 the status byte register transitions from zero to one and the corresponding bit in the service request enable register is set 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

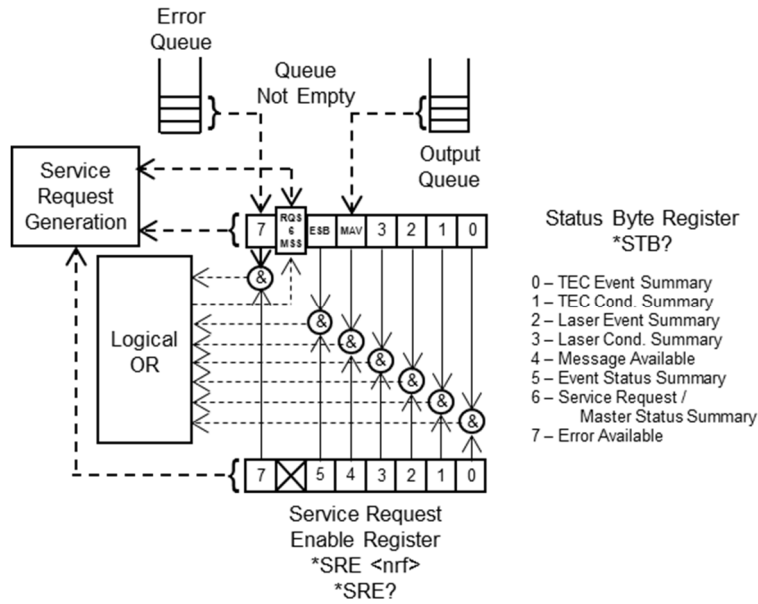
**Notes** The response is a value between 0 and 255, representing the bits of the standard event status enable register when expressed in base 2 binary format

**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

**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.

**\*WAI**  
**Wait to Continue**

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

**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

The following pages contain a reference for device-dependent commands of the LDC-3706 Laser Controllers.

---

### CALCulate:TRANSform:POWER:RESPonsivity <nrf> CALCulate:TRANSform:POWER:RESPonsivity?

LAS

<b>Description</b>	Sets/Reports photodiode responsivity.
<b>Parameters</b>	0.0 – 1000.0 – $\mu\text{A}/\text{mW}$ – Representing photodiode responsivity
<b>Reset Value</b>	0.0
<b>Example</b>	CALC:TRAN:POW:RESP 57; Sets Photodiode responsivity to 57 $\mu\text{A}/\text{mW}$

---

### CALCulate:TRANSform:TEMPerature:CVDusen:A <nrf> CALCulate:TRANSform:TEMPerature:CVDusen:A?

TEC

<b>Description</b>	Sets/Reports coefficient A (CVD A) for the Callendar-Van Dusen RTD resistance-to-temperature equation.
<b>Parameters</b>	-9.999 – 9.999 – The first coefficient of the Callendar-Van Dusen equation multiplied by $10^{-3} \text{ }^\circ\text{C}^{-1}$ .
<b>Notes</b>	The Callendar-Van Dusen equation: $R_T = R_0[1 + AT + BT^2 + CT^3(T - 100)]$ ( $T < 0 \text{ }^\circ\text{C}$ ) $R_T = R_0[1 + AT + BT^2]$ ( $T \geq 0 \text{ }^\circ\text{C}$ ) Where $R_T$ is the resistance at temperature $T$ .
<b>Reset Value</b>	3.908
<b>Example</b>	CALC:TRAN:TEMP:CVD:A 3.908; Sets CVD:A to $3.908 \times 10^{-3} \text{ }^\circ\text{C}^{-1}$ .

---

### CALCulate:TRANSform:TEMPerature:CVDusen:B <nrf> CALCulate:TRANSform:TEMPerature:CVDusen:B?

TEC

<b>Description</b>	Sets/Reports coefficient B (CVD B) for the Callendar-Van Dusen RTD resistance-to-temperature equation.
<b>Parameters</b>	-9.999 – 9.999 – The second coefficient of the Callendar-Van Dusen equation multiplied by $10^{-7} \text{ }^\circ\text{C}^{-2}$ .
<b>Notes</b>	The Callendar-Van Dusen equation: $R_T = R_0[1 + AT + BT^2 + CT^3(T - 100)]$ ( $T < 0 \text{ }^\circ\text{C}$ ) $R_T = R_0[1 + AT + BT^2]$ ( $T \geq 0 \text{ }^\circ\text{C}$ ) Where $R_T$ is the resistance at temperature $T$ .
<b>Reset Value</b>	-5.775
<b>Example</b>	CALC:TRAN:TEMP:CVD:B -5.775; Sets CVD:B to $-5.775 \times 10^{-7} \text{ }^\circ\text{C}^{-2}$ .

---

### CALCulate:TRANSform:TEMPerature:CVDusen:C <nrf> CALCulate:TRANSform:TEMPerature:CVDusen:C?

TEC

<b>Description</b>	Sets/Reports coefficient C (CVD C) for the Callendar-Van Dusen RTD resistance-to-temperature equation.
<b>Parameters</b>	-9.999 – 9.999 – The third coefficient of the Callendar-Van Dusen equation multiplied by $10^{-12} \text{ }^\circ\text{C}^{-3}$ .
<b>Notes</b>	The Callendar-Van Dusen equation: $R_T = R_0[1 + AT + BT^2 + CT^3(T - 100)]$ ( $T < 0 \text{ }^\circ\text{C}$ ) $R_T = R_0[1 + AT + BT^2]$ ( $T \geq 0 \text{ }^\circ\text{C}$ ) Where $R_T$ is the resistance at temperature $T$ .
<b>Reset Value</b>	-4.183
<b>Example</b>	CALC:TRAN:TEMP:CVD:C -4.183; Sets CVD:C to $-4.183 \times 10^{-12} \text{ }^\circ\text{C}^{-3}$ .



## CALCulate:TRANSform:TEMPerature:CVDusen:R <nrf> CALCulate:TRANSform:TEMPerature:CVDusen:R?

TEC

<b>Description</b>	Sets/Reports coefficient R0 (CVD R0) for the Callendar-Van Dusen RTD resistance-to-temperature equation.
<b>Parameters</b>	0 – 9999.9 Ω - The resistance of the transducer at 0 °C.
<b>Notes</b>	The Callendar-Van Dusen equation: $R_T = R_0[1 + AT + BT^2 + CT^3(T - 100)]$ ( $T < 0$ °C) $R_T = R_0[1 + AT + BT^2]$ ( $T \geq 0$ °C) Where $R_T$ is the resistance at temperature $T$ .
<b>Reset Value</b>	100
<b>Example</b>	CALC:TRAN:TEMP:CVD:R 100; Sets CVD:R to 100 Ω.

---

## CALCulate:TRANSform:TEMPerature:ICI:OFFSet <nrf> CALCulate:TRANSform:TEMPerature:ICI:OFFSet?

TEC

<b>Description</b>	Sets/Reports offset compensation for a temperature to current transducer.
<b>Parameters</b>	-9.999 – 9.999 – The compensating offset in °C.
<b>Reset Value</b>	0.0
<b>Example</b>	CALC:TRAN:TEMP:ICI:OFFS 0; Sets the ICI sensor offset to 0 °C.

---

## CALCulate:TRANSform:TEMPerature:ICI[:GAIN] <nrf> CALCulate:TRANSform:TEMPerature:ICI[:GAIN]?

TEC

<b>Description</b>	Sets/Reports slope compensation for a temperature to current transducer.
<b>Parameters</b>	0 – 9.999 – The compensating slope.
<b>Reset Value</b>	1.0
<b>Example</b>	CALC:TRAN:TEMP:ICI 1.0; Sets the ICI sensor slope to 1.0.

---

## CALCulate:TRANSform:TEMPerature:ICV:OFFSet <nrf> CALCulate:TRANSform:TEMPerature:ICV:OFFSet?

TEC

<b>Description</b>	Sets/Reports offset compensation for a temperature to voltage transducer.
<b>Parameters</b>	-99.99 – 99.99 – The compensating offset in °C.
<b>Reset Value</b>	0.0
<b>Example</b>	CALC:TRAN:TEMP:ICV:OFFS 0; Sets the ICV sensor offset to 0°C.

---

## CALCulate:TRANSform:TEMPerature:ICV[:GAIN] <nrf> CALCulate:TRANSform:TEMPerature:ICV[:GAIN]?

TEC

<b>Description</b>	Sets/Reports slope compensation for a temperature to voltage transducer.
<b>Parameters</b>	-99.99 – 99.99 – The compensating slope.
<b>Reset Value</b>	10.0
<b>Example</b>	CALC:TRAN:TEMP:ICV 10.0; Sets the ICV sensor slope to 10.

---

## CALCulate:TRANSform:TEMPerature:SHHart:A <nrf> CALCulate:TRANSform:TEMPerature:SHHart:A?

TEC

<b>Description</b>	Sets/Returns Steinhart-Hart parameter C1 for a thermistor temperature transducer.
<b>Parameters</b>	-9.9999 – 9.9999 – The first parameter of the Steinhart-Hart equation multiplied by 10 <sup>-3</sup> .
<b>Notes</b>	The Steinhart-Hart equation: $\frac{1}{T} = C1 - C2 \cdot \ln(R) + C3 \cdot \ln^3(R)$ Where <i>R</i> is the resistance at temperature <i>T</i> .
<b>Reset Value</b>	1.125
<b>Example</b>	CALC:TRAN:TEMP:SHH:A 1.125; Sets C1 to 1.125 x 10 <sup>-3</sup> .

---

## CALCulate:TRANSform:TEMPerature:SHHart:B <nrf> CALCulate:TRANSform:TEMPerature:SHHart:B?

TEC

<b>Description</b>	Sets/Returns Steinhart-Hart parameter C2 for a thermistor temperature transducer.
<b>Parameters</b>	-9.9999 – 9.9999 – The second parameter of the Steinhart-Hart equation multiplied by 10 <sup>-4</sup> .
<b>Notes</b>	The Steinhart-Hart equation: $\frac{1}{T} = C1 - C2 \cdot \ln(R) + C3 \cdot \ln^3(R)$ Where <i>R</i> is the resistance at temperature <i>T</i> .
<b>Reset Value</b>	2.347
<b>Example</b>	CALC:TRAN:TEMP:SHH:B 2.347; Sets C2 to 2.347 x 10 <sup>-4</sup> .

---

## CALCulate:TRANSform:TEMPerature:SHHart:C <nrf> CALCulate:TRANSform:TEMPerature:SHHart:C?

TEC

<b>Description</b>	Sets/Returns Steinhart-Hart parameters C3 for a thermistor temperature transducer.
<b>Parameters</b>	-9.9999 – 9.9999 – The third parameter of the Steinhart-Hart equation multiplied by 10 <sup>-7</sup> .
<b>Notes</b>	The Steinhart-Hart equation: $\frac{1}{T} = C1 - C2 \cdot \ln(R) + C3 \cdot \ln^3(R)$ Where <i>R</i> is the resistance at temperature <i>T</i> .
<b>Reset Value</b>	0.855
<b>Example</b>	CALC:TRAN:TEMP:SHH:C 0.855; Sets C3 to 0.855 x 10 <sup>-7</sup> .

---

## CALibrate:CURR100UA:START

TEC

<b>Description</b>	Begins the 100 µA thermistor calibration procedure.
--------------------	---

---

## CALibrate:CURR100UA:DATA <nrf>

TEC

<b>Description</b>	Send data point for the 100 µA thermistor calibration procedure.
<b>Parameters</b>	DATA – a number representing the actual current in Amps
<b>Example</b>	CAL:CURR100UA:DATA 0.01; Sends a data point of 0.01A.

## CALibrate:CURR10UA:START

TEC

**Description** Begins the 10  $\mu$ A thermistor calibration procedure.

---

## CALibrate:CURR10UA:DATA <nrf>

TEC

**Description** Send data point for the 10  $\mu$ A thermistor calibration procedure.

**Parameters** DATA – a number representing the actual current in Amps

**Example** CAL:CURR100UA:DATA 0.001; Sends a data point of 0.001A.

---

## CALibrate:CURRent:START

LAS

TEC

**Description** Begins 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).

---

## CALibrate:CURRent:DATA <nrf>

LAS

TEC

**Description** Send data point 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 actual current in Amps

**Example** CAL:CURR:DATA 0.5; Sends a data point of 0.5A.

---

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

LAS

TEC

**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

**Example** CAL:DATE 05,13,2016; Sets the calibration date to May 13, 2016.

---

## CALibrate:MDI:START

LAS

**Description** Begins the monitor photodiode current calibration procedure.

---

## CALibrate:MDI:DATA <nrf>

LAS

**Description** Send data point for the monitor photodiode current calibration procedure.

**Parameters** DATA – a number representing the actual current in Amps

**Notes** This is the same as CALibrate:PDI:START and CALibrate:PDI[:DATA] below; there are two versions for user flexibility

**Example** CAL:MDI:DATA 0.0005; Sends a data point of 0.0005A.

---

## CALibrate:PDI:START

LAS

**Description** Begins the monitor photodiode current calibration procedure.

---

## CALibrate:PDI:DATA <nrf>

LAS

**Description** Send data point for the monitor photodiode current calibration procedure.

**Parameters** DATA – a number representing the actual current in Amps

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

**Example** CAL:PDI:DATA 0.0005; Sends a data point of 0.0005A.

---

## CALibrate:RTD1000UA:START

TEC

**Description** Begins the 1 mA RTD resistance calibration procedure.

---

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

TEC

**Description** Send data point for the 1 mA RTD resistance calibration procedure.

**Parameters** DATA – a number representing the actual resistance in Ohms

**Example** CAL:RTD1000UA:DATA 1000; Sends a data point of 1000Ω.

---

## CALibrate:RTD2500UA:START

TEC

**Description** Begins the 2.5 mA RTD resistance calibration procedure.

---

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

TEC

**Description** Send data point for the 2.5 mA RTD resistance calibration procedure.

**Parameters** DATA – a number representing the actual resistance in Ohms

**Example** CAL:RTD2500UA:DATA 250; Sends a data point of 250Ω.

---

## CALibrate:SENSORI:START

TEC

**Description** Execute the TE ICI sensor current calibration procedure.

**Notes** There must be nothing connected to the sensor pins.

---

## CALibrate:SENSORV:START

TEC

**Description** Begins the TE ICV sensor voltage calibration procedure.

---

## CALibrate:SENSORV:DATA <nrf>

TEC

**Description** Send data point for the TE ICV sensor voltage calibration procedure.  
**Parameters** DATA – a number representing the actual voltage in Volts  
**Example** CAL:SENSORV:DATA 1.7; Sends a data point of 1.7V.

---

## CALibrate:VMEAS:START

LAS TEC

**Description** Begins 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).

---

## CALibrate:VMEAS:DATA <nrf>

LAS TEC

**Description** Send data point 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 actual voltage in Volts  
**Example** CAL:VMEAS:DATA 1.7; Sends a data point of 1.7V.

---

## DISPlay:BRIGhtness <nrf> DISPlay:BRIGhtness?

N/A

**Description** Sets/Reports brightness setting of the front panel displays.  
**Parameters** 0 – 10 – The level of brightness desired  
(1 = minimum brightness, 10 = full brightness)  
**Reset Value** 5.12  
**Example** DISP:BRIG 5; Changes the brightness to 5.

---

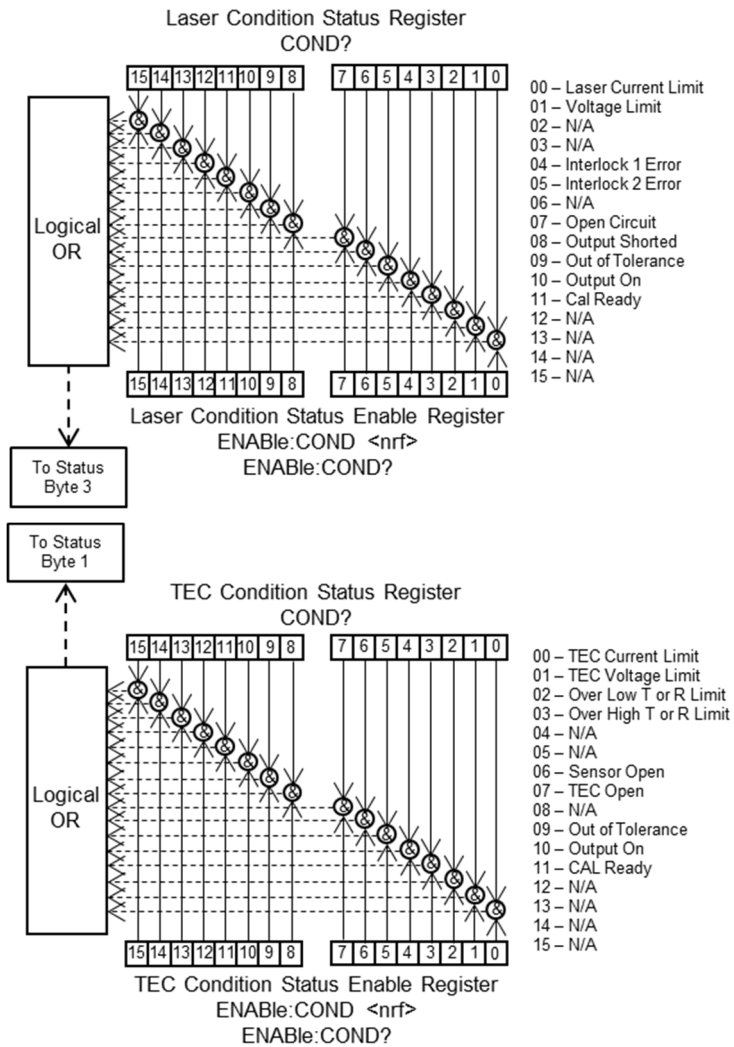
## DISPlay[:ENABle] <nrf> DISPlay[:ENABle]?

N/A

**Description** Sets/Reports on/off state of the front panel displays.  
**Parameters** 0 or 1 – 0 for off, 1 for on  
**Reset Value** 1  
**Example** DISP 1; Turns the display on.

# CONDition?

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



**Example** COND?  
A response of 1025 (bits 10 and 0 set) indicates the output is on and the laser is in current limit.

## ENABLE:CONDition <nrf> ENABLE:CONDition?

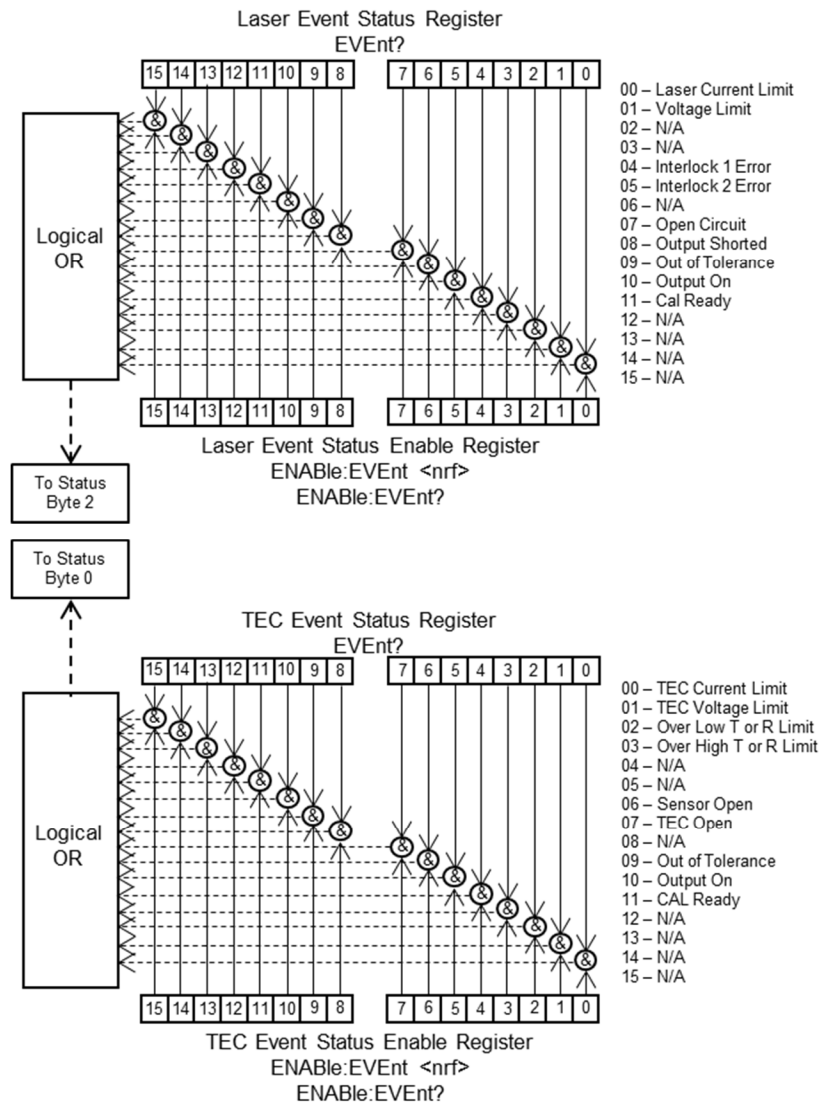
LAS TEC

- Description** Sets or reports the selected instrument's Condition Enable status register. See chapter 3, Status Reporting. See CONDition? Command for bit table.
- Parameter** A number containing the bit-encoded value to set in the register.
- Example** ENAB:COND 16  
Only bit 4 is set; when an interlock error occurs the Laser Condition Summary bit will be set in the Status Byte.

## EVEnt?

LAS TEC

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



- Example** EVE?  
A response of 8 (bit 3 set) indicates that a Over High T or R Limit condition occurred since the last read of the Event register.

## ENABle:EVEnt <nrf> ENABle:EVEnt?

LAS TEC

<b>Description</b>	Sets or reports the selected instrument's Event Enable status register. See chapter 3, Status Reporting. See EVEnt? Command for bit table.
<b>Parameter</b>	A number containing the bit-encoded value to set in the register.
<b>Example</b>	ENAB:EVE 2 Bit 1 is set, so a voltage-limit event will cause the Laser Event Summary bit to be set in the Status Byte.

---

## FORMat:SREGister <string> FORMat:SREGister?

N/A

<b>Description</b>	Sets or reports the output format for NR1 types.	
<b>Parameter</b>	Valid Parameter input strings: ASCIi HEXadecimal OCTal BINary	Report output format: 0 (numeric) 1 (hexadecimal) 2 (octal) 3 (binary)
<b>Reset Value</b>	ASCIi	
<b>Example</b>	FORMat:SREGister OCT; Changes the output format to Octal.	

---

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

LAS

<b>Description</b>	Sets/Reports photodiode bias voltage value.
<b>Parameters</b>	0.000 – 5.000 – The desired PD bias voltage in Volts.
<b>Reset Value</b>	0.0
<b>Example</b>	INP:BIAS:VOLT 2.5; Sets the photodiode bias voltage to 2.5V.

---

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

LAS

<b>Description</b>	Enables/Reports state of laser current filter.
<b>Parameters</b>	0 or 1 – 0 for disable low pass filter, 1 for enable low pass filter.
<b>Reset Value</b>	0
<b>Example</b>	INP:FILT 0; Sets the laser current filter to low pass.

---

## INSTrument:CATalog?

N/A

<b>Description</b>	Reports the possible instrument mode selections for the LDC-3706.
<b>Response</b>	Responds with the string "LAS, TEC", the two possible operating modes for the LDC-3706.



**INSTRument:NSElect <nrf>  
INSTRument:NSElect?**

N/A

**Description** Sets/Reports the instrument operating mode.  
**Parameters** 1 or 2 – 1 for laser driver mode and 2 for TEC controller mode  
**Reset Value** 1  
**Example** INST:NSEL 1; Sets the instrument operating mode to 1 for laser driver.

---

**INSTRument[:SElect] <string>  
INSTRument[:SElect]?**

N/A

**Description** Sets/Reports the instrument operating mode.  
**Parameters** LASer or TEC – LAS for laser driver mode and TEC for TEC controller mode  
**Reset Value** LASer  
**Example** INST LAS; Sets the instrument operating mode to LAS for laser driver.

---

**LIV:STABLELDI <nrf>  
LIV:STABLELDI?**

LAS

**Description** Sets/Reports laser diode current to be stable at before starting LIV.  
**Parameters** Setpoint in Amps.  
LDC-3726 0 – 0.5  
LDC-3736 0 – 4  
LDC-37620 0 – 20  
**Reset Value** 0.0  
**Example** LIV:STABLELDI 1.0; Sets the stable laser diode current for LIV to 1A.

---

**LIV:STARTLDI <nrf>  
LIV:STARTLDI?**

LAS

**Description** Sets/Reports the starting current for LIV.  
**Parameters** Starting setpoint in Amps.  
LDC-3726 0 – 0.5  
LDC-3736 0 – 4  
LDC-37620 0 – 20  
**Reset Value** 0.0  
**Example** LIV:STARTLDI 0.5; Sets the starting current for LIV to 0.5A.

---

**LIV:ENDLDI <nrf>  
LIV:ENDLDI?**

LAS

**Description** Sets/Reports the ending current for LIV.  
**Parameters** End point in Amps.  
LDC-3726 0 – 0.5  
LDC-3736 0 – 4  
LDC-37620 0 – 20  
**Reset Value** LDC-3726 0.1  
LDC-3736 2.0  
LDC-37620 2.0

**Example** LIV:ENDLDI 0.5;  
Sets the ending current for LIV to 0.5A.

**LIV:STEPLDI <nrf>**  
**LIV:STEPLDI?**

LAS

**Description** Sets/Reports the step size for the current for LIV measurements.  
**Parameters** 0 – 1 – Step size in Amps  
**Reset Value** LDC-3726 0.01  
LDC-3726 0.1  
LDC-37620 0.1  
**Example** LIV:STEPLDI 0.1; Sets the step size between current measurements for LIV to 0.1A.

---

**LIV:STEPTIME <nrf>**  
**LIV:STEPTIME?**

LAS

**Description** Sets/Reports the step time between LIV measurements.  
**Parameters** 0.010 – 100.0 – Step time in seconds.  
**Reset Value** 0.10  
**Example** LIV:STEPTIME 0.1; Sets the time between LIV measurements to 100ms.

---

**LIV:POINTS?**

LAS

**Description** Reports the number of points in an LIV measurement.

---

**LIV:BEGIN**

LAS

**Description** Starts the LIV sampling process.

---

**LIV:INPROGRESS?**

LAS

**Description** Reports if LIV measurements are in progress.  
**Notes** Returns 1 if LIV is in progress; 0 if there is no LIV in progress.

---

**LIV:READCOUNT <nrf>**  
**LIV:READCOUNT?**

LAS

**Description** Sets/reports the number of data points to return from the LIV:DATA? command.  
**Parameters** 1 – 10  
**Reset Value** 1  
**Example** LIV:READCOUNT 10; Sets the number of data points to return to 10.

---

**LIV:DATA? <nrf>**

LAS

**Description** Reports stored LIV data. Starting point must be specified.  
**Notes** This command will output LIV:READCOUNT points, starting at the value specified for LIV:DATA? <nrf>.  
**Example** LIV:DATA? 5; (Assuming LIV:READCOUNT 10, 15 total points)  
MDI<sub>5</sub>, LDI<sub>5</sub>, LDV<sub>5</sub>, MDI<sub>6</sub>, LDI<sub>6</sub>, LDV<sub>6</sub>... MDI<sub>15</sub>, LDI<sub>15</sub>, LDV<sub>15</sub>

---

## LIV:TEMPerature:INFO?

LAS

<b>Description</b>	Reports start and end temperature data for the LIV measurements.
<b>Notes</b>	Output will report starting temperature and ending temperature.
<b>Example</b>	25C, 50C

---

## LIV:IGNORETEMPSTAB <nrf> LIV:IGNORETEMPSTAB?

LAS

<b>Description</b>	Sets/Reports if LIV waits for the temperature to stabilize before measurement.
<b>Parameters</b>	0 or 1 – 0 for FALSE, 1 for TRUE
<b>Reset Value</b>	0
<b>Example</b>	LIV:IGNORETEMPSTAB 0; Sets the LIV measurement to perform an LIV without stabilizing temperature.

---

## MEASure[:SCALar]:[F]RESistance?

TEC

<b>Description</b>	Reports the TE sensor resistance in Ohms.
--------------------	---

---

## MEASure[:SCALar]:CURRent[1]?

LAS TEC

<b>Description</b>	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?

LAS

<b>Description</b>	Reports photodiode current measurement in milliamps.
--------------------	--

---

## MEASure[:SCALar]:POWER?

LAS

<b>Description</b>	Reports photodiode power measurement in milliwatts.
--------------------	---

---

## MEASure[:SCALar]:TEMPerature?

TEC

<b>Description</b>	Reports TE temperature measurement in °C.
--------------------	---

---

## MEASure[:SCALar]:VOLTage?

LAS TEC

<b>Description</b>	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?

TEC

<b>Description</b>	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] <nrf> OUTPut[1][:STATe]?

LAS TEC

<b>Description</b>	Sets/reports laser output state in laser driver mode or TEC output state in TEC controller mode.
<b>Parameter</b>	0 or 1 – 0 for off, 1 for on
<b>Reset Value</b>	0
<b>Example</b>	OUTP 0; Turns the output state for the selected instrument off.

---

## OUTPut2[:STATe] <nrf> OUTPut2[:STATe]?

LAS TEC

<b>Description</b>	Sets/reports external fan output state.
<b>Parameter</b>	0 or 1 – 0 for off, 1 for on
<b>Reset Value</b>	0
<b>Example</b>	OUTP 0; Turns off the external fan.

---

## PID:AUTOtune PID:AUTOtune?

TEC

<b>Description</b>	Sets/reports the status of PID Auto-tuning.
<b>Parameter</b>	“run” or “stop”
<b>Example</b>	PID:AUTO run; Begins the PID auto-tuning process.

---

## PID:PRESET <string> PID:PRESET:LIST?

TEC

<b>Description</b>	Sets/Reports a PID preset.
<b>Parameter</b>	GAIN1, GAIN3, GAIN10, GAIN30, GAIN100, GAIN300, LDM4405, LDM4980, LDM4990, LDM710, LDM4872, LDM49840, LDM49860, DEFAULT
<b>Notes</b>	Refer to Chapter 2, PID Temperature Control, for parameter values for each preset.
<b>Reset Value</b>	LDM-3726            LDM-3736            LDM-37620 LDM4872            GAIN1                GAIN1
<b>Example</b>	PID:PRESET GAIN10; Sets the PID preset to GAIN10.

## SENSor <string> SENSor?

TEC

<b>Description</b>	Sets/reports sensor type for TEC controller.
<b>Parameters</b>	String representing what type of sensor will be used
<b>Notes</b>	Acceptable strings for first parameter:  THERM100uA THERM10uA RTD1MA RTD2_5MA ICI ICV THERM_AUTO RTD_AUTO Default ( default is the same as THERM-AUTO)
<b>Reset Value</b>	THERM10uA
<b>Example</b>	SENS ICI; Sets the sensor to ICI.

---

## SENSor:ICI:SETpoint <nrf> SENSor:ICI:SETpoint?

TEC

<b>Description</b>	Sets/Reports current setpoint for the IC sensor.
<b>Parameters</b>	0 – 600 – Range in $\mu$ A
<b>Reset Value</b>	0.0
<b>Example</b>	SENS:ICI:SET 300; Sets the setpoint for the IC sensor to 300 $\mu$ A.

---

## SENSor:ICI:LIMit:LOW <nrf> SENSor:ICI:LIMit:LOW?

TEC

<b>Description</b>	Sets/Reports current lower limit for the IC sensor.
<b>Parameters</b>	0 – 600 – Range in $\mu$ A
<b>Reset Value</b>	0
<b>Example</b>	SENS:ICI:LIM:LOW 0; Sets the lower limit for the IC sensor to 0 $\mu$ A.

---

## SENSor:ICI:LIMit:HIGH <nrf> SENSor:ICI:LIMit:HIGH?

TEC

<b>Description</b>	Sets/Reports current upper limit for the IC sensor.
<b>Parameters</b>	0 – 600 – Range in $\mu$ A
<b>Reset Value</b>	600
<b>Example</b>	SENS:ICI:LIM:HIGH 600; Sets the high limit for the IC sensor to 600 $\mu$ A.

---

## SENSor:ICV:SETpoint <nrf> SENSor:ICV:SETpoint?

TEC

<b>Description</b>	Sets/Reports voltage setpoint for the IC sensor.
<b>Parameters</b>	0 – 6.0 – Range in Volts.
<b>Reset Value</b>	0.0
<b>Example</b>	SENS:ICV:SET 0; Sets the voltage setpoint for the IC sensor to 0V.

---

## **SENSor:ICV:LIMit:LOW <nrf> SENSor:ICV:LIMit:LOW?**

TEC

<b>Description</b>	Sets/Reports voltage lower limit for the IC sensor.
<b>Parameters</b>	0 – 6.0 – Range in Volts.
<b>Reset Value</b>	0.0
<b>Example</b>	SENS:ICV:LIM:LOW 0.0; Sets the lower voltage limit for the IC sensor to 0V.

---

## **SENSor:ICV:LIMit:HIGH <nrf> SENSor:ICV:LIMit:HIGH?**

TEC

<b>Description</b>	Sets/Reports voltage upper limit for the IC sensor.
<b>Parameters</b>	0 – 6.0 – Range in Volts.
<b>Reset Value</b>	6.0
<b>Example</b>	SENS:ICV:LIM:HIGH 6.0; Sets the upper voltage limit to 6V.

---

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

LAS

<b>Description</b>	Sets/reports enabled state of laser driver analog modulation.
<b>Parameters</b>	0 or 1 – 0 for off, 1 for on
<b>Reset Value</b>	0
<b>Example</b>	SOUR:AM 1; Sets analog modulation on.

---

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

TEC

<b>Description</b>	Sets/reports upper TEC current limit.
<b>Parameters</b>	Upper current limit in Amps LDC-3726            0.00 – 4.00 LDC-3736            0.00 – 8.00 LDC-37620          0.00 – 8.00
<b>Reset Value</b>	1.00
<b>Example</b>	SOUR:CURR:LIM:HIGH 4; Sets the upper current limit for the TEC to 4A.

---

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

TEC

<b>Description</b>	Sets/reports lower TEC current limit.
<b>Parameters</b>	Lower current limit in Amps LDC-3726            0.00 – -4.00 LDC-3736            0.00 – -8.00 LDC-37620          0.00 – -8.00
<b>Reset Value</b>	-1.00
<b>Example</b>	SOUR:CURR:LIM:LOW -4; Sets the lower current limit for the TEC to -4A.

---

## SOURce[1]:CURRENT:LIMit[:AMPLitude] <nrf> SOURce[1]:CURRENT:LIMit[:AMPLitude]?

LAS

**Description** Sets/reports laser driver current limit.

**Parameters** Limit in Amps  
 LDC-3726 0.00 – 0.505  
 LDC-3736 0.00 – 4.040  
 LDC-37620 0.00 – 20.20

**Notes** Current limit will be limited to the maximum current of range setting +1%.

**Reset Value** LDC-3726 0.100  
 LDC-3736 2.0  
 LDC-37620 10.0

**Example** SOUR:CURR:LIM 0.5; Sets the laser driver current limit to 0.5A.

## SOURce[1]:CURRENT:RANGe <nrf> SOURce[1]:CURRENT:RANGe?

LAS

**Description** Sets/reports laser driver current range. The range selected will be the lowest range that can output the specified current.

**Parameters** Range must be an accepted value for the instrument.

Range	LDC-3726	LDC-3736	LDC-37620
Low	0.100	1.00	10.0
Med	0.200	2.00	20.0
High	0.500	4.00	N/A

**Reset Value** LDC-3726 0.100  
 LDC-3736 1.00  
 LDC-37620 10

**Example** SOUR:CURR:RANG 0.500; Sets the laser driver current range to 500mA for the LDC-3726.  
 Sets the laser driver current range to 1.00A for the LDC-3736.  
 Sets the laser driver current range to 10.0A for the LDC-37620.

## SOURce[1]:CURRENT[:LEVel][:IMMediate] <nrf> SOURce[1]:CURRENT[:LEVel][:IMMediate]?

LAS TEC

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

**Parameters** Current setpoint in Amps

LDC-3726		LDC-3736		LDC-37620	
Laser	TEC	Laser	TEC	Laser	TEC
0.00 – 0.500	-4.00 – +4.00	0.00 – 4.00	-8.00 – +8.00	0.00 – 20.00	-8.00 – +8.00

**Example** SOUR:CURR 4; Sets the current for the selected instrument to 4A.

## SOURce[1]:FUNction[:MODE] <string> SOURce[1]:FUNction[:MODE]?

LAS TEC

<b>Description</b>	Sets/reports laser driver operating mode in laser driver mode or TEC operating mode in TEC controller mode.		
<b>Parameters</b>	String representing operation mode, see notes		
<b>Notes</b>	Acceptable strings for first parameter: "POWer" (laser driver mode only) "CURRent"  "TEMPerature" (TEC controller mode only) "RESistance" (TEC controller mode only)		
<b>Reset Value</b>	Laser: CURR	TEC: TEMP	
<b>Example</b>	SOUR:FUNC POW; Sets the laser driver to power mode.		

---

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

LAS

<b>Description</b>	Sets/reports laser driver photodiode power limit.		
<b>Parameters</b>	Power limit in Watts.		
<b>Note</b>	Maximum value depends on responsivity: limited by maximum IPD of 5 mA for the LDC-3726 and 10 mA for the LDC-3736 & LDC-37620. See Calculate:Transform:Power:Responsivity command.		
<b>Example</b>	SOUR:POW:LIM 0.001; Sets the photodiode power limit to 1mW.		

---

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

LAS

<b>Description</b>	Sets/reports laser driver photodiode power setpoint.		
<b>Parameters</b>	Power setpoint in Watts. Maximum value depends on responsivity.		
<b>Reset Value</b>	0.0 Watts		
<b>Example</b>	SOUR:POW 0.1; Sets the photodiode power setpoint to 0.1W.		

---

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

TEC

<b>Description</b>	Sets/reports derivative term for TEC controller PID loop in sensor mode. See Chapter 2 for a summary of PID control.		
<b>Parameters</b>	0.000000 – 10.000000 – Derivative value setting		
<b>Reset Value</b>	0.05		
<b>Example</b>	SOUR:RES:LCON:DER 0.05; Sets the derivative term for resistance to 0.05.		

---

## SOURce[1]:RESistance:LCONstants:INTEgral <nrf> SOURce[1]:RESistance:LCONstants:INTEgral?

TEC

<b>Description</b>	Sets/reports integral term for TEC controller PID loop in sensor mode. See Chapter 2 for a summary of PID control.		
<b>Parameters</b>	0.000000 – 10.000000 – Integral value setting		
<b>Reset Value</b>	0.1		
<b>Example</b>	SOUR:RES:LCON:INT 0.1; Sets the integral term for resistance to 0.1.		

---



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

TEC

<b>Description</b>	Sets/reports proportional term for TEC controller PID loop in sensor mode. See Chapter 2 for a summary of PID control.
<b>Parameters</b>	0.000000 – 100.000000 – proportional value setting
<b>Reset Value</b>	15.0
<b>Example</b>	SOUR:RES:LCON 15; Sets the proportional term for resistance to 15.

---

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

TEC

<b>Description</b>	Sets/reports TE sensor resistance low limit.
<b>Parameters</b>	0.00 – 500000 – Limit in $\Omega$
<b>Reset Value</b>	0.00
<b>Example</b>	SOUR:RES:PROT:LOW 0; Sets the resistance low limit to 0 $\Omega$ .

---

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

TEC

<b>Description</b>	Sets/reports TE sensor resistance high limit.
<b>Parameters</b>	0.00 – 500000 – Limit in $\Omega$
<b>Reset Value</b>	40000 (40k $\Omega$ )
<b>Example</b>	SOUR:RES:PROT:LOW 100000; Sets the resistance high limit to 100k $\Omega$ .

---

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

TEC

<b>Description</b>	Sets/reports TE controller resistance setpoint.
<b>Parameters</b>	0.00 – 500000 – Setpoint in $\Omega$
<b>Reset Value</b>	10000
<b>Example</b>	SOUR:RES:SPO 10000; Sets the resistance set point to 10k $\Omega$ .

---

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

TEC

<b>Description</b>	Sets/reports TE controller resistance tolerance. This setting is used in status reporting (see chapter 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.
<b>Parameters</b>	0.00 – 500000.0 – Tolerance in $\Omega$
<b>Reset Value</b>	5000.0
<b>Example</b>	SOUR:RES:TOL 7500.0; Sets the resistance tolerance to 7.5k $\Omega$ .

---

## **SOURce[1]:TEMPerature:AM[:STATe] <bool>**

TEC

### **SOURce[1]:TEMPerature:AM[:STATe]?**

<b>Description</b>	Sets/reports TE analog modulation enabled state.
<b>Parameters</b>	0 or 1 – 0 is disabled, 1 in enabled
<b>Reset Value</b>	0
<b>Example</b>	SOUR:TEMP:AM 1; Turns on the analog temperature modulation.

---

## **SOURce[1]:TEMPerature:LCONstants:DERivative <nrf>**

TEC

### **SOURce[1]:TEMPerature:LCONstants:DERivative?**

<b>Description</b>	Sets/reports derivative term for TEC controller PID loop in temperature mode. See Chapter 2 for a summary of PID control.
<b>Parameters</b>	0.000000 – 10.000000 – Derivative value setting
<b>Reset Value</b>	0.05
<b>Example</b>	SOUR:TEMP:LCON:DER 0.05; Sets the derivative term for temperature mode to 0.05.

---

## **SOURce[1]:TEMPerature:LCONstants:INTEgral <nrf>**

TEC

### **SOURce[1]:TEMPerature:LCONstants:INTEgral?**

<b>Description</b>	Sets/reports integral term for TEC controller PID loop in temperature mode. See Chapter 2 for a summary of PID control.
<b>Parameters</b>	0.000000 – 10.000000 – Integral value setting
<b>Reset Value</b>	0.10
<b>Example</b>	SOUR:TEMP:LCON:INT 0.1; Sets the integral term for temperature mode to 0.1.

---

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

TEC

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

<b>Description</b>	Sets/reports proportional term for TEC controller PID loop in temperature mode. See Chapter 2 for a summary of PID control.
<b>Parameters</b>	0.000000 – 100.000000 – Proportional value setting
<b>Reset Value</b>	15
<b>Example</b>	SOUR:TEMP:LCON 15; Sets the proportional term for temperature mode to 15.

---

## **SOURce[1]:TEMPerature:PROTection:LOW <nrf>**

TEC

### **SOURce[1]:TEMPerature:PROTection:LOW?**

<b>Description</b>	Sets/reports low limit for temperature.
<b>Parameters</b>	-100.00 – 200.00 – Low temperature limit in °C.
<b>Reset Value</b>	0
<b>Example</b>	SOUR:TEMP:PROT:LOW 0; Sets the lower limit for temperature to 0°C.

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

TEC

<b>Description</b>	Sets/reports high limit for temperature.
<b>Parameters</b>	-100.00 – 200.00 – High temperature limit in °C.
<b>Reset Value</b>	50
<b>Example</b>	SOUR:TEMP:PROT 50; Sets the upper limit for temperature to 50°C.

---

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

TEC

<b>Description</b>	Sets/reports temperature setpoint.
<b>Parameters</b>	-100.00 – 200.00 – Temperature setpoint in °C.
<b>Reset Value</b>	25
<b>Example</b>	SOUR:TEMP:SPO 25; Sets the set point for temperature to 25°C.

---

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

TEC

<b>Description</b>	Sets/reports TE controller temperature tolerance. This setting is used in status reporting (see chapter 3). When the measured temperature 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.
<b>Parameters</b>	0 – 200 – The tolerance value in °C.
<b>Reset Value</b>	10.0
<b>Example</b>	SOUR:TEMP:TOL 10.0; Sets the tolerance value to 10°C.

---

## **SOURce[1]:TOLerance:TIME <nrf> SOURce[1]:TOLerance:TIME?**

TEC

<b>Description</b>	Sets/reports TE controller temperature tolerance time. This setting is used in status reporting (see chapter 3). Allows the user to set/report the amount of time for the unit to be stable before the setpoint operation completes.
<b>Parameters</b>	0 – 600 – The tolerance time in seconds.
<b>Reset Value</b>	60
<b>Example</b>	SOUR:TOL:TIME 60; Sets the tolerance time to 60 seconds.

---

## **SOURce[1]:STABle?**

TEC

<b>Description</b>	Reports if the temperature has settled to user-specified temperature and time window.
--------------------	---

---

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

LAS

<b>Description</b>	Sets/reports laser diode compliance voltage maximum limit.
<b>Parameters</b>	0.000 – 18.000 – Maximum voltage in Volts.
<b>Reset Value</b>	9.000; Sets the compliance voltage to 9V.

---

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

<b>Description</b>	Sets/reports external fan voltage setpoint.
<b>Parameters</b>	0 – 12 – External fan voltage in Volts.
<b>Reset Value</b>	12
<b>Example</b>	SOUR2:VOLT 9; Sets the external fan voltage to 9V.

---

## **SYSTem:BEEPer:ENABLE <nrf> SYSTem:BEEPer:ENABLE?**

N/A

<b>Description</b>	Sets/reports the status of the audio indicator from the unit.
<b>Parameters</b>	0 or 1 – 0 for off, 1 for on
<b>Reset Value</b>	1
<b>Example</b>	SYST:BEEP:ENABL 1; Turns on the audio indicator.

---

## **SYSTem:ERRor:ALL?**

N/A

<b>Description</b>	Empties the queue.
--------------------	--------------------

---

## **SYSTem:ERRor:CODE:ALL?**

N/A

<b>Description</b>	Empties the queue.
--------------------	--------------------

---

## **SYSTem:ERRor:CODE[:NEXT]?**

N/A

<b>Description</b>	Reports the first error code and removes it from the error queue.
--------------------	---

---

## **SYSTem:ERRor:COUNt?**

N/A

<b>Description</b>	Reports the number of errors in the error queue.
--------------------	--

---

## **SYSTem:ERRor[:NEXT]?**

N/A

<b>Description</b>	Reports the first error and removes it from the error queue.
--------------------	--

---

## **SYSTem:PRESet**

N/A

<b>Description</b>	Resets laser controller and TE controller to default settings.
--------------------	--



# Chapter 5: Troubleshooting and Calibration

---

This chapter will help resolve any problems that may be experience with the LDC-3706 Laser Controller quickly. If additional assistance is needed, 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-3706 instruments, require yearly calibration to ensure performance to published specifications. ILX factory calibrations employ NIST traceable measurement instrumentation, and our calibration engineers and technicians use automated test equipment to accurately and efficiently capture and record calibration data. An original certificate of calibration authenticity is provided with all instrument calibrations, and a detailed report showing any pre-calibration out-of-tolerance conditions is available upon request.

Calibration turn-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 us online at [www.newport.com/b/ilx-lightwave](http://www.newport.com/b/ilx-lightwave).

## 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 ix for contact information).

SYMPTOM	CORRECTIVE ACTION
<b>GENERAL</b>	
The instrument does not power up	<p>Check the power cord to make sure that it is securely connected and check the wall outlet by connecting to a known operational device.</p> <p>Check the rear panel voltage selector to match your current region supply. Using the incorrect setting will damage the instrument.</p> <p>There are no user-serviceable fuses on this device, but there are several internal fuses. Contact customer support at ILX Lightwave.</p>
The instrument reads “Internal Communication Error”	<p>Error code 516 is the internal communication error indication that the LDC-3706 instrument is not functioning correctly. The instrument must be returned to ILX Lightwave if this error occurs.</p>
Slow or unexpected response to remote commands	<p>Check that no two devices are set to the same GPIB address.</p> <p>Make sure that there are less than 15 devices on the bus.</p> <p>Check the configuration of the GPIB controller card or COM port. Specifically note the information regarding the terminating character.</p> <p>Check that total GPIB cable length is less than 20 meters (65 feet).</p> <p>Remove all other instruments from the bus to isolate the LDC-3706. 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.</p>
The LDC-3706 instrument is not being recognized by USB	<p>Check the USB cable connection between the LDC-3706 and the computer. Ensure proper drivers are installed.</p>

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-3706. If GPIB is being used, 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 the correct address is displayed.

Check that the 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 the 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. 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.



<b>LASER CONTROLLER</b>	
Power on, but no current output	<p>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.</p> <p>If an "Open Circuit Error" is shown on the display, check the load connections and then try again.</p> <p>Check the OUTPUT ON switch, the corresponding LED should be lit.</p>
Output current at limit, cannot be lowered	<p>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.</p> <p>If in constant current mode, check the current set point and current 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.</p>
Output goes off intermittently	<p>Check the interlock circuit. An intermittent interlock will turn the output off.</p> <p>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.</p>
Unable to adjust output	<p>Check the LASER (ADJUST) indicator, the indicator must be lit for any LASER adjustments to be made.</p> <p>Check the I LIMIT parameter for the output range in use and that it is set above 0 mA.</p>
Power Mode operation has high output current, but little or no power is measured	<p>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).</p> <p>Ensure that the current limit is set correctly according to laser manufacturer's datasheet.</p>
Output exceeds Power Limit	<p>The "Power Limit" is not a hardware limit. It only serves as a warning that the power measurement has exceeded the limit set point.</p> <p>Ensure that the current limit is set correctly according to laser manufacturer's datasheet.</p>
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 error 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-3706 has an adjustable laser compliance voltage. Check to see if the LASER voltage limit setting is too low (see Chapter 2). Check laser connections.

<b>TEMPERATURE CONTROLLER</b>	
The instrument reads "Sensor Open"	<p>Confirm the appropriate sensor has been selected under the PARAM menu.</p> <p>Check the cable connections to the sensor.</p> <p>If the problem persists, contact customer support at ILX Lightwave.</p>
Power on, but temperature is not controlled or is unstable.	<p>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.</p> <p>Check that the appropriate coefficients have been set for the sensor. Refer to the <i>Sensor Options</i> section under <i>General Operating Procedures</i> in Chapter 2.</p> <p>Check that the P, I and D constants are optimized for the thermal load and that the current limit value is not too low.</p> <p>If the problem persists, contact customer support at ILX Lightwave.</p>
IC-Current sensor value is not changing on the LDC-3706.	<p>Insure the 4-wire sensor voltage measurement (pins 1 and 2) are not connected to the sensor.</p>
Inaccurate sensor, TEC voltage, or TEC current measurement on the LDC-3706.	<p>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.</p>

## Error Messages

Error messages may appear on the LDC-3706 instrument 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
[-199, -100]	Command Error
[-299, -200]	Execution Error
[-399, -300]	Device-Specific Error
[-499, -400]	Query Error
[400, 499]	TEC Control Errors
[500, 599]	Laser Control Errors

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

**Table 5.2** – Error Messages

Error Code	Explanation
-104	Data type error.
-109	Command is missing a parameter.
-113	Undefined command header.
-120	General numeric data error.
-130	General suffix error.
-150	General string data error.
-203	Command is protected and cannot be called.
-220	Error with parameter during execution.
-221	A settings conflict has occurred.
-222	Data out of range.
-224	Illegal parameter value received.
-225	Execution ran out of memory.
-232	Data received is in an invalid format.
-313	Calibration memory has been lost.
-315	Configuration memory has been lost.
-320	A storage fault has occurred.
-321	The device is out of memory.
-340	The calibration procedure has failed.
-341	The calibration data entered is invalid.
-342	The measurement calibration has failed.

<b>Error Code</b>	<b>Explanation</b>
-343	The limit calibration has failed.
-344	A calibration memory write error has occurred.
-345	A calibration memory read error has occurred.
-350	A queue overflow has occurred.
-360	General communications error.
-410	Query interrupted.
-420	Query unterminated.
-430	Query deadlock.

402	Temperature sensor open error.
403	TEC open circuit error.
407	TEC temperature limit error.
412	General TEC programming error.
501	Laser interlock error.
503	Laser open circuit error.
504	Laser over current error.
509	Laser temperature out of range error.
596	Unknown laser board detected.
597	Laser over power.

## Calibration Overview

The LDC-3706 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.

### CAUTION

**Running through calibration procedures will overwrite the factory calibration data stored on the instrument. Contact ILX Lightwave for proper annual factory calibration services.**

### WARNING

**Lasers and TECs should never be connected to the output of the LDC-3706 during calibration procedures. All calibration routines have the potential to surpass protection limits and can result in damage to lasers and TECs.**

## Recommended Equipment

Recommended test equipment for calibrating the LDC-3706 instrument 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 k $\Omega$ (for all temperature sensors) 100 $\Omega$ (for MDI) 1.2 k $\Omega$ and 300 $\Omega$ (for 1 mA RTD) 60 $\Omega$ and 240 $\Omega$ (for 2.5 mA RTD)
High Power Resistors	1 $\Omega$ , 25 W (for LDI of LDC-3726 & LDC-3736) 0.1 $\Omega$ , 100 W (for LDI and LDV of LDC-37620) 2 $\Omega$ , 150 W (for ITE and VTE) 4.5 $\Omega$ , 100 W (for LDV of LDC-3726 & LDC-3736)
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  $\pm$  1.0°C. When necessary, however, the LDC-3706 instrument 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-3706 instrument 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-3706 Laser Controller. These calibrations pertain to temperature sensor measurement, the  $I_{TE}$  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  $\mu\text{A}$  or 10  $\mu\text{A}$  constant current sources so that thermistor resistance measurements will be accurate. This procedure does not calculate  $C_1$ ,  $C_2$ , and  $C_3$ . 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  $\mu\text{A}$  or 100  $\mu\text{A}$ ). 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 (pins 7 and 8) or the 25-pin output connector of the LDC-3736/LDC-37620 (pins 14 and 15). (Note: the current from the sensor pins should be less than 120  $\mu\text{A}$ .)
2. Enter the sensor calibration mode by navigating to the "100  $\mu\text{A}$  Cal" or "10  $\mu\text{A}$  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  $C_1$  and  $C_2$ . 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  $\mu$ A thermistor, and the IC-I calibration procedures have been performed. The order in which these three procedures are performed is not important.



**For IC-Current sensors used with the LDC-3706 instrument 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  $C_1$  and  $C_2$ . 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 k $\Omega$  ( $\pm$  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 (pins 7 and 8) or the 25-pin output connector of the LDC-3736/LDC-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 $\Omega$  and 1200 $\Omega$  metal film resistor. A 4-point probe resistance measurement is recommended.
2. Connect the 300 $\Omega$  resistor to the sensor pins of the 15-pin output connector of the LDC-3726 (pins 7 and 8) or the 25-pin output connector of the LDC-3736/LDC-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 recorded for the 300  $\Omega$  resistor. Press the **TEC** button.
6. Connect the 1200 $\Omega$  resistor to the sensor pins.
7. Turn the ADJUST knob until the display indicates the same resistance recorded for the 1200  $\Omega$  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 $\Omega$  and 240 $\Omega$  metal film resistor. A 4-point probe resistance measurement is recommended.
2. Connect the 60 $\Omega$  resistor to the sensor pins of the 15-pin output connector of the LDC-3726 (pins 7 and 8) or the 25-pin output connector of the LDC-3736/LDC-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 recorded for the 60 $\Omega$  resistor. Press the **TEC** button.
6. Connect the 240 $\Omega$  resistor to the sensor pins.
7. Turn the ADJUST knob until the display indicates the same resistance recorded for the 240 $\Omega$  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  $I_{TE}$  constant current source for both polarities of current. During this procedure the  $I_{TE}$  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-3706 Laser Controller then automatically calibrates the TEC current source and limits.

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

$$I = \frac{V}{R}$$

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  $I_{TE}$  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  $I_{TE}$  current as described in the section above.
2. With the output off, connect a 2 $\Omega$ , 150 W resistor across the TEC output terminals. Pins 1, 2 (TEC+) and 3, 4 (TEC-) on the 15-pin connector for the LDC-3726 or pins 9, 10, 21, 22 (TEC+) and 12, 13, 24, 25 (TEC-) for the LDC-3736/LDC-37620.
3. Connect a calibrated DMM across the load resistor. Navigate to the " $V_{TE}$  Cal" selection in the Calibration submenu of TEC parameter menu tree.
4. Enter the calibration mode by pressing the **SET** button while the " $V_{TE}$  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 the 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 there is no intent to use any of the ranges or modulation states, calibration may be performed for only the combinations intended to be used. For example, if modulation is not intended to be used, only the three current ranges for the instrument need to be calibrated 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-3706 instrument then automatically calibrates the laser diode current source and limits.

1. Measure and record the exact resistance of a resistor, using the chart below to determine what type to measure based upon the unit:

LDC-3726	9 Pin Connector 1Ω, 25W
LDC-3736	9 Pin Connector 1Ω, 25W
LDC-37620	9W4 Pin Connector 0.1Ω, 100W

A 4-point probe resistance measurement is recommended.

2. Connect the appropriate resistor across the laser output terminals of the LDC-3706 instrument (pins {4, 5} for Laser Cathode (-) and {8, 9} for Laser Anode (+) on the 9-pin connector or pins {A3, A4, 5} for Laser Cathode (-) and {A1, A2, 3} for Laser Anode (+) on the 9W4 connector).
3. Navigate to the "LDI" selection in the Laser Calibration submenu of the laser parameter menu tree.  
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:

$$I = \frac{V}{R}$$

Where V is the accurately measured voltage across the resistor with a precision multimeter and R is the accurately measured load resistance.

Alternatively, an ammeter in series with the 1Ω resistor may be used to measure the current.

4. 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.
5. The instrument will apply a new current after a short time. Repeat step 5 for the second current.
6. 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 a resistor across the laser output terminals, using the below chart to determine which resistor to use for which unit:

LDC-3726	4.5 $\Omega$ , 100W	9 Pin Connector Pins 4,5 to 8,9
LDC-3736	4.5 $\Omega$ , 100W	9 Pin Connector Pins 4,5 to 8,9
LDC-37620	0.1 $\Omega$ , 100W	9W4 Pin Connector A3, A4, 5 to A1, A2, 3

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 the 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. The emitter must be in series with R2 (72Ω, 5W resistor). R2 and the emitter must be in parallel with R3 ({3.3Ω, 25W for the LDC-3726} or {1.25Ω, 100W for the LDC-3736 & LDC-37620}).

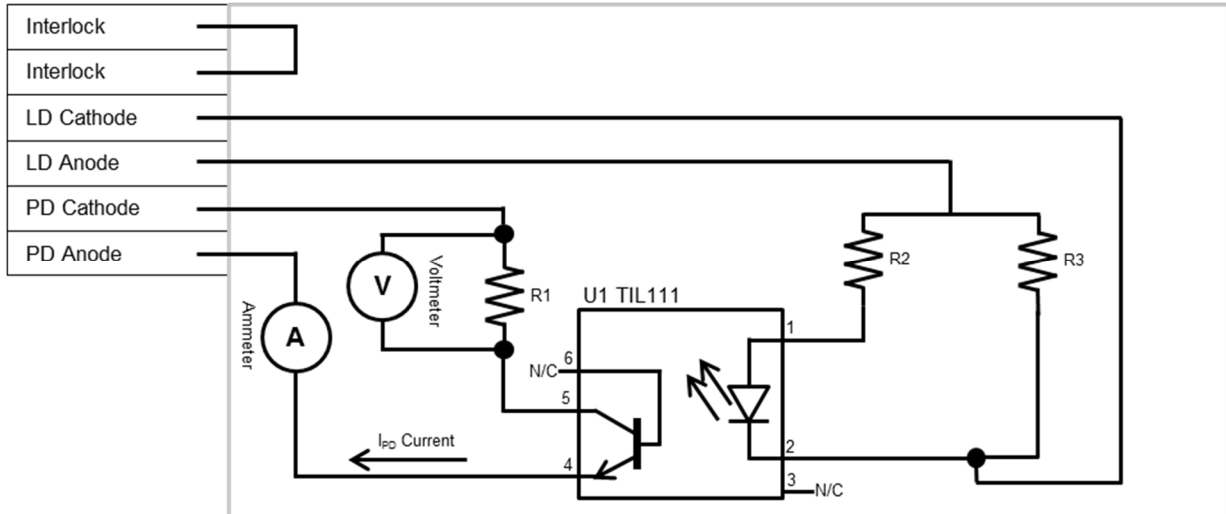


Figure 5.1 –  $I_{PD}$  Calibration Circuit

2. Connect this circuit across the laser output terminals of the LDC-3706 instrument (pins {4, 5} and {8, 9} for the LDC-3726 or LDC-3736) on the 9-pin connector or (pins {A1, A2, 3} and {A3, A4, 5} for the LDC-37620) on the 9W4 connector.
3. Measure and record the exact resistance of a 1Ω metal film resistor. A 4-point probe resistance measurement is recommended.
4. Connect the 1Ω metal film resistor (R1) to the emitter of the optocoupler detector and connect the photodiode cathode and anode input terminals of the LDC-3706 instrument (pins 6 and 7 of the 9-pin connector) to the free end of the 1Ω metal film resistor and to the collector of the optocoupler detector, respectively. Connect a calibrated DMM in parallel across the 1Ω 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:

$$I = \frac{V}{R}$$

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-3706 Laser Controllers use 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:

$$I = 1 \frac{\mu A}{K}$$

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

The LDC-3706 uses current to determine the nominal temperature,  $T_n$ , by the formula:

$$T_n = \frac{I}{1 \frac{\mu A}{K}} - 273.15$$

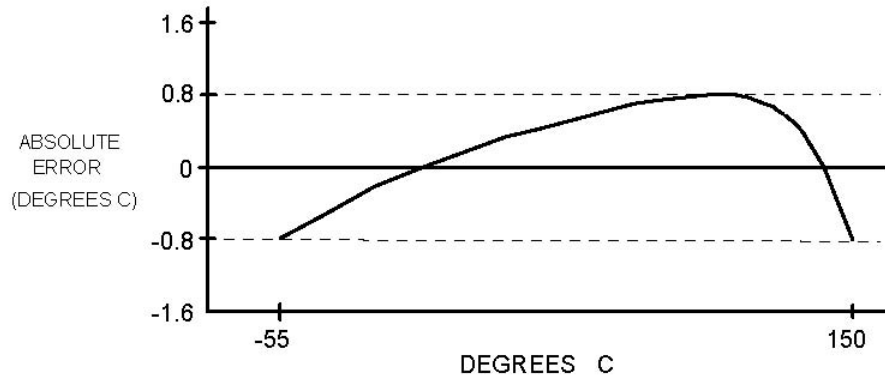
Where  $T_n$  is in °C.

The temperature,  $T_d$ , which is displayed by the LDC-3706, is first calibrated as follows:

$$T_d = C_1 + (C_2 * T_n)$$

Where offset and slope are the constants stored by the user in the LDC-3706 for the AD590.

The AD590 measurement is calibrated, at the factory, with  $C_2 = 1$  and  $C_1 = 0$  (nominal values). The AD590 grades of tolerance vary, but typically this means that without adjusting  $C_1$  or  $C_2$ , the temperature accuracy is  $\pm 1^\circ\text{C}$  over its rated operating range. If  $C_1$  and  $C_2$  are also calibrated, the temperature accuracy is  $\pm 0.2^\circ\text{C}$  over its rated operating range. However, the AD590 is not perfectly linear, and even with  $C_1$  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  $C_1$  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  $C_1$  should be used. If  $C_1$  is calibrated at 25°C, and the intended operating range is 0 to 50°C, a maximum error of about  $\pm 0.2^\circ\text{C}$  may be expected over that operating range. If a greater accuracy is desired, the two point method of determining  $C_1$  and  $C_2$  should be used. Note however, the absolute error curve is non-linear; therefore, the constant  $C_2$  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 ( $-40^\circ\text{C}$  to  $+100^\circ\text{C}$ ). This nominal value can be expressed as:

$$V = 10 \frac{mV}{K}$$

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

The LDC-3706 instruments use  $V$  to determine the nominal temperature,  $T_n$ , by the formula:

$$T_n = \frac{V}{10 \frac{mV}{K}} - 273.15$$

Where  $T_n$  is measured in  $^\circ\text{C}$ .

The temperature,  $T_d$ , which is displayed by the LDC-3706, is first calibrated as follows:

$$T_d = C_1 + \frac{C_2}{10} * T_n$$

Where  $C_1$  and  $C_2$  are the constants stored by the user in the LDC-3706 for the LM335.



When the LDC-3706 instrument is shipped from the factory, the LM335 measurement system is calibrated, but the sensor ( $C_1$  and  $C_2$ ) is not. Nominally,  $C_1 = 0$ , and  $C_2 = 10$ . In that case, the temperature accuracy is typically  $\pm 1^\circ\text{C}$  over the rated operating range. With  $C_1$  and  $C_2$  calibrated also, the temperature accuracy is typically  $\pm 0.3^\circ\text{C}$  over the rated operating range. The temperature accuracy may be improved over a narrow temperature range by a two-point calibration of  $C_1$  and  $C_2$ . However, the LM335 is not perfectly linear, and even with  $C_1$  accurately known (and  $C_2$  uncalibrated) there is a non-linear absolute temperature error associated with the device. This non-linearity caused error is typically  $\pm 0.3^\circ\text{C}$ , with the error associated with  $C_1$  assumed to be zero.

If a maximum absolute error of  $\pm 1^\circ\text{C}$  is tolerable, no calibration of  $C_1$  or  $C_2$  is required, just set  $C_1 = 0$ ,  $C_2 = 10$ . If a maximum absolute error of  $\pm 0.5^\circ\text{C}$  is tolerable, the one point calibration of  $C_1$  may be used. If a greater accuracy is desired, the two point method of determining  $C_1$  and  $C_2$  should be used. Note however, the absolute error associated with the constant  $C_2$  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-3706 instrument 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  $C_1$  parameter. Read and record the value of  $C_1$ .
3. Place the sensor at an accurately known and stable temperature,  $T_a$ . Connect the sensor to pins 14 and 15 of the LDC-3736 or LDC-37620 25-pin connector or pins 7 and 8 for the LDC-3726. Set the LDC-3706 instrument for normal constant temperature (T mode) operation. Allow the LDC-3706 instrument to stabilize at the known temperature,  $T_a$  and read the displayed temperature,  $T_d$ .
4. Determine the new value of the offset, offset-new, from the formula:

$$\text{Offset} - \text{New} = \text{Previous Offset Value} + T_a - T_d$$

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-3706 instrument 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  $C_1$  parameter. Read and record the value of  $C_1$ . Select the  $C_2$  parameter. Read and record the value of  $C_2$ .
3. Place the sensor at an accurately known and stable temperature,  $T_{a1}$ . Connect the sensor to pins 14 and 15 for the LDC-3736 or LDC-37620 25-pin connector or pins 7 and 8 of the LDC-3726 15-pin connector. Set the LDC-3706 instrument to normal constant temperature (T mode) operation. Allow the LDC-3706 instrument to stabilize at the known temperature,  $T_{a1}$  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 be 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  $C_1$  ( $C_{1n}$ ) and  $C_2$  ( $C_{2n}$ ) from the following calculations. First determine the intermediate values U and V, where

$$V = \frac{T_{a1} - T_{a2}}{T_{d1} - T_{d2}} \quad \text{and} \quad U = T_{a1} - (T_{d1} * V)$$

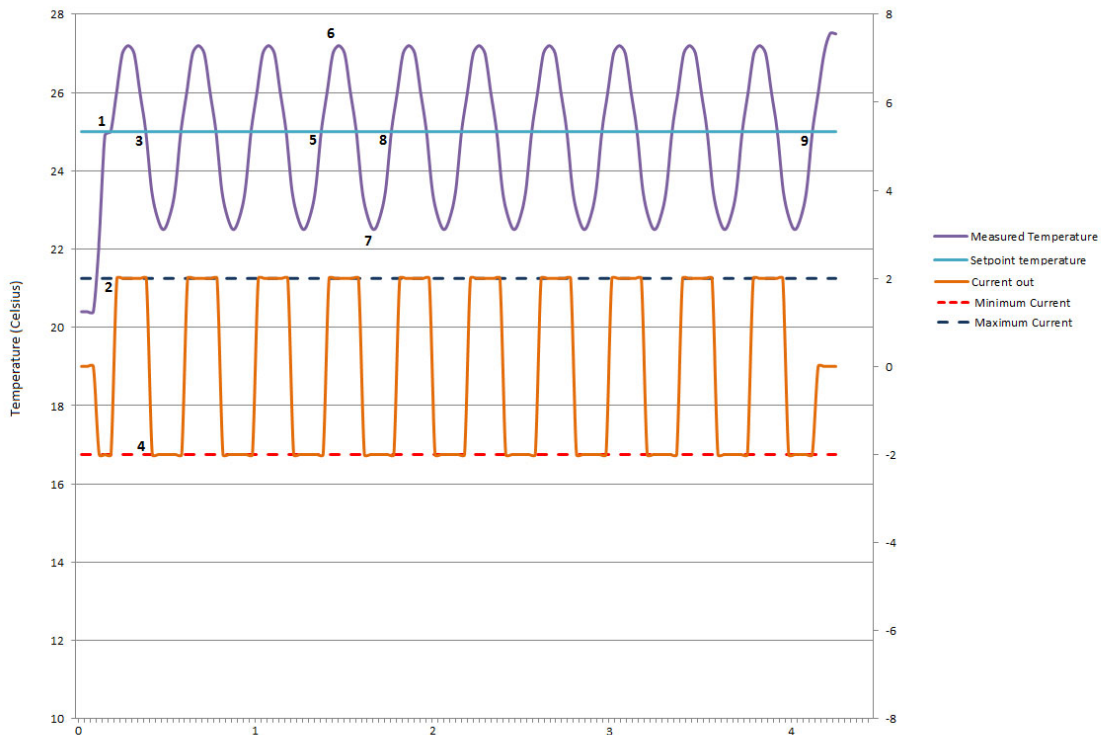
Then  $C_{1n}$  and  $C_{2n}$  can be determined by the following:

$$C_{1n} = U + (V * C_1) \quad \text{and} \quad C_{2n} = V * C_2$$

6. Replace  $C_1$  with  $C_{1n}$  by selecting the  $C_1$  parameter and entering the new  $C_{1n}$  value. Replace  $C_2$  with  $C_{2n}$  by selecting the  $C_2$  parameter and entering the new  $C_{2n}$  value.

# Appendix B: Auto-Tune Method

The LDC-3706 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 auto-tune 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 auto-tune 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 auto-tune, 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 point 1, 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 auto-tune procedure. This is why there are 10 cycles shown between point 1 and point 9 on the graph.

After the first three cycles have been completed (point 5 on the graph), the auto-tune 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:

$$\text{Driving Amplitude} = \text{Maximum TEC current} - \text{Minimum TEC current}$$

$$\text{Amplitude Ratio} = \frac{4 * \text{Driving Amplitude}}{\pi * \text{Average Measured Amplitude}}$$

$$P = 0.6 * \text{Amplitude Ratio} \qquad I = \frac{1}{\left(\frac{\text{Average Period}}{2}\right)} \qquad D = \frac{\text{Average Period}}{32}$$

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 auto-tune 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.