User's Guide

Precision Thermoelectric Temperature Controller LDT-5412

ILX Lightwave
Photonic Test & Measurement Instrumentation

ILX Lightwave Corporation · P. O. Box 6310 · Bozeman, MT, U.S.A. 59771 · U.S. & Canada: 1-800-459-9459 · International Inquiries: 406-586-1244 · Fax 406-586-9405
E-mail: support@ilxlightwave.com
www.ilxlightwave.com

70003602_7/01

TABLE OF CONTENTS

SAFETY AND WARRANTY INFORMATION

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

Safety Information and the Manual

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

CAUTION

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

WARNING

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

WARNING

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

General Safety Considerations

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

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

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

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

SAFETY SYMBOLS

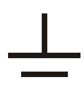
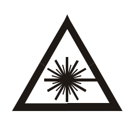
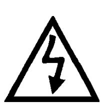
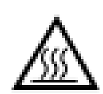
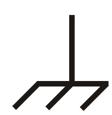
This section describes the safety symbols and classifications.

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

- Indoor use only
- Ordinary Protection: This product is NOT protected against the harmful ingress of moisture.
- Class I Equipment (grounded type)
- Mains supply voltage fluctuations are not to exceed ±10% of the nominal supply voltage.
- Pollution Degree II
- Installation (overvoltage) Category II for transient overvoltages
- Maximum Relative Humidity: <80% RH, non-condensing
- Operating temperature range of 0 °C to 40 °C
- Storage and transportation temperature of –40 °C to 70 °C
- Maximum altitude: 3000 m (9843 ft)
- This equipment is suitable for continuous operation.

Safety Marking Symbols

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

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

WARRANTY

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

Limitations

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

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

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

Returning an Instrument

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

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

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

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

Claims for Shipping Damage

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

Comments, Suggestions, and Problems

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

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

Fax . . . . (406) 586-9405

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

Or mail to:

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

When you contact us, please have the following information:

Model Number: ______________________

Serial Number: ______________________

End-user Name: ______________________

Company: ______________________

Phone: ______________________

Fax: ______________________

Description or sketch of what is connected to the ILX Lightwave instrument: ______________________

Description of the problem: ______________________

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

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

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

CHAPTER 1

GENERAL INFORMATION

This manual contains operation and maintenance information for the LDT-5412. Operating instructions are found in Chapter 2. It is recommended that Chapter 2 be read before operating the 5412.

Product Overview

The LDT-5412 is a precision thermoelectric temperature controller which reads and displays a thermistor's resistance value. This allows accurate and stable control of temperature with low noise, at a low cost. Temperature is set by setting the resistance value on the display or by connecting an external reference resistor (for a more precise reference) whose value corresponds to the desired temperature.

Specifications

OUTPUT			
Output type:	Bipolar		
Current Range:	0 to 2 A, floating		
Compliance Voltage:	≥2 VDC		
DISPLAY			
Type:	3-1/2 digit green LED		
	10 uA	**100 uA**	**TE Current**
Max Reading:	199.9 Kohms	19.99 Kohms	2 A
Resolution:	0.1 Kohm	0.01 Kohm	0.01 A
Accuracy:	±0.5 Kohms	±0.05 Kohms	±0.05
CURRENT LIMIT			
Range:	0 - 2 A		
Accuracy:	±0.25 A		
ACTUAL R MONITOR	10 Kohm/V, ±5%	100 Kohm/V, ±5%	
GENERAL			
AC Power:	100, 120, 220, 240 nominal line voltage, ±10%, 50-60 Hz		
Operating Temperature:	0 °C to 40 °C		
Storage Temperature:	-40 °C to 70 °C		
Warm-up:	1 hour for rated accuracy		
Minimum Load:	1v min on output at max current and temperature		
Connectors:	15-pin D-sub connector BNC connector		
Overall Size:	267 x 140 x 66 mm, or 10.5 x 5.5 x 2.6 inches		

Your Comments

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

CHAPTER 2

OPERATION

This chapter is a guide to setting up and operating the LDT-5412. The controls and connectors are described, and then step-by-step instructions for connecting and using the LDT-5412 are presented.

Installation

Before plugging the LDT-5412 into your AC power source, read Section 2.3. After power-up, make sure that the OUTPUT is off (LED unlit) until you have set the 5412 for your application. For operating procedure, see Section 2.5.

AC Power Considerations

The LDT-5412 can be configured for operation with nominal line voltages of 100, 120, 220, and 240 VAC. The unit is configured at the factory for the appropriate range. Check to be sure that the correct range is marked on the rear panel. The AC POWER switch is located on the front panel.

WARNING

To avoid electrical shock hazard, connect the instrument to properly earth-grounded, 3-prong receptacles only. Failure to observe this precaution can result in severe injury or death.

LDT-5412 Familiarization

The following sections describe the front panel controls on the LDT-5412. Generally these controls are intuitive and simple to operate.

Front Panel

The 5412 front panel is shown in Figure 2.1. Each of the front panel features is described in Sections 2.3.2 - 2.3.8.

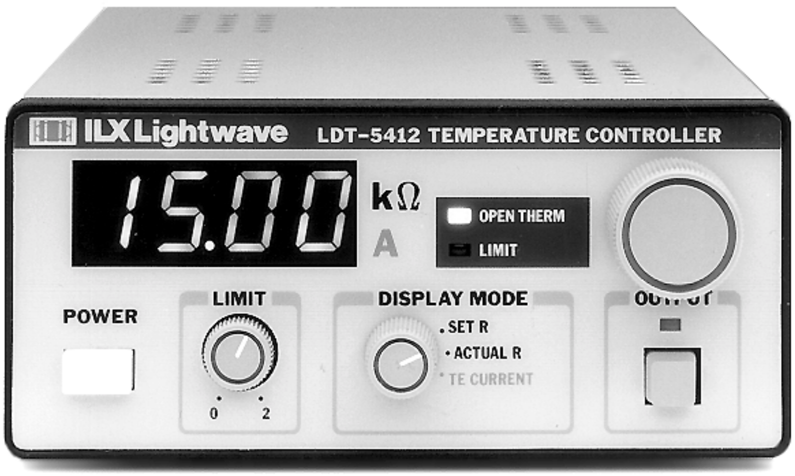


Figure 2.1 5412 Front Panel

AC Power-Up Sequence

With the LDT-5412 connected to an AC power source, pressing the POWER off/on switch will supply power to the instrument and start the power up sequence.

DISPLAY MODE Selection

The DISPLAY MODE select switch allows the user to select between the three display modes. SET R mode is used to set the desired resistance of the thermistor, and thereby set the temperature. ACTUAL R mode is used to read the actual resistance of the thermistor, and thereby determine the actual temperature. TE CURRENT mode sets the display to read the output current going to the TE module. In this mode, the actual TE current can be read, but the LIMIT TE current cannot be read on the display.

Current LIMIT Adjustment

The current LIMIT knob allows the user to set the upper limit of the output current. The user may adjust the output current from zero (LIMIT knob fully counter-clockwise CCW) to 2 Amps (LIMIT knob fully clockwise CW). This LIMIT knob is recessed to prevent accidental readjustment of the output current during operation.

The LIMIT current value is not displayed, but the adjustment is linear. For example, setting the LIMIT knob half-way between 0 and 2 Amps will limit the output current to 1 Amp. A more accurate LIMIT setting may be attained by the following procedure.

1. Connect a short between pins 2 and 3 of J301 (TE OUTPUT connector on rear panel). Connect a 10 Kohm resistor across pins 7 and 8 of J301.

2 Set the DISPLAY MODE switch to TE CURRENT. Turn the OUTPUT switch on (LED lit). Adjust the Main Control Knob fully counter-clockwise (CCW).

3 Adjust the LIMIT control until the display reads the desired limit current. Turn the OUTPUT off, remove the short from pins 2 and 3 of J301, and remove the resistor form pins 7 and 8 of J301.

During operation the TE output current is unconditionally limited to the value set by the LIMIT adjustment.

Main Control Knob

The main control knob is used whenever the SET Resistance is adjusted. Turning this knob clockwise (CW) increases the value on the display.

OUTPUT Off/On Switch

The OUTPUT off/on switch is located in the lower right-hand corner of the front panel. This switch has a toggling action which turns the output current of the LDT 5412 on and off. When the output is active, the LED indicator just above the switch will be lit.

When the OUTPUT is off, it is safe to connect or disconnect sensitive devices from the LDT 5412, even though the power supply itself is on.

The OUTPUT is off when AC power is first applied to the instrument. Additionally, there are two other conditions which will automatically cause the output to reset to the off state:

- Power Drop-outs - AC line power drop-outs lasting more than about 1 second will trigger an internal power monitor and cause the output to switch unconditionally to the off state. This sequence is also initiated when the LDT-5412 is switched off or unplugged.
- OPEN THERM - If the externally connected thermistor or set point resistor is open, the output is switched to the off state and the OPEN THERM indicator is activated. (See also Section 2.3.7, Fault Indicators.)

If any of these conditions occur and the OUTPUT goes off, the output may be turned on again by first correcting the cause of the fault and then pressing the OUTPUT off/on switch.

Fault Indicators

The LDT 5412 has two visual front panel fault indicators, OPEN THERM and LIMIT.

- OPEN THERM - indicates that the externally connected thermistor or set point resistor is open. Most commonly this happens when there is no load attached to the output or the load becomes disconnected when the output is active. When an OPEN THERM condition occurs, the LDT 5412 output is automatically turned off. The OPEN THERM indicator will remain on until the fault is corrected and the OUTPUT is manually turned on again.
- LIMIT - indicates that the LDT 5412 output is being limited to the setting of the front panel LIMIT knob. When a LIMIT condition occurs, the LIMIT indicator becomes lit.

Rear Panel

The rear panel contains the 15-pin D sub connector (J301), analog output of ACTUAL R, external set resistor connectors (located on J301) and SET RESISTOR switch, GAIN control, power cord receptacle, and serial number sticker.

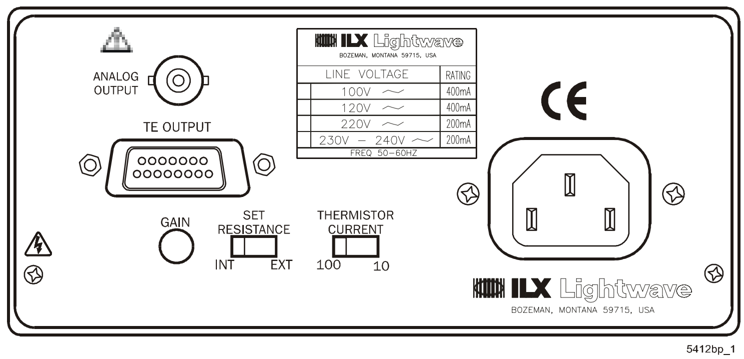
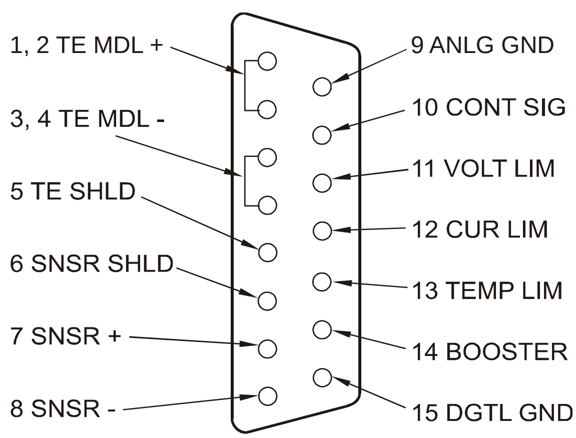


Figure 2.2 LDT-5412 Rear Panel



Note: A solid line indicates that the pins are internally jumpered.

Figure 2.3 D-connector (J301) Pinout

Output Connectors

The TE drive current is available at the 15-pin D-connector (J301). Pins 1 and 2 are jumpered for the positive output, and pins 3 and 4 are jumpered for the negative output to the TE module. The thermistor connects to pins 7 and 8.

If an external resistor is to be used for the SET RESISTANCE, it must be connected across pins 5 and 6. The SET RESISTANCE switch must be in the EXT position in order to activate that mode of operation.

The Control Signal is available at pin 10 of J301. This provides (approximately) a 1 V/A signal which can be used to drive booster current supplies.

Grounding Considerations

The outputs of the LDT-5412 are isolated from chassis ground, allowing either output terminal to be grounded at the user's option.

THERMISTOR CURRENT Switch

The thermistor source current set switch selects the thermistor current supply of either 10 uA or 100 uA. Selecting the supply current depends on the thermistor operating temperature range and the required temperature resolution. Guidelines for setting this switch are contained in Chapter 6.

SET RESISTANCE Switch

The SET RESISTANCE switch allows the user to bypass the set resistance function of the front panel and externally connect a known resistor for temperature control.

When the switch is in the EXT position, and a resistor is connected between pins 5 and 6 of J301, the 5412 uses the external resistance as its reference set point and adjusts the output accordingly. In this mode, the front panel set resistance is ignored; if the external resistor becomes disconnected (open circuit), the OPEN THERM fault indicator will come on (in addition to it coming on if the thermistor is open). This mode is useful if operation at one specific temperature is normally required. A wire-wound resistor is recommended for greatest temperature stability.

When the switch is in the INT position, the external resistor is disconnected, the front panel controls the set resistance, and the OPEN THERM fault indicator will only light when the thermistor connection is an open circuit.

GAIN Control

The GAIN control adjusts the control loop gain. This adjustment affects the slew rate and settling time of the 5412 in reaching the desired set resistance (temperature). If the GAIN is set too low, the 5412 will take longer to reach the desired resistance. If the GAIN is set too high, the 5412 may oscillate around the desired resistance and take longer to settle in.

To adjust the GAIN, use a small blade screwdriver. Turn the control fully clockwise (CW) for maximum gain. During operation, if the resistance value oscillates by more than one significant digit, reduce the GAIN counterclockwise (CCW) slightly until the resistance value settles.

ANALOG OUTPUT Connector

The ANALOG OUTPUT BNC connector allows the user to access the actual resistance measurement signal of the 5412. The signal at this connector is 1 V = 10 Kohms when the THERMISTOR CURRENT switch is in the 100 uA setting, or 1 V = 100 Kohms with the 10 uA setting.

This signal could be used for direct conversion of resistance to temperature. The user would need a computer or calculator and an algorithm to derive temperature from resistance for the specific temperature sensor device used.

Warm-up and Environmental Considerations

The LDT-5412 should be operated at an ambient temperature between 0 and 50 ûC. Storage temperatures should be in the range of -40 to 70 ûC. In order to achieve rated accuracy, the LDT-5412 should be warmed up for 1 hour before use.

> **Note:** To prevent overheating, the LDT-5412 must be kept well ventilated. Allow at least 1/2 inch clearance around the vent holes.

Operating Instructions

The following sections contain instructions on the set-up and operation of the LDT-5412.

Connecting to Your Device

When connecting or disconnecting laser diode modules and other sensitive devices to your 5412, we recommend that the OUTPUT be turned off (LED unlit). Before turning the OUTPUT on, adjust the LIMIT control. If in doubt, refer to the manufacturer's specifications. (For example, many commercial thermoelectric modules in DIL package laser diodes should not be continuously driven over 1000 mA).

General Operating Procedure

The following steps outline the operating procedure of the 5412.

1. Connect the 5412 to AC power and turn the POWER switch on (in).
2. Set the maximum current for the TE module by adjusting the 5412's LIMIT control.
3. Set the DISPLAY MODE switch to the SET R position and adjust the Main Control Knob until the display reads the desired resistance. Be sure that the SET RESISTANCE switch is in the INT position.

   Or, connect the external set resistor to J301 pins 5 and 6 and put the SET RESISTANCE switch in the EXT position. This method bypasses the front panel SET R mode.
4. Adjust the GAIN control fully clockwise (CW) for maximum gain. Set the THERMISTOR CURRENT to 10 or 100 uA, depending on the desired temperature control range.
5. Connect the TE module and thermistor to the TE OUTPUT connector (J301) and turn the OUTPUT on (LED lit).

6 Set the DISPLAY MODE switch to the ACTUAL R position and monitor the resistance on the display. If the resistance value does not settle at the set point value, but instead oscillates by more than one significant digit around the set point, turn the GAIN control slightly counter-clockwise (CCW) until the resistance value settles in.

7 To check the TE current at any time during operation, set the DISPLAY MODE switch to the TE CURRENT position.

8 To reset the resistance (temperature), repeat Steps 3 - 6 (the GAIN control may not need re-adjustment).

Temperature from Resistance

Negative temperature coefficient (NTC) thermistors are non-linear devices. Their typical resistance vs. temperature curve looks like that shown in Figure 2.4. The 5412 displays the resistance of the thermistor, and several methods for determining the temperature from this resistance value are presented below.

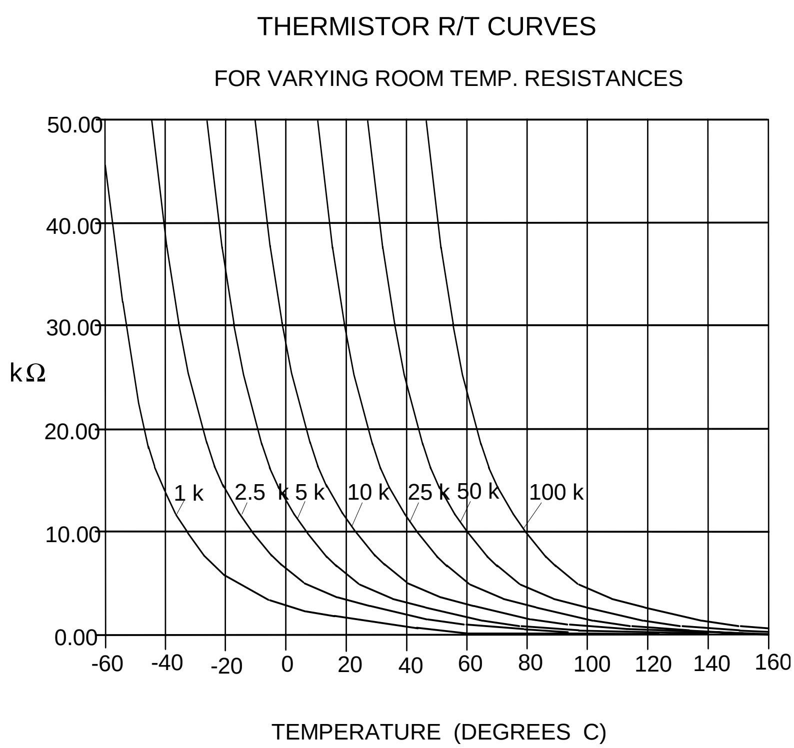


Figure 2.4 Typical R-T Curves for NTC Thermistors

Use of R-T Conversion Charts

Most thermistor manufacturers will supply a resistance - temperature (R-T) chart for their thermistors. These charts provide a direct and simple conversion. Although the temperature accuracy will not be better than the tolerance of the thermistor, this accuracy may be more than adequate for most applications. If temperature accuracy to within 1 °C is all that is required, this method is the best.

In many cases the manufacturer will supply a universal conversion table for each particular thermistor material type that they sell. This table is used for all 25 °C nominal resistance value thermistors made of that material. In these tables the resistance is not given directly. But rather, a scaling factor is given at each temperature. Resistance is found then by multiplying the nominal resistance value by the scaling factor at a given temperature. The scaling factor is often represented as the ratio R_T/R_{25}.

For example, if the thermistor is rated as a 10 Kohm thermistor, then R25 = 10,000 ohms (the resistance at 25°C). To find the resistance at 10°C, find the ratio factor at 10°C as supplied by the manufacturer. If the ratio was 1.99, then the resistance at 10°C would be 10,000 x 1.99 = 19,900 ohms.

Table 2.1 shows some typical values of resistance ratios and temperatures for a thermistor.

Table 2.1 Typical Thermistor R/T Data

Temperature in °C	R_T/R_{25}
10	1.990
11	1.897
12	1.809
13	1.726
14	1.646
15	1.571

Use of the Steinhart-Hart Equation

The Steinhart-Hart (S-H) equation accurately models the non-linear R-T characteristic curve of a negative temperature coefficient (NTC) thermistor. When the correct constants for a thermistor are known, the S-H equation can be used to convert between resistance and temperature. This method offers the advantage of accurately calculating R-T values at any point on the curve, not just those supplied by the manufacturer.

There are several forms of the Steinhart-Hart equation. The form of the S-H equation which is used by ILX Lightwave is:

$$T = 1/(C1 + C2(\text{Ln } R) + C3(\text{Ln } R)^3)$$

where R is the resistance in ohms; C1, C2, and C3 are the Steinhart-Hart constants for a particular thermistor

Generally, the Steinhart-Hart constants for a thermistor are not specified by the thermistor manufacturer. These constants may be derived specifically for each thermistor, or the nominal value for a thermistor may be used (see Appendix A). ILX Lightwave supplies the S-H constants when a Model 5001 calibrated thermistor is purchased.

Calibrated Thermistors

We offer pre-calibrated thermistors (ILX Model 5001) for use with the Steinhart-Hart equation or tabular R-T conversion. Table 5.2 shows some of the data which is supplied with the Model 5001 Calibrated Thermistor. With this data, either direct R-T conversion from the table or through use of the Steinhart-Hart constants and S-H equation is possible.

Table 2.2 Typical R/T Data with ILX Thermistor

C1 = 1.111E-3; C2 = 2.355E-4; C3 = 0.900E-7	
Temperature in °C	**Resistance in Ohms**
10.0	20038.55
10.5	19567.99

Table 2.2 Typical R/T Data with ILX Thermistor

C1 = 1.111E-3; C2 = 2.355E-4; C3 = 0.900E-7	
11.0	19109.85
11.5	18663.78
12.0	18229.43
12.5	17806.45
13.0	17394.52

Using the ANALOG OUTPUT

The measured resistance value (analog) of the thermistor is available at the rear panel BNC connector (ANALOG OUTPUT) in the form of a reference voltage. The value of this signal is 1 V = 10 Kohms when the 100 uA THERMISTOR CURRENT is selected, or 1 V = 100 Kohms when 10 uA is selected. The ANALOG OUTPUT voltage is linear with resistance, and has a 0 - 2 V range.

When the ANALOG OUTPUT signal is connected to a calculator or meter with external control signal capability and memory to store a conversion formula (such as the Steinhart-Hart equation), the resistance can be converted to temperature directly.

Sensing Current and Thermistor Selection

Choosing the right sensing current depends on the range of temperature you want to measure and the resolution you require at the highest measured temperature. To correctly set the current switch you must understand how the thermistor and the LDT-5412 interact and how temperature range and resolution values are inherent in the nature of thermistors.

Thermistor Range

Thermistors can span a wide temperature range, but their practical range is limited by their non-linear resistance properties. As the sensed temperature increases, the resistance of the thermistor decreases significantly and the thermistor resistance changes less for an equivalent temperature change -the thermistor becomes less sensitive. Consider the temperature and sensitivity figures in Table 2.3.

Table 2.3 Thermistor Sensitivity Values

Temperature	Sensitivity
-20 °C	5600 ohms/°C
25 °C	439 ohms/°C
50 °C	137 ohms/°C

In the LDT-5412 the practical upper temperature limit is the temperature at which the thermistor becomes insensitive to temperature changes. The lower end of the temperature range is limited by the maximum input voltage of the 5412. Thermistor resistance and voltage are related through Ohms Law (V = I x R). The LDT-5412 supplies current to the thermistor, either 10 uA or 100 uA, and as the resistance changes a changing voltage signal is available to the thermistor inputs of the 5412. The LDT-5412 will over-range when the input voltage exceeds about 2.0 Volts. Figure 2.5 graphically shows the lower temperature and upper voltage limits for a typical 10 Kohm thermistor. The maximum temperature ranges for a typical 10 K thermistor (a 10 K thermistor has a resistance of 10 K ohms at 25°C) are given in the table below.

Table 2.4 Temperature Ranges (10 K Thermistor)

Sensing Current	Temperature Range
10 µA	-37 to over +60 °C
100 µA	+8 to over +100 °C

Selecting the Sensing Current

To select the current setting for a typical 10 K thermistor, determine the lowest temperature you will need to sample and set the switch according to the range limits given above. If the temperature you want to sample is below 15°C you will need to set the switch to the 10 uA setting, otherwise use the 100 uA setting.

Selecting and Using Thermistors

The type of thermistor you choose will depend primarily on the operating temperature range. From Figure 5.1 you can also see that 10 K thermistors are generally a good choice for most laser diode applications where high stability is required at near room temperatures. Similarly, 5 K thermistors are often a good choice for detector cooling applications where you want to operate at temperatures from -30°C to room temperature. Much higher or lower temperature ranges can be controlled through the use of higher or lower resistance thermistors. For more information on thermistor selection, see ILX Application Note #2, Selecting and Using Thermistors for Temperature Control.

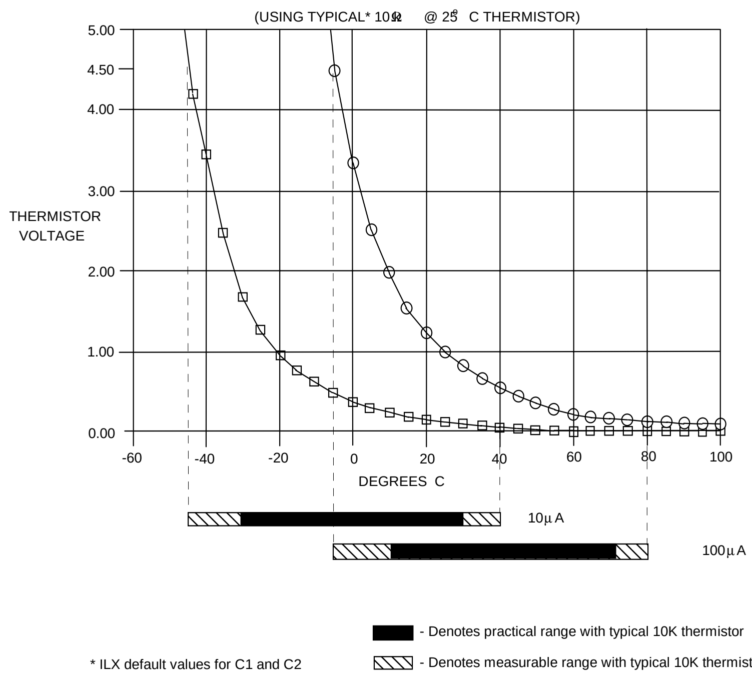


Figure 2.5 Thermistor Temperature Range

CHAPTER 3

MAINTENANCE AND TROUBLESHOOTING

Calibration and Line Voltage Selection require opening the case and exposure to potentially lethal voltages. These procedures are to be performed by qualified service personnel only. Consult the factory for service instructions.

Troubleshooting

This appendix is a guide to troubleshooting the LDT-5412. Some of the more common symptoms are listed here, and the appropriate troubleshooting actions are given. We recommend that the user start at the beginning of this guide. Read the symptom descriptions, and follow the steps for the corrective actions which apply. If you encounter problems which are beyond the scope of this troubleshooting guide, contact ILX Lightwave at the number listed at the front of this manual. Our Service Engineers will be glad to answer any questions concerning this or any other ILX Lightwave product.

Table 3.1 Troubleshooting Symptoms and Actions

SYMPTOM	CORRECTIVE ACTIONS
LDT-5412 will not power up.	• Check AC Power line voltage and power cord connection.
LDT-5412 powers up, but OUTPUT won't come on or OPEN THERM light stays lit.	• Check the SET RESISTOR switch. If it is in EXT position, there must be an external resistor connected across pins 5 and 6 of the TE OUTPUT connector (J301). Otherwise, set it to INT. • Check the thermistor connections to be sure they are not open.
After setting the SET Resistance, ACTUAL Resistance values diverge from the set value.	• Reverse the polarity on the leads of the TE module.
ACTUAL Resistance values oscillate greatly around the SET Resistance value.	• Reduce the GAIN control slightly by turning thecontrol counter-clockwise (CCW). • Check the THERMISTOR CURRENT setting. If the temperature is out of range for the thermistor current, the resistance may be erratic.
OUTPUT turns off during operation.	• Check the AC line voltage. If the AC line drops out for more than 1 sec, the OUTPUT will turn off. • Check the AC line cord to make sure that it is well-connected.
TE module won't heat or cool.	• Check the LIMIT control. If the current is too low, the desired temperature (resistance) may never be attained.

APPENDIX A

USE OF THE STEINHART-HART EQUATION

The Steinhart-Hart equation models the non-linear curve of the NTC thermistor's R-T curve. In order to use the equation, the temperature and resistance must be accurately determined at three or more points. Then, the constants C1, C2, and C3 can be determined.

T = 1/(C1 + C2(Ln R) + C3(Ln R)3)

where R is the resistance in ohms; C1, C2, and C3 are the Steinhart-Hart constants for a particular thermistor

Applying the Steinhart-Hart equation with known constants for a thermistor, the temperature can be determined at any point along the R-T curve. However, the accuracy beyond the endpoints of the R-T values used in determining the constants deteriorates as the resistance value goes out of these bounds. Therefore, it is recommended that the values of resistance and temperature used to calculate the constants for a thermistor be at the extents of the required temperature range. For example, if the temperature range of interest is -20 to +30 oC, it is best to measure the resistance at these points and near the midpoint, +5oC. The following program can be used to simultaneously solve the three equations to determine the constants C1, C2, and C3.

Some nominal values for the Steinhart-Hart constants for various thermistors are presented at the end of this appendix.

Determining the Steinhart-Hart Constants

STNHRT1b.BAS is a simple program for calculating the Steinhart-Hart constants.

```
5'  ****************** STNHRT1b.BAS **************
10 CLS
20 '
30 'Program is in GWBASIC 3.2 for IBM or compatible computers.
40 'Enter the data in the form: T1, R1, T2, R2, T3, R3
50 'where T, R are the measured temp. and resistance pairs.
60 'T is in degrees C, and R in ohms.
70 '
80 INPUT "T1, R1, T2, R2, T3, R3"; T1, R1, T2, R2, T3, R3    'input data
90 '
100 K = 273.15       'conversion factor for Kelvin
110 T1=T1+K : T2=T2+K : T3=T3+K          'convert to absolute temp.
120 A1=LOG (R1) : A2=LOG (R2) : A3=LOG (R3)  'simplify variables
130 '
140 Z=A1-A2 : Y=A1-A3          'combine elements of the equations to
150 X=1/T1-1/T2 : W=1/T1-1/T3     'form 2 equations with 2 unknowns
160 V=A1^3-A2^3 : U=A1^3-A3^3  'solve 1 unknown by substitution
170 '
180 'For simplicity, intermediate steps have been omitted.
190 '
200 C3=(X-Z*W/Y)/(V-Z*U/Y)
210 C2=(X-C3*V)/Z                      'use C3 to solve for C2
220 C1=1/T1-C3*A1^3-C2*A1         'use C3 and C2 to solve for C1
230 '
240 PRINT "C1 = "; C1
250 PRINT "C2 = "; C2
260 PRINT "C3 = "; C3
270 PRINT
280 PRINT "If any of the values are negative, there was an error. Check"
290 PRINT "data and rerun the program."
300 END
```

Once the constants, C1, C2, and C3 have been determined (using this program or other means), temperature can be calculated from resistance, or resistance calculated from temperature using the RandT.BAS program below.

For more information on using the S-H equation, refer to ILX Lightwave Application Note #4.

Using the S-H Equation to Find Resistance or Temperature

The program below, RandT.BAS, will calculate the thermistor resistance for a given temperature, or the temperature given the resistance, using the S-H equation above. The accuracy of this conversion depends on the accuracy of the S H constants.

```
5  '**************** RandT.BAS ******************
10 CLS
20 '
30 'Program is in GWBASIC 3.2 for IBM or compatible computers.
40 'Enter the S-H constants in the form: C1, C2, C3
50 'This program calculates resistance or temperature, given the S-H
60 'constants and one known parameter.
70 'T is in degrees C, and R in ohms.
80 '
90 INPUT "C1, C2, C3"; C1!, C2!, C3!           'input S-H constants
100 '
110 PRINT "Enter R to find resistance, T to find temperature,"
120 PRINT "or Q to quit."
130 '
140 A$ = INKEY$                             'input selection
150 IF A$ = "R" GOTO 190
160 IF A$ = "T" GOTO 290
170 IF A$ = "Q" GOTO 330 : ELSE GOTO 140
180 '
190 INPUT "T"; T!                          'find resistance given temperature
200 K! = T + 273.15                              'convert to Kelvin
210 U! = C2! / (3! * C3!)                        'intermediate steps
220 V! = ((1! / K!) - C1!) / (2! * C3!)
230 W! = SQR((V! * V!) + (U! * U! * U!))
240 X! = (V! + W!)^(1! / 3!)
250 Y! = (W! - V!)^(1! / 3!)
260 R! = EXP(X! - Y!)
270 PRINT " Resistance in ohms = "; R! : PRINT : GOTO 140
280 '
290 INPUT "R"; R!                         'find temperature given resistance
300 T! = (1! / (C1! + C2! * LOG(R!) + C3! * (LOG(R!)^3))) - 273.15
310 PRINT " Temperature in C = "; T! : PRINT : GOTO 140
320 '
330 END
```

Steinhart-Hart Constants

Table A.1 Nominal Steinhart-Hart Constants for some Thermistors

Manufacturer and Type	C1	C2	C3
Fenwal 3K @ 25C Curve 1	1.557	2.162	1.259
Fenwal 5K @ 25C Curve 1	1.448	2.152	1.165
Fenwal 10K @ 25C Curve 1	1.302	2.137	1.058
Fenwal 3K @ 25C Curve 10A	1.089	2.712	1.812
Fenwal 5K @ 25C Curve 10A	0.957	2.690	1.707
Fenwal 10K @ 25C Curve 10A	0.780	2.660	1.582
Fenwal 3K @ 25C Curve 16	1.405	2.369	1.006
Fenwal 5K @ 25C Curve 16	1.286	2.360	0.939
Fenwal 10K @ 25C Curve 16	1.126	2.346	0.861
Fenwal 3K @ 25C Curve 17	0.999	2.807	2.091
Fenwal 5K @ 25C Curve 17	0.864	2.780	1.977
Fenwal 10K @ 25C Curve 17	0.685	2.742	1.840
Fenwal 3K @ 25C Curve 18	1.436	2.289	1.657
Fenwal 5K @ 25C Curve 18	1.324	2.271	1.553
Fenwal 10K @ 25C Curve 18	1.174	2.246	1.432
Dale 2K @ 25C Curve 1	1.500	2.377	1.067
Dale 3K @ 25C Curve 1	1.405	2.369	1.006
Dale 4K @ 25C Curve 1	1.338	2.364	0.968
Dale 5K @ 25C Curve 1	1.286	2.360	0.939
Dale 6K @ 25C Curve 1	1.244	2.356	0.918
Dale 7K @ 25C Curve 1	1.208	2.353	0.900
Dale 8K @ 25C Curve 1	1.177	2.351	0.885
Dale 9K @ 25C Curve 1	1.150	2.348	0.872
Dale 10K @ 25C Curve 1	1.126	2.346	0.861
Dale 2K @ 25C Curve 2	1.259	2.669	1.509
Dale 5K @ 25C Curve 2	1.024	2.638	1.349
Dale 10K @ 25C Curve 2	0.848	2.615	1.248
Dale 10K @ 25C Curve 9	1.031	2.388	1.576
Dale 2.252K @ 25C Curve 1	1.472	2.375	1.048
Spectra Diode Labs Modules	0.848	2.615	1.248
Lasertron Modules	1.126	2.346	0.861
General Optronics Modules	1.126	2.346	0.861

The nominal S-H constant values listed above were determined from the manufacturer's raw data, assuming 0% resistance tolerance. The better the tolerance of your thermistor, the better the accuracy when using these nominal values.