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INSTRUCTION MANUAL

MODEL LDT-5910

THERMOELECTRIC TEMPERATURE CONTROLLER

ILX Lightwave Corporation
34368 East Frontage Road
Bozeman, Montana, U.S.A.
(406) 586-1244

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CHAPTER 1

GENERAL INFORMATION

1.1 Introduction

This manual explains how to operate and maintain the LDT-5910 Thermoelectric Temperature Controller and optional model 1227 GPIB/IEEE-488 Interface. This section gives a detailed overview of the LDT-5910. If you want to get started using the LDT-5910 right away, skip to Chapter 2 (Operation).

1.2 Product Overview

The LDT-5910 is a microprocessor-based, precision thermoelectric temperature controller designed for temperature control of laser diodes, detectors and other temperature sensitive devices. The LDT-5910 can be used for laser diode testing, laser diode frequency stabilization, IR detector cooling, and to determine the characteristics of electronic devices. The LDT-5910 combines high analog stability with the versatility of a microprocessor-based instrument. The internal microprocessor controls the operation of the LDT-5910 and performs the non-linear conversion of thermistor resistance to temperature based on three user defined constants. You can configure the LDT-5910 to operate with a wide variety of thermistor temperature sensors and TE modules. The model 1227 GPIB/IEEE-488 interface allows remote programming and completely automated control of the LDT-5910.

Features of the LDT-5910 include:

* Intuitive front panel layout
* Large and easy-to-read green LED display
* Display resolution of 0.1 degree Centigrade
* Output current limit control to safely operate all TE coolers
* Configurable for most thermistors
* Output will supply 4.6 amps
* Actual, Set and Auto display modes
* Set temperature lock
* GPIB/IEEE-488 interface available
* Booster modules can be added to extend the output power

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1.3 Specifications

Output

Output Type:	Bipolar constant current source.
Compliance Voltage:	8 Volts at 1 A, 7 Volts at 2 A, 6 Volts at 3 A.
Maximum Current Output:	4.6 Amps.
Maximum Output Power:	15 Watts typical.
Current Limit Control Range:	0 to 9999 mA, ±20 mA.
Current Limit Accuracy:	± 30 mA.

Temperature Control

Temperature Range[1]: -50 °C to >100 °C with typical 10 K thermistor.

Resolution and Accuracy[2]:

Temperature	Resolution	Accuracy
0 °C	±0.1 °C	±0.2 °C
20 °C	±0.1 °C	±0.2 °C
50 °C	±0.2 °C	±0.2 °C

Short Term Stability[3]:	0.01 °C or better.
Sensor Type:	2-wire thermistor.
Usable Resistance Range:	0 to 450 K ohm typical.
Sensing Current:	10 uA or 100 uA (user selectable).
Calibration:	Thermistors are calibrated by storing three constants of the Steinhart-Hart equation, listed below, in internal non-volatile memory. $1/T=(C1*10^{-3})+(C2*10^{-4})(\ln R)+(C3*10^{-7})(\ln R)^3$.

Display

Display Type:	4 digit green LED display.
Maximum Reading:	9999 mA, 999.9 °C.
Resolution:	±1.0 mA, ±0.1 °C.

General

Power Requirements:	105-125 or 210-250 VAC(jumper selectable) 50-60 Hz.
Size:	88 mm x 212 mm x 269 mm (3.5" x 8.4" x 10.6").
Temperature Range:	Operating: 0 to 50 °C, Storage: -40 to 70 °C.
Warmup:	1 hour to rated accuracy.

1. Temperature control range depends primarily on the type of thermistor and TE module used. The range can be extended higher and lower by selecting appropriate components. See Appendix B for more details.
2. Accuracy figures quoted are typical for a 10 K ohm thermistor and 100 uA source current setting. Accuracy figures are relative to calibration standard. Both resolution and accuracy are dependent on the user defined configuration of the instrument.
3. Short term temperature stability is a strong function of the thermal environment of the thermistor and TE module. Room air currents in particular can easily cause fluctuations of 0.1 C in an exposed mounting configuration.

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1.4 Available Options and Accessories

The following options and accessories are available for the LDT-5910.

DESCRIPTION	MODEL NUMBER
GPIB/IEEE-488 interface	1227
Output power booster module	5310
Rack mount flange kit	302
Rack mount, 1/2 width filler panel kit	324
Enclosure interlocking kit	112

The 1227 interface permits GPIB bus control of the LDT-5910 for automated test and measurement applications. Chapter 6 describes this option in detail.

The LDT-5910 enclosure can be rack mounted by itself or interlocked with other ILX Lightwave, X-series instruments. The accessories listed above are for rack mounting and interlocking these instruments.

1.5 Your Comments

ILX Lightwave Corporation is committed to making the best laser diode instrumentation available anywhere. To serve you best, 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.

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CHAPTER 2

OPERATION

2.1 Introduction

This chapter describes how to install, program and operate the LDT-5910. It is divided into five sections covering installation, front panel controls, procedures for programming the LIMIT, GAIN and constants C1, C2, and C3, the back panel connections, and normal operating procedures.

2.2 Installation

2.3 AC Power Considerations

You can configure the LDT-5910 to operate at line voltages from 105 to 125 VAC or 210 to 250 VAC. Before using the LDT-5910 check that the voltage printed on the rear panel matches the power-line voltage supplied in your area. If it is necessary to reconfigure the input voltage range refer to chapter 5 (Maintenance).

WARNING

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

2.4 Tilt-Foot Adjustment

The LDT-5910 has front legs that extend to make it easier to view the LED display. To use them, place the LDT-5910 on a stable base and rotate the legs downward until they lock into position.

2.5 Rack Mounting

The LDT-5910 may be rack mounted by installing a rack mount flange on one side of the enclosure and a half width filler panel on the other side. Alternately, two X-series enclosures will interlock side-by-side, with a pair of rack mount flanges, for rack mounting as one unit. All rack mount accessory kits contain detailed mounting instructions. Refer to Section 1.4 for applicable rack mount accessory part numbers.

2.6 LDT-5910 Front Panel Controls

The following sections describe the front panel controls on the LDT-5910. Generally these controls are simple to operate. The setup parameters, however, are intentionally a bit awkward to use so that their values are not inadvertently changed. Figure 2-1 shows the LDT-5910 front panel and its controls.

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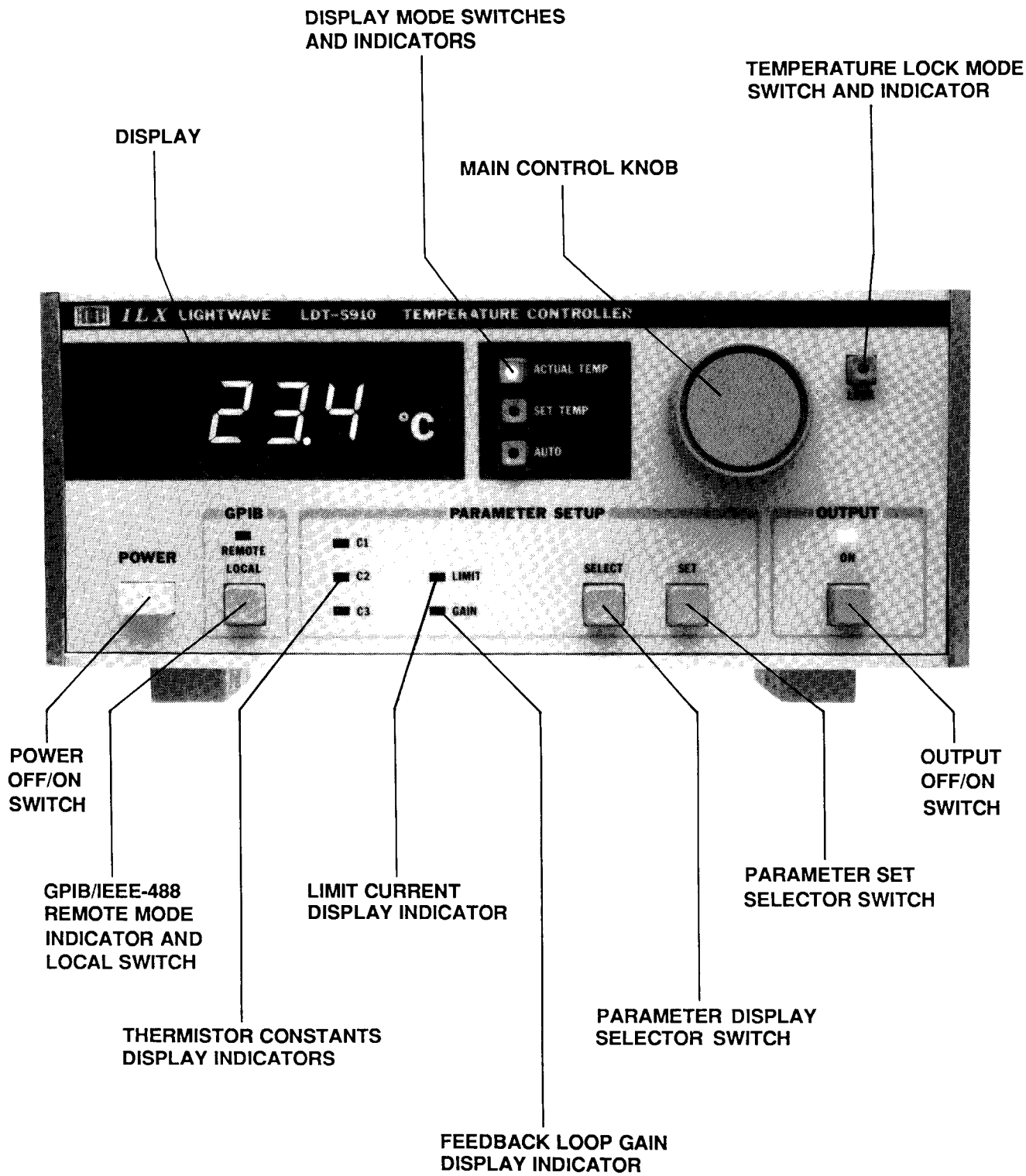


FIGURE 2-1 LDT-5910 FRONT PANEL LAYOUT

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2.7 Power

With the LDT-5910 connected to an AC power source, pressing the Power off/on switch will supply power to the instrument and start the power-up sequence. All the front panel LEDs will light. After approximately three seconds the display will read the actual temperature in degrees centigrade and the instrument will be in Auto mode.

2.8 Main Control Knob

The main control knob is a precision ten turn potentiometer that adjusts the instrument set temperature. This knob is also used to change the instrument set point temperature setup parameters. Turning this knob to the right increases the value on the display.

2.9 Auto

When in Auto mode the display shows the actual thermistor temperature until you turn the main control knob. The LDT-5910 senses that you have turned the knob and "knows" that you want to input a new set temperature. The instrument displays the new set point temperature for three seconds and then returns to displaying the actual temperature. The Auto mode allows you to accurately change the set point temperature and quickly see how your device is responding. The Auto button has a toggling action; press it to enter auto mode and press it again to exit auto mode.

2.10 Actual Temp

When this button is pressed the LDT-5910 displays the actual thermistor temperature and the LED on the button lights to indicate that the actual temperature is displayed.

2.11 Set Temp

This button, when pressed, displays the temperature set point and the LED on the button lights to indicate that the set temperature is displayed. Turn the main control knob to enter a new set point.

2.12 Lock

When you press the front panel LOCK button the LDT-5910 stores the current set temperature in memory and disables the main control knob. The LED lights to show that the unit is in lock mode. The value stays in memory even if the LDT-5910 is shut off. If you use the same set point temperature day after day you will appreciate the LDT-5910 LOCK feature. To release the LDT-5910 from lock mode, press the lock button again.

Caution

Turn the output off before releasing the unit from lock mode. If the main control knob position has changed the LDT-5910 will read the new knob position and try to control the temperature to that setting.

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2.13 Output On

This button switches the output of the LDT-5910 on. The off/on button has a toggling action. If the output is off, pressing it will turn the output on and vice versa. The LED above the indicator button lights when the output is active. When the output is off it is safe to connect or remove sensitive devices from the LDT-5910 even though power is on. The output is off when power is first applied to the instrument.

The output off/on button also indicates when a thermal limit condition occurs. In the rare event that excessive heating occurs in the LDT-5910 output stage (or in an attached booster module) the output of the LDT-5910 is turned off and the output off/on LED flashes. The output automatically turns back on when the output stage cools down.

2.14 GPIB Remote/Local Switch

This button returns the instrument to local control when it is in remote mode with the optional Model 1227 GPIB/IEEE-488 interface installed. Any command sent to the LDT-5910 via the GPIB bus automatically places the instrument in remote mode and the REMOTE LED lights. All the front panel controls, except power and GPIB REMOTE/LOCAL, are disabled and will only operate remotely. Pressing the LOCAL button will return the instrument to local mode and all the front panel controls will operate.

If no command has been sent over the GPIB bus, the LDT-5910 is in LOCAL mode and its address will be displayed when you press this button. If the instrument is in remote mode and a local lockout (LLO) message has been sent, the host has complete control of the LDT-5910 and the LOCAL button has no effect. For more information on GPIB programming, read chapter 3.

2.15 Parameter Set-Up

2.16 Select

The select function displays the setup parameters so you can review or change their values to configure the LDT-5910 for your thermistor and TE cooler. Press the SELECT button and the limit will be displayed until you release the button. The value will show for three seconds before the LDT-5910 returns its previous state. Press the Select button again to sequence the display through GAIN, C1, C2 and C3. The sections below describe each of these values and how to change them.

2.17 Set

This button, along with the main control knob, is used to change the setup parameters: LIMIT, GAIN, C1, C2 and C3. Sequence to the setup parameter you wish to change and hold the SELECT button in to continuously display this value. Simultaneously press and hold in the SET button. Now turn the main control knob until the new value is displayed. Release the Set button to store the parameter in non-volatile memory. The instrument will automatically go into lock mode to save the present set point when the SET button is pushed.

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2.18 Limit

The limit function limits the output current so that the LDT-5910 does not provide more current than your device can safely handle. To read the limit, press the select button until the LED by the LIMIT is lit and the display will show the value of the LIMIT (in mA). To change the limit, sequence to the LIMIT value and hold in the SELECT and the SET button. Turn the main control knob until the new value is on the display and then release the SET button. The LIMIT should be entered in milliamperes, e.g., 1 amp would be entered as 1000 mA.

The LDT-5910 will supply as much current as it can, up to a current limit set point of 4600 mA, to control the temperature as quickly as possible. The LDT-5910 can supply up to 10 A with the optional power booster module installed.

The LIMIT LED also indicates two special conditions, current and voltage limiting. If the output is current limited, as when the output is first turned on, the LIMIT LED will flash slowly (2 times/second). If the output is voltage limited, if for instance no load is connected, the LIMIT LED will flash faster (4 times/second).

2.19 Gain

The gain function sets the analog feedback gain which determines how fast the actual temperature reaches and settles to the set point temperature. If the gain is set too low the TE cooler will take longer to reach the temperature set-point. If it is set too high the actual temperature will overshoot and may cycle around the set temperature. The gain setting depends on the type of TE cooler that you are using, but we can give guidelines for selecting the proper gain. Set the gain to its lowest value and increase it until the actual temperature oscillates around the set temperature. Then reduce the gain one increment. To set the gain, sequence to the GAIN value and hold in the SELECT and the SET button. Turn the main control knob until the new value is displayed and then release the SET button. The feedback loop gain can be selected in increments of 1, 3, 10, 30, 100 and 300.

2.20 Calibration Constants - C1, C2 and C3

These are the constants of Steinhart-Hart equation that you enter to calibrate the LDT-5910 for different thermistors. Appendix A contains an explanation of the Steinhart-Hart equation, the values of these constants for some common thermistors and a computer program to determine these values for any thermistor. To read a constant press the SELECT button until it sequences to C1, C2 or C3. The LED next to the constant will light. To change the value, press the SELECT and the SET buttons and turn the main control knob until the correct number is displayed. Release the SET button to store the new value in non-volatile memory.

2.21 Back Panel

The back panel contains the thermistor input, TE module output, AC power entry connector, fuse, and a thermistor source current set switch. When the optional model 1227 GPIB/IEEE-488 interface is installed, the back panel additionally contains the standard GPIB bus connector and the GPIB address selector switch. The back panel is shown in figure 2-2.

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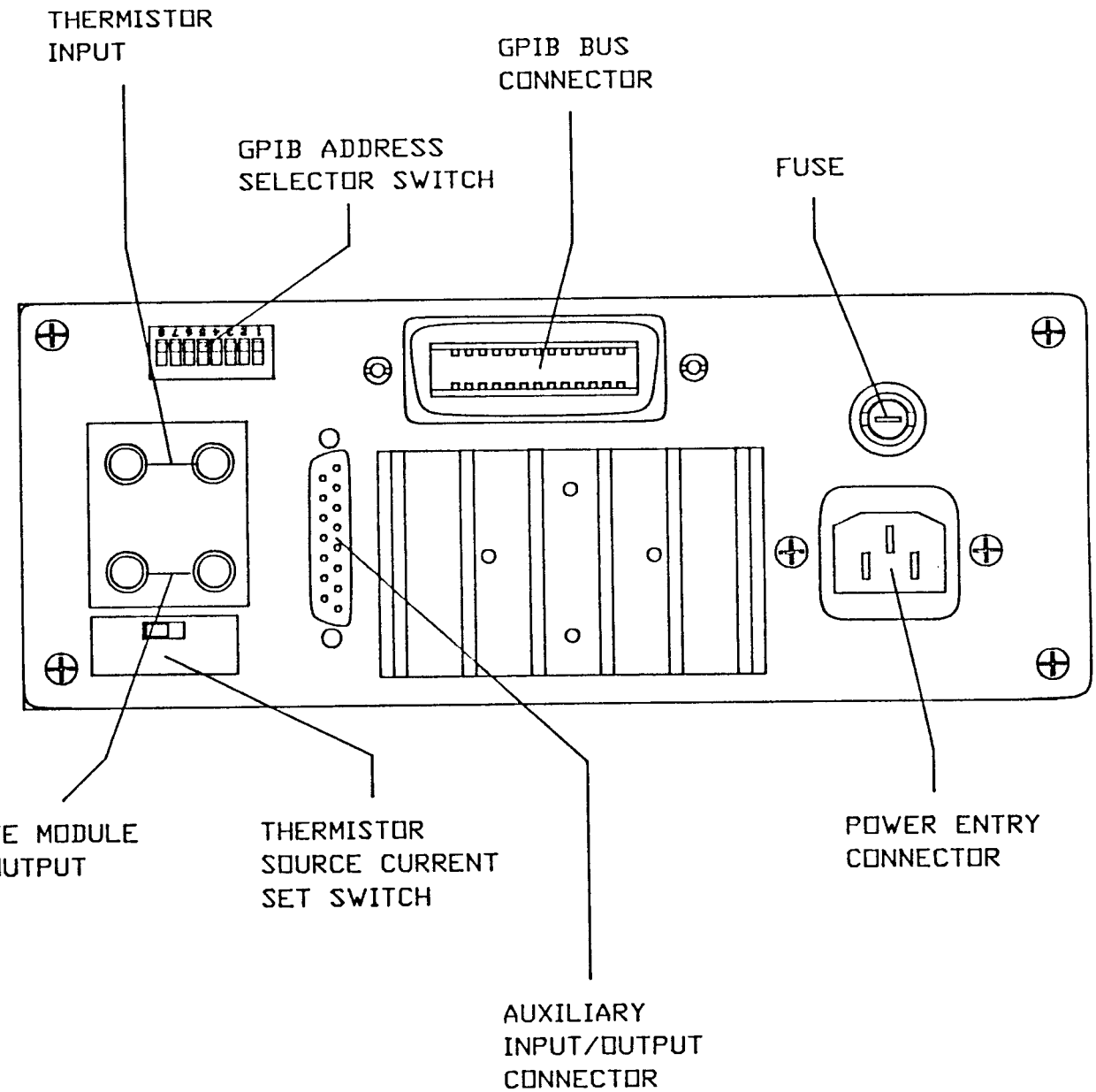


FIGURE 2-2 LDT-5910 BACK PANEL LAYOUT

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2.25 Operating Instructions

2.26 Warm Up and Environmental Considerations

Operate the LDT-5910 at an ambient temperature between 0 and 50 degrees centigrade. Storage temperatures should be in the range -40 to 70 C. To achieve the rated accuracy let the LDT-5910 warm up for about 1 hour before use.

2.27 General Operating Procedure

You can operate the LDT-5910 in several modes. The following operating procedure is applicable for most common use.

a. Plug the LDT-5910 into an AC power source supplying the correct voltage and frequency for your unit (refer to the rear panel for the correct ratings).

b. Turn on the LDT-5910. The output stage will be off at power-up.

c. Check the setting of the GAIN, LIMIT and C1, C2, and C3 to insure that they are compatible with the equipment you are using. Refer to sections 2.15 to 2.20 if you need to change them.

d. Press the Set Temp button and check the set point temperature. If it requires changing refer to the section above.

e. Turn the output on by pressing the output on button.

f. The LDT-5910 will automatically control the temperature to the set point.

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CHAPTER 3

GPIB/IEEE-488 BUS CONTROL

3.1 Introduction

When the model 1227 GPIB/IEEE-488 interface is installed and the instrument is connected to a host computer, the LDT-5910 can be used as an automated temperature controller and temperature recorder for test measurement applications.

3.2 Capabilities

The model 1227 GPIB/IEEE-488 interface allows GPIB/IEEE-488 bus control of the LDT-5910. All of the features accessible from the front panel and some advanced features can be accessed via the interface bus. Information can also be read by the host computer and printed or stored. Other features include:

* A concise and simple command set
* Full talk/listen capability
* Full serial poll capability, with bit-maskable SRQ
* Selectable output terminators
* Full local/remote capability including LOCAL LOCKOUT
* Resistance Control Mode controls to a set resistance
* Support for the following interface messages: REN, DCL,LLO, GTL and SDC

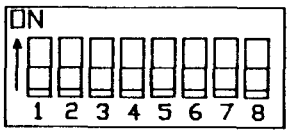
3.2 Preparation for Bus Control

To use the LDT-5910 remotely, you will need to install an IEEE-488 interface adapter in your host computer. These adapters and support software are available from several manufacturers and can be installed in most computers. This manual assumes that you have a basic knowledge of the GPIB/IEEE-488 interface bus and how to use it for instrument control. This section also assumes that you are familiar with the controls on the LDT-5910. Read Chapter 2 again if you need more details on how to operate the LDT-5910.

Install the 1227 interface using the procedure outlined in Chapter 6. Prepare the LDT-5910 for bus control using the following procedure:

1. Turn off the power to the LDT-5910/1227 and set the GPIB/IEEE-488 interface address with the DIP switches on the back panel. The switch settings are shown in figure 3-1. You can choose any address for the LDT-5910/1227 but this address should be unique, i.e., different than any other instrument connected to the bus.

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Address	Switch Positions 1	2	3	4	5
00	0	0	0	0	0
01	1	0	0	0	0
02	0	1	0	0	0
03	1	1	0	0	0
04	0	0	1	0	0
05	1	0	1	0	0
06	0	1	1	0	0
07	1	1	1	0	0
08	0	0	0	1	0
09	1	0	0	1	0
10	0	1	0	1	0
11	1	1	0	1	0
12	0	0	1	1	0
13	1	0	1	1	0
14	0	1	1	1	0
15	1	1	1	1	0

Address	Switch Positions 1	2	3	4	5
16	0	0	0	0	1
17	1	0	0	0	1
18	0	1	0	0	1
19	1	1	0	0	1
20	0	0	1	0	1
21	1	0	1	0	1
22	0	1	1	0	1
23	1	1	1	0	1
24	0	0	0	1	1
25	1	0	0	1	1
26	0	1	0	1	1
27	1	1	0	1	1
28	0	0	1	1	1
29	1	0	1	1	1
30	0	1	1	1	1
31	-Not Allowed-				

FIGURE 3-1 ADDRESS SELECTION SWITCH SETTINGS

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2. Plug the GPIB/IEEE-488 bus cable into the LDT-5910/1227 rear panel connector and secure it with the plug-mounted screws.

3. Turn on the LDT-5910/1227 and press the local button to display the selected IEEE-488 instrument address on the front panel display.

3.3 An Overview of Remote Programming

The block diagram, figure 3-2 shows the flow of data from the LDT-5910/1227 to the host computer (the controller). Each block represents a register, buffer etc, contained in the LDT-5910. The input buffer receives data from the IEEE-488 bus. The output buffer receives data from the blocks to its left and sends data to the IEEE-488 bus. The serial poll register is a separate buffer that gets the attention of the controller in special conditions.

Information is transferred between blocks by device dependant commands. For example, a Put command takes a number from the input buffer and stores it in the internal memory of the LDT-5910. Likewise the Get command gets the contents of the LDT-5910 internal memory and copies it into the output buffer.

Programming commands, like print and read in BASIC or FORTRAN, transfer the information from the input or output buffers to the controller. The following simple program provides an example of how the LDT-5910 is controlled by the host computer. The exact programming statements you will need to use will depend on the programming language and IEEE-488 interface card that you are using. This program instructs the LDT-5910 to display actual thermistor temperatures and then reads out the current display. The LDT-5910 is assumed to be at GPIB address 1.

```
100 Print @1:"D2"
110 Input @1:A$
120 Print A$
130 End
```

3.4 Command Set

There are two types of commands that you can use with the LDT-5910/1227 and the GPIB bus. Messages that only the LDT-5910/1227 understands are called device dependant commands. Messages that are common to any instrument on the GPIB bus are called interface messages. The device dependant commands are summarized in Table 3.1 and described in sections 3.7 to 3.17. The LDT-5910/1227 also responds to a number of interface messages to participate in IEEE-488 bus communication. The interface messages are summarized in Table 3.5.

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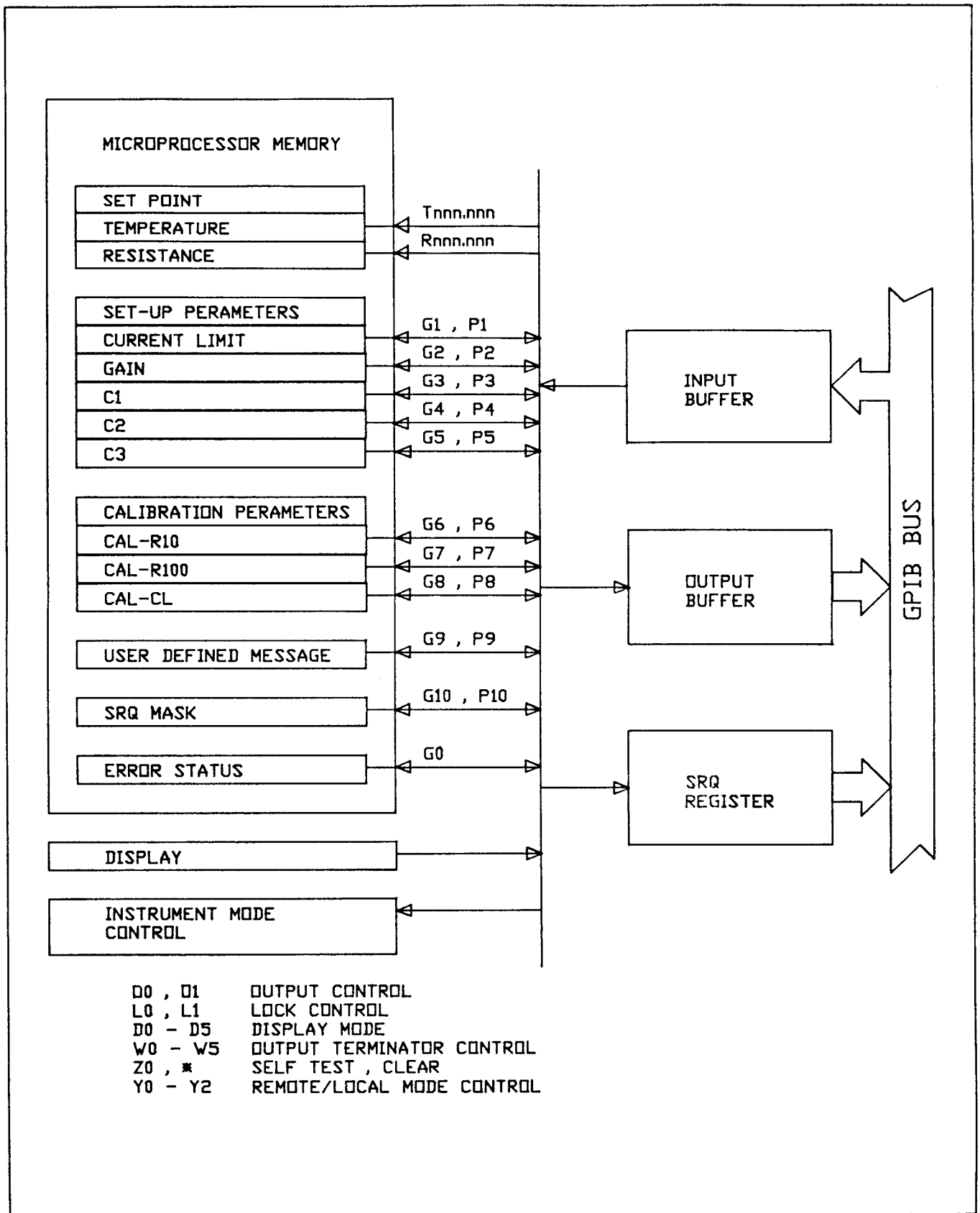


FIGURE 3-2 GPIB REMOTE OPERATION DIAGRAM

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TABLE 3.1
LDT-5910/1227 DEVICE DEPENDENT COMMAND SET

Set Point Commands

Tnnn	Adjusts the set temperature to nnnnnn C.
Rnnn	Adjust the set Resistance to nnnnnn K ohm.

Data Entry Commands

Nnnn	Numeric data
'aaa'	Alphanumeric data

Output Control Commands

O0	Turn the output off.
O1	Turn the output on.

Lock Commands

L0	Disables set temp. lock
L1	Enables set temp. lock

Display Commands

D0	Blank the display
D2	Actual Temperature
D3	Set Temperature
D4	Auto display mode enable
D5	Resistance display mode

Get Commands

G0	Get error status
G1	Get current limit
G2	Get gain
G3	Get C1
G4	Get C2
G5	Get C3
G6	Get CAL-R10 value
G7	Get CAL-R100 value
G8	Get CAL-CL value
G9	Get user defined message
G10	Get SRQ Mask

Put Values

P0	Not Used
P1	Put current limit (mA)
P2	Put gain
P3	Put C1
P4	Put C2
P5	Put C3
P6	Put CAL-R10 value
P7	Put CAL-R100 value
P8	Put CAL-C1 value
P9	Put user defined message
P10	Put SRQ mask

Terminator Commands

W0	Enable CR LF EOI (default)
W1	Enable CR LF only
W2	Enable CR EOI only
W3	Enable CR only
W4	Enable LF EOI only
W5	Enable LF only
W6	Enable EOI only
W7	Disable all output terminators

Clear Commands

*	Device Clear

Self Test Command

Z0	Begin Self Test

Control Mode Commands

Y0	Enable LOCAL mode
Y1	Enable REMOTE mode
Y2	Enable LOCAL LOCKOUT mode

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3.5 Remote Programming Procedure

To program the LDT-5910/1227 send it an ASCII string of characters made of one or more device dependant commands. The commands set the operating parameters such as the temperature set point, output current limit, etc.. A simple example of a command string would be:

"O1 D2 T-2.0"	In this example the LDT-5910/1227 output is turned on, the display is configured to read actual temperature and the set point temperature would be set to -2.0 C.

In the examples in this manual, device dependent commands are shown enclosed in quotation marks, as they would be entered in BASIC or other programming languages. The commands are also separated by spaces. The spaces are for clarity and may be omitted.

Example	*Explanation*
"* G9 T10.0"	This is the same as "*G9T10.0"

When the LDT-5910/1227 receives a command string it is placed in remote mode and then each command in the string is executed sequentially.

To read the display simply send an instruction to read ASCII data from the 1227 interface. When the LDT-5910/1227 receives the instruction, the contents of the interface output buffer are transmitted, as a string of ASCII characters, over the bus to the controller. Specific programming examples are given at the end of this chapter.

3.6 Input Syntax

This section describes the syntax rules for constructing device dependent command strings used to control the LDT-5910/1227. A command string is formed by a series of individual commands followed by a terminator.

The LDT-5910/1227 accepts alphabetic characters in either upper or lower case. Commands may be strung together into an ASCII string up to 30 characters long. Any character beyond thirty is truncated. Certain characters are ignored and may be included anywhere in a command string to make it easier to read. These ignored characters are shown below:

Space	" "
Back slash	"/"

A command string must be concluded with one or more input terminators. Processing of the command string begins when the first input terminator is received. Acceptable input terminators are shown below:

Carriage return	[CR]	ASCII (013)
Line feed	[LF]	ASCII (010)
EOI	[EOI]	

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Illegal commands and unrecognized characters (eg, O3) will set the software error flag but are otherwise ignored. The following characters are known to produce error codes:

!@#$^()<>;[] ~

Examples of correct and incorrect Command strings are given in Table 3.2.

Table 3.2 Command String Examples

Correct Command Strings

O1T30[CR] o1t30[CR][LF]	Upper or lower case alphabetic characters may be used. These command strings are identical and will turn the output on and set the control temperature to 30 C.
O1/R4.5 L1[EOI]	Spaces (and back slashes) may be used within the command string for clarity. This command turns the output on, the set point is controlled to 4.5 K ohms and the set point lock is activated.

Incorrect Command Strings

T45.34 @ o1 [EOI]	The "@" is an unrecognized character. When the "@" is encountered the software error status bit (error 32) is set and processing continues normally. The LDT-5910/1227 controls to 45.34 C and the output is turned on.
T0 T0.34 T L1 [CR]	The operator couldn't decide which temperature to set. A numeric entry was expected following the third "T". The software error status bit (error 32) will be set but processing will continue normally beginning with L1 command.
O1 B3 R10.011 [CR]	"B3" is an unknown command and this sets software error status bit. Processing will continue normally with the next command. In this case, the output will be turned on and the LDT-5910/1227 will control to 10.011K ohm.
T1.00E-1 D2 [CR]	Although "1.00E-1" is often used as scientific notation to mean 0.100 the LDT-5910/1227 does not recognize this form of notation. In this case the "E-1" is interpreted as an unrecognized command and the software error status bit (error 32) will be set. The D2 command will change the display mode so the LDT-5910/1227 displays actual temperature.

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3.7 Device Dependant Commands

3.8 Data Entry Commands

Nnnnnnn - Numeric Entry

N numeric entry where "n" is one of the following:

{signed or unsigned integer}
{signed or unsigned real number}

The N command enters the numeric values for subsequent Put commands. The interpretation of the numeric value depends on which put command it is used with. The decimal is "free floating" for real numbers, i.e., it can be placed anywhere but the LDT-5910/1227 will only control to its internal range and accuracy.

Example	*Explanation*
"N1.234 P4"	Put a value of 1.234 into the calibration constants memory in the LDT-5910/1227 as the new value of the constant C2.
"N1000 P1"	Sets the current limit to 1000.

'aaaaaaa' - Alphanumeric Data Entry

This command is used with the P9 command to put any message into non-volatile memory in the LDT-5910. Up to sixteen characters of alphanumeric data may be entered with this command. The alphanumeric information must be surrounded with the single quote sign (ASCII 39). This message can be read with the Get command, G9.

Example	*Explanation*
"'This is a test' P9"	Places the message "This is a test" into the non-volatile memory.

3.9 Set Point Commands

Tnnnnnn

This command changes the Set Temperature in the LDT-5910. Notice that there are six digits (nnnnnn) for this command. The set-point accuracy and range depend on the thermistor used and the source current setting. Appendix B discusses the limits of range and accuracy for typical thermistors.

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Example	*Explanation*
"T-2.0"	Set the Set Temperature to -2.0 C.
"T200."	The LDT-5910/1227 will try to control the output to 200 C but will be limited by the available output current and the accuracy of the set-point D/A convertor.

Rnnnnnn

This control makes the LDT-5910/1227 control to a resistance value instead of a temperature value. This function is not accessible from the front panel. The resistance is entered in K ohms. The range and accuracy is limited as shown in Table 3.3.

Example	*Explanation*
"R10.2"	The LDT-5910/1227 will control to a Resistance of 10.2 K ohm.

Table 3.3 Thermistor Range and Accuracy

	10 uA	100uA
Range	0 to 450K ohms	0.2K ohms
Resolution	0 to 45 K ohms	0.02K ohms

3.10 Output Control Commands

The Output control commands toggle the LDT-5910/1227 output off or on. The output must be turned on for the LDT-5910/1227 to control to a set temperature or resistance.

Example	*Explanation*
"O1 T30.33"	Turns the output on and controls the temperature to 30.33 C.
"O0"	Turns the output off.

3.11 Lock Commands

The lock commands lock the set temperature or set resistance into memory so that it will not be lost when the power is turned off. The last number received with the set temperature or set resistance command will be the number that is stored in memory. When the lock is active, other set temperature or set resistance commands will be ignored.

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Example	*Explanation*
"R8 L1 T20"	Controls to a resistance of 8K, locks this value into memory and ignores the set temperature command.
"T20 L0 R9"	The first set temperature is ignored (if the temperature is already locked), the lock is disabled and the new set resistance (9K) is entered.

3.12 Display Commands

The Display commands allow you to select what the LDT-5910/1227 will display on its front panel display. The display will indicate whatever it last displayed, before going to remote mode, until you send it a command to display something different.

DO - Blank the Display.

This command is used for best performance when high IEEE-488 Interface Data rates are required.

D2 - Actual Temperature

The display will indicate the actual temperature in degrees Centigrade.

D3 - Set Temperature

The Set Temperature will be displayed.

D4 - Auto Display Mode

This command enables the Auto display mode. In remote operation the display will indicate the actual temperature until a new temperature is sent to the LDT-5910. Then the new set temperature will be displayed for three seconds before reverting to the actual temperature again.

D5 - Resistance Display Mode

This command enables the display of the measured resistance, in K ohms, of the thermistor connected to the LDT-5910. This is only available in The remote mode and is useful when controlling to a set resistance.

Example	*Explanation*
"R8 d5 o1"	The LDT-5910/1227 controls to a resistance of 8K, the displays indicates resistance and the output is turned on.
"t30.2 d3 o1"	The set temperature is 30.2 C and the display reads this temperature. The output is turned on.

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3.13 Get Commands

The get commands place information into the LDT-5910/1227 output buffer for the host computer. Each Get command loads the output buffer with an ASCII output string. The get commands must precede any computer language commands, e.g., BASIC commands like read or input, because the information must be loaded into the output buffer of the LDT-5910/1227 before it can be read. After the buffer is read, any subsequent read commands will return the number displayed on the LDT-5910 front panel display.

G0 Command - Get Error Status

This command reads the status of the internal software error byte in the LDT -5910. The ASCII string generated by the G0 command may be read back over the bus by executing a read immediately after sending the G0 command. If the G0 command is sent with a string of commands, any errors set by previous commands in the string will set the appropriate error bit. After loading the ASCII string into the interface output buffer, the software command error flag is reset.

Two digits are sent back that represent the appropriate error code if an error has occurred. A summary of the error codes are listed below.

00	No Error
01	A/D Overrange
02	Temperature Calculation Unsuccessful
04	Current Limit
08	Voltage Limit
16	Thermal Limit
32	Software Error

If there is no error a zero is returned. If there was more than one error condition the number sent back equals the sum of the errors codes. Some example output strings are given here:

Example	*Explanation*
"g0"	If a 10 is returned then the temperature calculation was unsuccessful and a voltage limit condition occurred. The error byte is reset to zero.
"t-999g0"	This set temperature command will cause the current to be limited which will set error number 04. If no other errors have been recorded, the 04 will be returned by the G0 command. If another error was present before the t-999 command, say an A/D Overrange condition, a five (05) will be returned.

G1 - Get current limit

The current limit is placed in the output buffer.

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G2 Get gain

The gain will be placed in the output buffer. The gain will be one of the accepted gains (1,3,10,30,100,300).

G3 Get C1
G4 Get C2
G5 Get C3

The Get C1,C2 or C3 commands will move values, for an internally stored thermistor calibration constant, to the output buffer.

G6 Get CAL-R 10 value
G7 Get CAL-R100 value

This moves the internal resistance scaling factors, for the 10 uA and 100 uA internal resistance calibration, into the output buffer. Read chapter 5 for an explanation of what these scaling factors represent.

G8 Get CAL-CL value

This moves the internally stored current limit calibration scaling factor into the output buffer. Read chapter 5 for an explanation of what this calibration scaling factor represents.

G9 Get User Defined Message

The G9 command loads the output buffer with the user defined message that has been stored in the non-volatile memory. The message is stored in the LDT-5910's memory with the P9 command.

G10 Get SRQ Mask

This command copies the present SRQ mask into the output buffer. The SRQ mask is placed into memory with the P10 command. Service Requests, the serial poll register and the SRQ mask are discussed in sections 3.18 and 3.19.

3.14 Put Values

The put commands can configure the LDT-5910/1227 and select the operating mode by entering "putting" information in the appropriate registers. The PUT commands are described in this section.

P1-Put Current Limit (mA)

Enters the current limit for the LDT-5910.

Example	*Explanation*
"N1000 P1"	Sets the current limit to 1000 mA.

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P2 - Put Gain

Enters the gain. The gain must be one of the acceptable gains for the instrument. i.e. 1, 3, 10, 30, 100 or 300. Any other number will generate an error code.

Example	*Explanation*
"N300 P2"	Sets the gain to 300.

P3 - Put C1
P4 - Put C2
P5 - Put C3

These put commands store values, of the constants C1,C2 or C3 for the Steinhart-Hart equation, in the LDT-5910's non-volatile memory.

Example	*Explanation*
"N1.434 P5"	Puts the value of 1.434 into memory for C3.

P6 Put CAL-R10 Value
P7-Put CAL R100 Value

The P6 and P7 commands enter an input calibration scaling factor used to calibrate the resistance values. The input must be a five digit integer. For more information about this calibration constant refer to Chapter 5.

Example	*Explanation*
"n10437 p6"	Puts the scaling factor 10437 into memory for the 10 uA calibration constant.

P8 - Put Calibration CL Value

The P8 command inputs the current limit calibration scaling factor to calibrate the Current Limit. The input must be a five digit integer. For more information about this calibration constant refer to Chapter 5.

Example	*Explanation*
"N11237 p8"	Puts the value of 11237 into memory for the current limit calibration constant.

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P9 - Put User Defined Message

The P9 command stores user defined messages in the internal calibration memory. The message may be read with a G9 command. The message may consist of up to 16 ASCII characters and typically represents the instruments identification, calibration date, etc. Lower case letters are converted to upper case. The data must be entered in alphanumeric format and must be surrounded by single quotes (ASCII 39).

Example	*Explanation*
"'CALDATE 7.13.87'p9"	Loads the message "CALDATE 7.13.87" into the non-volatile memory.

P10 - Put SRQ Mask

The P10 command programs the LDT-5910/1227 to make service requests on user-specified conditions. The two digit number code for the SRQ mask is interpreted below.

00	To disable the SRQ
01	For SRQ on an A/D Overrange
02	For SRQ on an Unsuccessful Temperature Calculation
04	For SRQ on a Current Limit Condition
08	For SRQ on a Voltage Limit Condition
16	For SRQ on a Thermal Limit Condition
32	For SRQ on a Software Error

To enable more than one condition, add the numbers to get the mask value. Numeric entries for the P10 command must be between 0 and +63 inclusive or an error will occur and the SRQ mask will not change. The entry may be expressed as an integer, real number as described in the n command. any factional part is ignored. For more information on the SRQ mask refer to sections 3.18 and 3.19.

Example	*Explanation*
"N17 P10"	Sets the SRQ mask to 17 and enables a SRQ on A/D Overrange or Thermal Limit.
"N1 P10"	Sets the SRQ mask to 01 and enables the SRQ on A/D overrange.
"N40 P10"	The controller is alerted to generate a SRQ when there is a Software Error or a voltage limit condition. All other errors still effect the error status register, and can be read with the G0 command, but do not generate a Service Request.

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3.15 Terminator Commands

The terminator commands select what terminators the LDT-5910/1227 appends to every output string. The available terminators are Carriage Return, Line feed and End or Identify. CR and LF are ASCII control codes, sent over the data lines just like output data. EOI is a uni-line message which is sent simultaneously with the last character in the output string. Normally ,each output string is terminated with CR followed by LF and EOI. The LDT-5910/1227 defaults to W0 on power up and any device clear command.

Example	*Explanation*
"W1"	The host computer will append a carriage return and a line feed to each command that is sent.

3.16 Clear Command

The asterisk command resets the LDT-5910/1227 to the power-up default settings and clears all registers and buffers except for the input buffer. The remote/local status remains unchanged. The asterisk is executed in its proper turn in a string, just like any other command, without affecting the contents of the input buffer. All commands which precede the * command are performed. The asterisk is useful to insure that the LDT-5910/1227 is initialize to the same state each time a program is run. By contrast the similar interface messages DCL (Device Clear) and SDC (Selected Device Clear) cause the entire input buffer to be cleared immediately.

Example	*Explanation*
"* t20.0 O1"	These commands first reset the LDT-5910/1227 to the power-up configuration of auto display mode, output off and local mode. The t20 command places the unit in remote and sets the control temperature to 20.0 C and the output is turned on.

3.17 Self Test Command

The Z0 command starts the diagnostic self-tests. If an error is detected an error message is loaded into the output buffer and displayed on the front panel After the last test, the LDT-5910/1227 is reset to the power-on condition and the display indicates actual temperature.

Since the LDT-5910/1227 is reset at the end of the self-test the Z0 command should only be sent by itself. The LDT-5910/1227 will ignore any subsequent commands in a command string.

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Example	*Explanation*
"z0"	The LDT-5910 does a diagnostic self test and resets to the Power On conditions.
"z0 11"	The LDT-5910/1227 diagnostic self test is performed. The instrument then defaults to the power-up settings and the L1 command is ignored.

3.18 Control Mode Command

Y0 Enable Local Mode

This command will return the LDT-5910/1227 to local mode after the Local Lockout command is issued.

Y1 Enable Remote Mode

This command is automatically sent from the 1227 interface board to the LDT-5910 with any device dependant command. It is primarily reserved for remote operation via an RS-232 interface connection.

Y2 Enable Local Lockout Mode

Local Lockout Mode will disable the remote/local button on the front panel of the LDT-5910. The instrument cannot be returned to local mode until the Enable Local Mode command (Y0) is sent.

Example	*Explanation*
"y2 d4"	The instrument is placed in local lockout and the front panel controls are disabled (including the LOCAL /REMOTE switch). The Auto display mode is activated.
"y0"	The LDT-5910/1227 is returned to local mode.

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3.19 Service Requests

Service requests let bus instruments get the attention of the host computer. If more than one instrument on the bus is capable of sending service requests, the host can learn which one made the request by taking a serial poll. Each device, including the LDT-5910, responds to the poll by sending the contents of its serial poll register. The serial poll register indicates whether the device requested service, and if so, the reason for the request. Service requests are sent over a separate line (one of the IEEE-488 bus lines called the SRQ line) and do not affect the output buffer.

The LDT-5910/1227 can be programmed to make a service request on user-specified conditions. The conditions are specified by entering a value for the service request (SRQ mask) with the P10 command (which can be read with the G10 command). The SRQ mask is a two digit integer that specifies which conditions will generate a service request. The SRQ mask works by selectively ignoring any unspecified conditions of all the conditions that are monitored by the serial poll register in the LDT-5910.

3.20 The Serial Poll Register and the SRQ Mask

The serial poll register is a binary register which contains eight bits, as shown in table 3.4. The SRQ mask can enable any combination of serial poll register bits 1 through 6. Its six-bit binary representation is AND-ed bit-for-bit with error register bits 1 through 6 and the results sent to the serial poll register. If any mask-enabled bit in the serial poll register comes true the RQS bit (bit 7) is set true, generating a service request.

At power-up of on any device-clear command, the SRQ mask is set to 00. This prevents service requests by holding each bit false under all conditions. The serial poll register is cleared whenever the LDT-5910/1227 receives a new input command string.

Table 3.4 Serial Poll Register

Bit	Condition
0	No Error
1	A/D Overrange
2	Temperature Calculation Unsuccessful
3	Current Limit
4	Voltage Limit
5	Thermal Limit
6	Software Error
7	RQS

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3.21 Interface Messages

Programmers working with high level languages (like BASIC) generally need not be concerned with these messages since they are often handled by the internal software drivers. The interface messages understood by the LDT-5910/1227 are listed in Table 3.5. All of these messages originate at the controller.

Table 3.5 Interface Messages

MLA	My Listen Address - Addresses the 1227 to listen.
MTA	My Talk Address - Addresses the 1227 to talk.
UNL	Unlisten - Addresses all devices to unlisten.
UNT	Untalk - Addresses all talkers to untalk.
ATN	Attention - A uni-line message that instructs the 1227 to interpret a multi-line message as an interface message (as opposed to a device dependent command).
DCL	Device Clear - A multi-line message that causes the 1227 to reset to its power-up configuration: output off, auto display and local mode.
LLO	Local Lockout - A multi-line message that disables all LDT-5910/1227 front-panel controls including the LOCAL/REMOTE button.
GTL	Go To Local - Causes the LDT-5910/1227 to switch to LOCAL mode.
SDC	Selected Device Clear - Causes the 1227 to reset to its power up configuration: output off, mode set to local. This command differs from DCL above in that it affects only the addressed interface whereas DCL affects all listeners on the bus.
REN	Remote Enable - A uni-line message which, when received with MLA, switches the LDT-5910/1227 to remote. When REN is set false the LDT-5910/1227 switches to local and removes the local lockout.

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3.22 Example Programs

An example program is shown below that exercises commonly used, remotely accessible features of the LDT-5910/1227.

```
10 '*************************** TCTRL1 ******************************
12 '
14 'Program to control the LDT-5910 to a user specified temperature
16 'and determine when temperature stabilization has been achieved.
20 '
24 'This program is written for use with an IBM PC/XT or compatible
26 'using IOTech's GP488 controller card and PERSONAL488 software
28 '(IOTech, PO Box 21204, Cleveland, OH  44121).
30 '
32 'The program is written in Microsoft's GWBASIC and will also run
34 'under IBM's BASICA.
90 '*********************************************************************
100 '
102 ' Set up program parameters
104 '
110 ADDR$="01"              'LDT-5910 GPIB bus address
120 '
122 DELTMAX = .5             'Acceptable temp tolerance in deg C
124 DTDSMAX = .1             'Acceptable temp change rate in deg/sec
180 '
182 KEY OFF
200 '
202 ' Initialize the GPIB device software drivers
204 '
210 OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1
212 OPEN "\DEV\IEEEIN" FOR INPUT AS #2
300 '
302 ' Initialize the LDT-5910
304 '
312 PRINT #1, "OUTPUT ";ADDR$;";G0"      'Check error status
314 PRINT #1,"ENTER ";ADDR$
316 INPUT #2, R$
318 IF VAL(R$)<>0 THEN BEEP : LOCATE 12,1 : PRINT "ERROR DETECTED: ";R$
: END
340 '
342 PRINT #1,"OUTPUT ";ADDR$;";W1"       'Set output terminator to <CR> <LF>
400 '
402 ' Get user set temperature
404 '
406 SLAST=0
410 CLS : PRINT "                TEMPERATURE CONTROLLER DRIVER"
412       PRINT "               ============================="
420 '
422 LOCATE 10,1 : INPUT "SET TEMPERATURE (C)... ",TS$
500 '
502 ' Print output headings
```


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```
504 '
512 LOCATE 10,41 : PRINT "ACTUAL TEMPERATURE (C)... ";
514 LOCATE 11,41 : PRINT "RATE OF CHANGE (DEG/SEC)... ";
600 '
602 ' Send set temperature to the 5910, turn the output on and
604 ' the display mode to actual temperature
606 '
618 PRINT #1, "OUTPUT ";ADDR$;"; T";TS$;" O1 D2"
620 '
621 ' Check to see if done
622 '
624 PRINT #1, "ENTER ";ADDR$              'Get a temperature reading
626 INPUT #2, R$ : SNOW=TIMER
630 '
634 TACT=VAL(R$) : TSET=VAL(TS$)          'Some calculations
636 DTDS=(TACT-TLAST)/(SNOW-SLAST)
640 '
642 LOCATE 10,68 : PRINT R$;"     ";     'Print current values
644 IF SLAST>0 THEN LOCATE 11,67 : PRINT USING "##.##";DTDS;
650 '
652 SLAST=SNOW : TLAST=TACT
654 IF ABS(TACT-TSET)<DELTMAX AND ABS(DTDS)<DTDSMAX THEN 700
660 '
661 ' Wait for 2 sec delay before getting new reading
662 '
664 IF TIMER-SNOW<2 THEN 664 ELSE 622
700 '
701 ' Program termination
702 '
712 BEEP
714 LOCATE 15,20 : PRINT "DONE...STRIKE <CR> TO REPEAT"
720 '
722 A$=INKEY$ : IF A$="" THEN 722
724 IF A$=CHR$(13) THEN 400
730 '
732 CLS
734 END
```


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CHAPTER 4

THEORY OF OPERATION

4.1 Introduction

There are three electronic circuit boards inside the LDT-5910. They are the Power Supply Board, the Main Board which contains the microprocessor and the analog circuitry, and the Display Board which contains the front panel display and the display circuitry. A fourth board, the optional model 1227 GPIB/IEEE-488 interface, may be installed. A functional block diagram of the LDT-5910 is shown in Figure 4-1. You may also want to refer to the schematics in Appendix C. This chapter explains each board and each circuit in the block diagram.

4.2 Power Supply Board

4.3 Internal Power Supplies

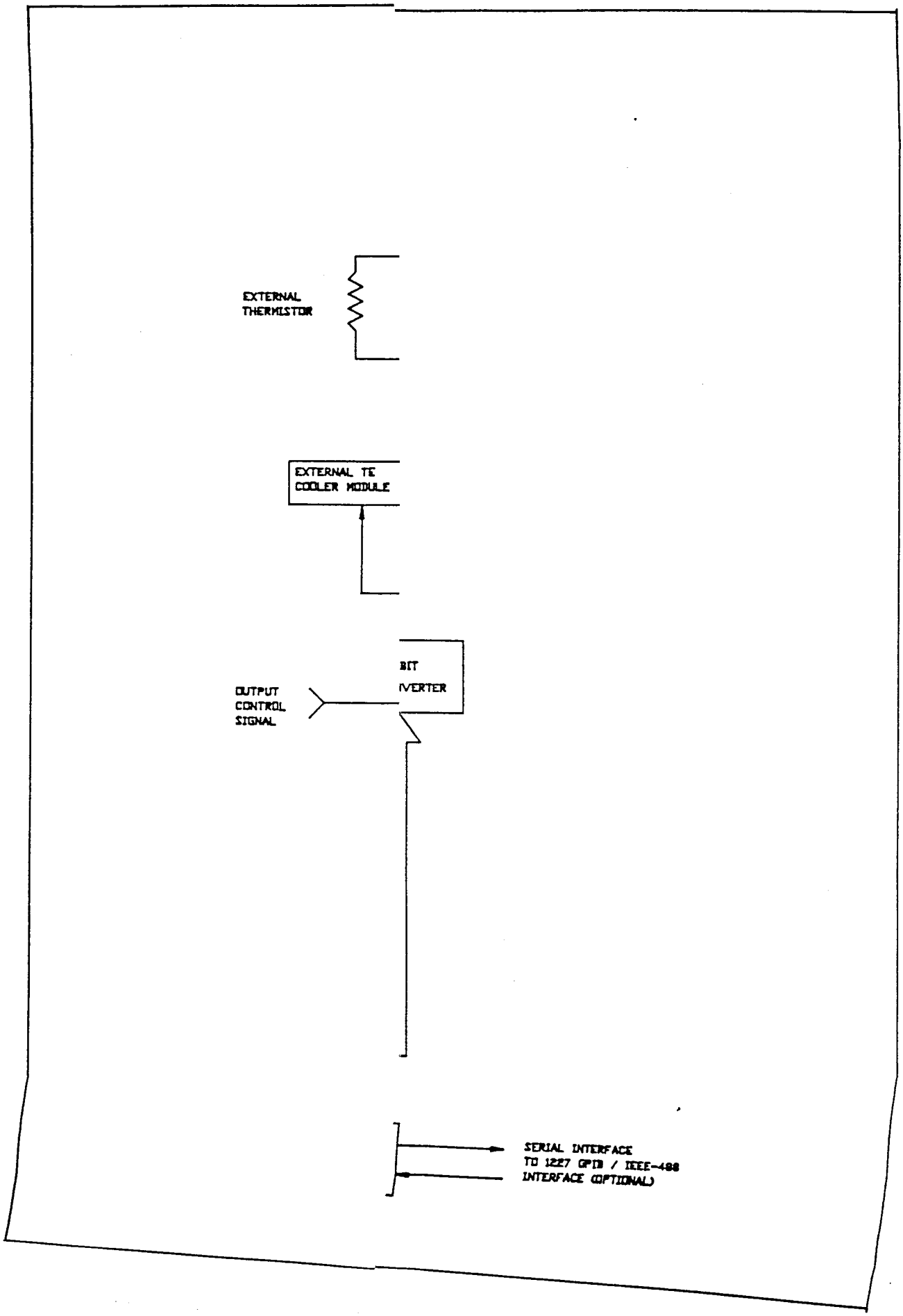
The internal power supplies include a +15 and -15 VDC supply for the main board, an unregulated 12 volt supply for the main current source and two +5 volt DC regulated supplies. One +5 volt supply powers the internal analog and digital circuitry and the other is reserved for the 1227 GPIB/IEEE-488 interface board when it is installed. The GPIB/IEEE-488 supply is isolated, through the transformer and with a separate ground, from the other power supplies.

Power is supplied through the rear panel mounted entry module Z401 which provides in-line transient protection and RF filtering. The back panel also houses the in line fuse F401. The main power switch S101 is located on the main circuit board and supplies power to the transformers T201 and T202. Two jumpers located on the power supply subassembly select series or parallel connection of the transformer primaries for operation from 115 VAC or 230 VAC respectively.

The +15 and -15 volt supplies use a full-wave, center-tapped bridge rectifier arrangement (BR201) followed by voltage regulators (U201, U202). Capacitors installed before and after the regulators provide filtering. Each +5 volt supply has a full-wave bridge rectifier (BR202, BR204) followed by a three-terminal regulator (U203, U204) and appropriate filtering capacitors.

The unregulated bipolar current supply uses a full-wave, center-tapped bridge rectifier (BR203) followed by filter capacitors. This power is supplied unregulated to the main board.

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4.4 Main Board

4.5 Constant Current Source

The constant current source is formed by U101 and its associated circuitry and supplies either 10 uA or 100 uA to the externally connected thermistor. As the current flows through the external thermistor, a voltage proportional to resistance develops across the thermistor terminals. This voltage is buffered by U102. The back panel current switch selects the output current and the position of this switch is also sensed by the microprocessor so that it correctly calculates resistance and temperature.

4.6 Input Buffer

A unity gain buffer (U102) presents a high impedance input to the thermistor and provides adequate output drive capability for succeeding stages. The voltage output of this buffer is proportional to the sensed resistance of the thermistor and represents the actual thermistor temperature. This signal is applied to the difference amplifier (U103C) and is also sent through the analog switch (U109) to the A/D convertor (U108) where it is read by the microprocessor and used to compute actual temperature.

4.7 Difference Amplifier

The difference amplifier (U103C) compares the actual temperature signal, from the input buffer, to the set point temperature signal. The set point temperature signal comes from the main control knob, when in Set Temperature or Auto mode, or from the set point control D/A (U107B) when in remote or lock mode. The difference signal at the output of U103C is available to the gain stage and the integrator input.

4.8 Digitally Controlled Gain Stage

The digitally controlled gain stage consists of a feedback amplifier (U103A), the analog switches U110 and feedback resistors. The analog switches vary the ratio of resistance in the feedback circuit to change the gain to 1, 3, 10, 30, 100 or 300. The gain setting determines how fast the LDT-5910 reaches the set point temperature and how quickly it settles to this temperature.

4.9 Integrator

The signal from the difference amplifier is sent to an integrator (U103B) which reduces the difference between the set point temperature and the actual temperature to zero, regardless of the gain setting. An analog switch (U110) discharges the integrating capacitor at power-up and when the output is turned off to prevent unnecessary difference signal integration.

4.10 Summing Amplifier

The summing amplifier (U103D) sums the signal from the integrator with the signal from the digital controlled gain and sends this signal to the voltage controlled current source.

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4.11 Current Limiting

The output of the summing amplifier (U103D) acts as the control signal to the main voltage controlled current source. Output current limiting is effected by bounding the control signal so that it is always less than the limit current. The limit current is set with the front panel controls or through the GPIB interface bus. The bipolar current limit levels are established by the output of the current limit D/A and the unity gain invertor U104B. U104A, U104C, Q104 and the associated circuitry provide the necessary control signal bounding.

4.12 Current Limit D/A

The current limit D/A converter is made up of U107A and U105B. The microprocessor loads the digitally stored current limit value into the 12 bit D/A (U107A) which converts it to a voltage at the output of U105B. The current limit value is updated at power-up and whenever the value is changed.

4.13 Current Limit Condition Sensing

Comparators U112C and U112D sense the output of U104A to determine when output current limiting is occurring. When this condition occurs, I/O port A0 of U127 is pulled low by the comparator to signals the microprocessor. The microprocessor responds by flashing the front panel LIMIT LED at approximately 2 Hz and then updates its internal error status register.

4.14 Voltage Controlled Current Source

The bounded output control signal is applied to U104D. This amplifier along with darlington transistors Q102, Q103, and the current sensing amplifier U113 form the output voltage controlled current source. The output of this stage directly drives the externally connected TE cooler module. A one-tenth volt signal at the input to this stage causes a one amp output.

4.15 Voltage Limit Condition Sensing

Comparators U112A and U112B sense the output of U104D to determine when output compliance voltage limiting is occurring. This condition occurs whenever the LDT-5910 rear panel TE cooler output is open or connected to a high resistance. If this condition occurs, one of the comparators pulls I/O port A1 of U127 low, signaling the microprocessor. The microprocessor responds by flashing the front panel LIMIT LED at approximately 4 Hz and updates its internal error status register.

4.16 Set Point Control D/A

When the LDT-5910 goes into the LOCK mode the position of the control knob is converted to a digital number and stored. This digital number is reconverted to an analog signal at the D/A convertor (U107B) and then fed through the current to voltage op amp (U105C). When the LDT-5910 is in LOCK mode or REMOTE mode the output of U105C establishes the set temperature control signal at the input to U103C.

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4.17 Precision Voltage Reference

The precision voltage reference (U105A) provides reference voltages for the main control knob (RV501), the A/D convertor (U108), and the D/A converters (U107). U105D buffers the output of the resistor divider network for driving the 10K ohm load presented by RV501.

4.18 A/D Convertor

The A/D converter (U108) is a monolithic, 12 bit converter with a 35 msec conversion time. This converter, along with a CMOS analog switch (U109), allows the microprocessor to read analog signals in the LDT-5910. In particular, the actual temperature, set temperature, and position of the front panel control knob (RV501) is read.

4.19 Microprocessor

The LDT-5910 uses a CMOS 8085 microprocessor (U120) to control its internal operations. The address decoder (U128) selects the memory, either the RAM (U124), ROM (U122) or EEPROM (U123), the 8085 can access. The I/O decoder (U126) selects the I/O device the 8085 can access. The available I/O devices on the main board are the serial interface (U125), the main board I/O port (U127), the current limit D/A (U107A), the set point control D/A (U107B), and the A/D converter (U108).

The counters (U130 and U131) interrupt the microprocessor to update the display and provide a fail safe countdown which generates a reset in the event of a malfunction.

Since the lower eight address lines in the 8085 architecture are also used as data lines, an address latch (U121) holds necessary address information when data is loaded onto the bus. This latch is enabled by the ALE signal from the 8085.

4.20 Memory

The LDT-5910 uses three types of memory. The first is short term memory, RAM (U124), that is retained only while power is applied to the unit. The second is 256 K of read only memory, ROM (U122) which contains the internal instructions that make the LDT-5910 function as a temperature controller. The third type of memory is electrically erasable programable memory, EEPROM (U123). EEPROM stores calibration constants and other data which must be retained even when power is removed from the unit. Examples of data stored in this memory include the GAIN, LIMIT, C1, C2, C3, and calibration constants. EEPROM may be re-programmed at least 10,000 times, providing ample capacity for most applications.

4.21 Serial Interface

The 8085, in the LDT-5910, communicates with external controllers through a serial interface. Parallel data from the microprocessor is converted to a bi-directional serial signal at the asynchronous serial interface (U125).

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4.22 Latched Parallel I/O Port

The latched parallel I/O port (U302) is an 8255 I/O controller that controls all of the analog switches on the main board and acts as an input port for several digital input signals (current limit, voltage limit, thermal limit, etc).

4.23 Display Board

4.24 Display Driver

The display driver (U301) is a specialized output port that requires four I/O addresses. Each address corresponds one of the four front panel display digits. Internal bus data is written to these addresses, decoded and appears on the LDT-5910 front panel display.

4.25 Latched Parallel I/O Port

The latched I/O port (U302) is used to sample the front panel input switches and drive all of the front panel LEDs.

4.26 LED Drivers

U303, U304, and U305 provide the output current sinking capability necessary to drive the front panel LEDs.

4.27 GPIB Interface Board

4.28 Microprocessor and Memory

The 1227 IEEE-488/GPIB interface, shown in figure 4-2, uses the 8085 microprocessor (U101) to control its operations. The interface card has PROM and RAM memory (U104).

The interrupt timers (U113 and U114) interrupt the microprocessor to provide a fail safe countdown counter that generates a reset if there is a malfunction.

Since the lower eight address lines in the 8085 architecture are also used as data lines, an address latch (U102) holds necessary address information when data is loaded onto the bus. This latch is enabled by the ALE signal from the 8085.

4.29 Optical Isolators

The optical isolators (U106 and U107) isolate the LDT-5910 from the GPIB interface bus.

4.30 Serial Interface

The parallel signal is converted to a serial signal at the synchronous serial interface (U105). The serial input and output lines are optically isolated from the main board. The serial interface is bi-directional. It receives serial information from the interface controller and converts it to a parallel signal for the microprocessor.

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4.31 GPIB Interface

The microprocessor communicates with the IEEE Standard 488 instrumentation bus through the 8291 GPIB TALKER/LISTENER chip U110. This chip implements all of the IEEE 488 Standards' interface functions, except for controller operations. The output of the interface controller is sent to bus line drivers U111 and U112.

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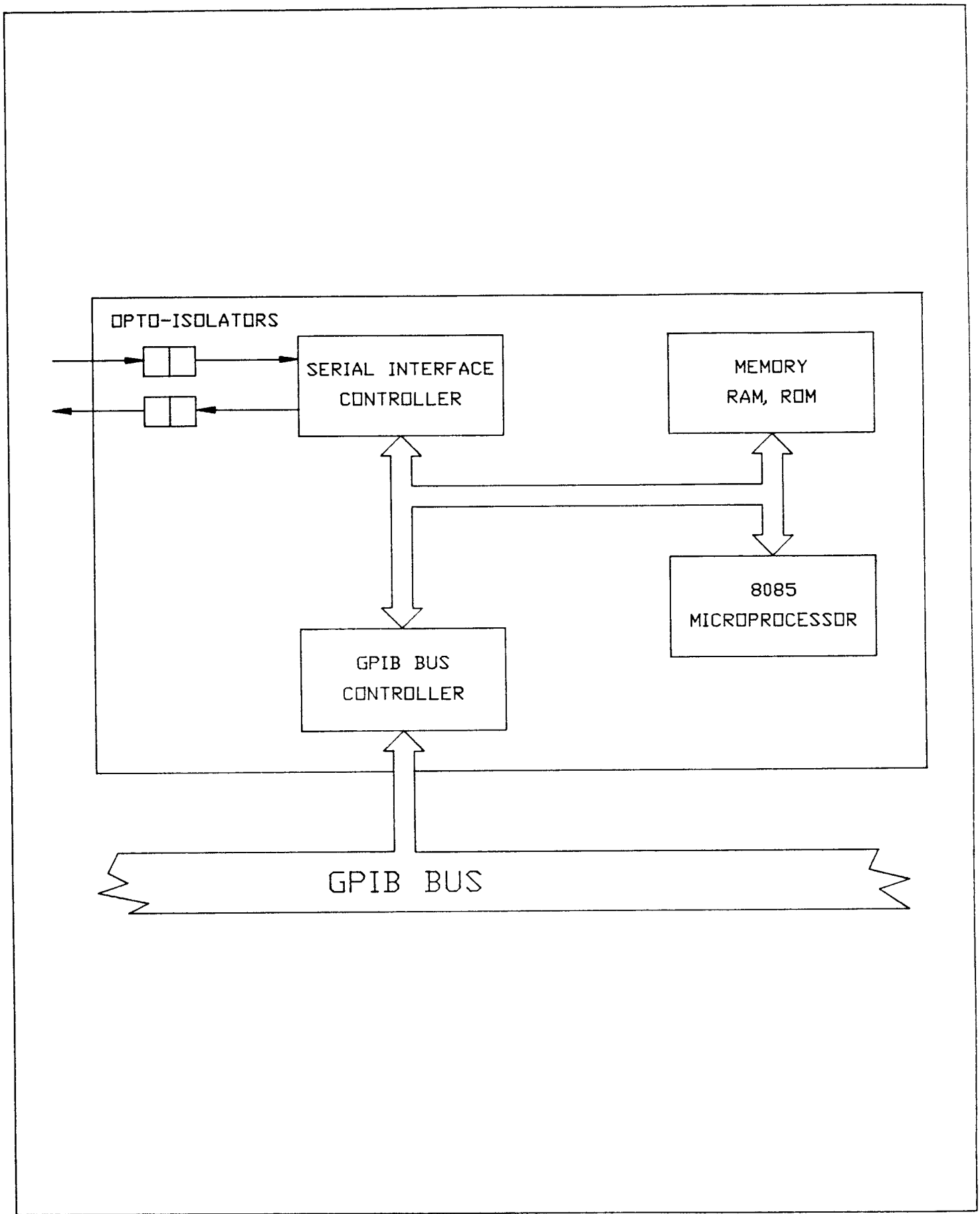


FIGURE 4-2 FUNCTIONAL BLOCK DIAGRAM OF 1227 INTERFACE

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CHAPTER 5

MAINTENANCE

5.1 Overview

This chapter describes how to maintain the LDT-5910. Included are sections covering calibration, fuse replacement, line voltage selection, and disassembly.

WARNING
THE SERVICE PROCEDURES DESCRIBED IN THIS CHAPTER ARE FOR USE BY QUALIFIED PERSONNEL. POTENTIALLY LETHAL VOLTAGES EXIST WITHIN THE LDT-5910. TO AVOID ELECTRIC SHOCK, DO NOT PERFORM ANY OF THE PROCEDURES DESCRIBED IN THIS CHAPTER UNLESS YOU ARE QUALIFIED TO DO SO.

5.2 Calibration

The LDT-5910 should be calibrated every 12 months or whenever performance verification indicates that calibration is necessary.

5.3 Recommended Equipment

Recommended test equipment for calibrating the LDT-5910 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. If your LDT-5910 is equipped with the model 1227 GPIB/IEEE-488 interface refer to sections 5.9 and 5.10 for calibration procedures using the GPIB bus.

Table 5.1 Recommended Test Equipment

Description	Mfg./Model	Specification
DMM	Fluke 8840A	DC Amps (@ 1.0 A): ±1 % Resistance (@ 10 ohms):.02 %
Resistor	Metal Film	9.00 to 9.9K for 100 uA calibration 90.0 to 99.9K for 10 uA calibration 10.00 K for current limit calibration

5.4 Environmental Conditions

Calibrate this instrument under laboratory conditions. We recommend calibration at 23 °C ± 1.0 °C. When necessary, however, the LDT-5910 may be calibrated at its intended use temperature if this is within the specified operating temperature range of 0 to 50 °C.

5.5 Warm-Up

The LDT-5910 should be allowed to warm up for at least 1 hour before calibration.

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5.6 Calibration Adjustments

There are only three calibration adjustments that need to be made for this unit. They are to calibrate the resistance at the 10 microamp and the 100 microamp source current settings and to calibrate the current limit. If you have the optional Model 1227 IEEE-488/GPIB interface you may follow the procedure in sections 5.9 and 5.10 to calibrate the LDT-5910 from the bus. All calibrations can be done with the case closed. The instrument is calibrated by changing the internally stored digital calibration constants.

5.7 Manual Resistance Calibration

a. Set the back panel switch to the 10 uA position.

b. Measure and record the exact resistance of your metal film resistors.

c. Connect the correct metal film resistor to the thermistor input of the LDT-5910.

d. Enter the resistance calibration mode by pushing local and select at the same time. The LED display will now indicate resistance in K ohm.

e. Turn the main control knob until the display indicates the same resistance you recorded for the metal film resistor.

f. Press the set button to store the new value into non-volatile memory.

g. Switch the back panel switch to the 100 uA position and repeat this procedure with the other resistor.

5.8 Manual Current Limit Calibration

a. With the output off, connect a calibrated ammeter to the TE module output of the LDT-5910.

b. Set the current limit to 1000 mA (1 amp).

c. With the output off, turn the knob to mid-scale (about five turns clockwise).

d. Turn the output on.

e. Record the current indicated on the calibrated ammeter.

f. Turn the output off.

g. Press the LOCAL and OUTPUT ON button at the same time to place the LDT-5910 in the Current Calibration mode.

h. If the number on the LED display is different from the number that the calibrated ammeter indicated, turn the main control knob until it reads the number that you recorded.

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i. Press the set button to store the new calibration value into non-volatile memory.

j. Input a new current limit value since the current limit must be reset to use the new calibration value.

5.9 Resistance Calibration Over the GPIB Bus

a. Set the back panel switch to the 10 uA position. The bus commands for calibrating the 10 uA and 100 uA are given here with the commands for the Cal R100 given in parenthesis.

b. Measure and record the exact resistance of your metal film resistors.

c. Connect the correct metal film resistor to the LDT-5910 thermistor input.

d. Set the display to read actual resistance by sending the bus command "D5".

e. Record the indicated resistance from the LDT-5910 front panel display.

f. Send the "G6" (G7) bus command to read the Cal R10 value. Record this number.

g. Calculate the new value for Cal R10 using the following equation:

$$\text{New Cal R} = \frac{\text{Measured Resistance}}{\text{Displayed Resistance}} * \text{Old Cal R}$$

h. Input a new Cal R10 value with the "P6" (P7) command.

i. Switch the back panel switch to the 100 uA position and repeat this procedure with the other resistor and the bus commands in parenthesis.

5.10 Current Limit Calibration Over the GPIB Bus

a. With the output off, connect a calibrated ammeter to the TE module output of the LDT-5910.

b. Set the current limit to 1000 mA (1 amp) with the bus command "N1000P1".

c. Connect a 10K thermistor to the thermistor terminals.

d. Input a set temperature of 50 °C with the GPIB command "T50."

e. Turn the output on with the bus command "O1."

f. Record the current indicated on the calibrated ammeter.

g. Retrieve the Cal CL value with the "G8" command.

h. Turn the output off.

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i. Calculate the new Cal CL value using the equation:

$$\text{New Cal CL} = \frac{\text{Actual Current}}{\text{Set Current}} * \text{Old Cal CL}$$

j. Input a new current limit value since the current limit must be reset to use the new calibration value.

5.11 Fuse Replacement

The fuse is accessible from the rear panel of the LDT-5910. Before replacing the fuse, turn power off and disconnect the line cord. Use only the fuses indicated below in Table 5.2.

Table 5.2 Fuse Replacement

Line voltage	Fuse Replacement
105 - 125 VAC	1 Amp, 3AG, Slow Blow
210 - 250 VAC	1/2 Amp, 3AG, Slow Blow

5.12 Line Voltage Selection

Line voltage selection is made by installing jumpers according to figure 5-1. Normally these jumpers are factory preset. When necessary, however, they may be moved to accommodate new line voltage conditions. You must remove the LDT-5910 top cover and then remove the power supply. To remove the power supply, remove the four outside screws, closest to the side rails, and lift the power supply straight up. Locate the zero-ohm jumpers on the Power Supply Board. Carefully remove the jumpers and then install them in the new position.

5.13 Disassembly

The top and bottom covers of the LDT-5910 may be removed by extracting the countersunk screws on the sides of the instrument near the rear panel. After these screws are out, slide either cover towards the rear of the instrument and then pull it up and off.

To remove the front panel of the instrument first peel out the decorative plastic inserts located on the sides of the front bezel to access the four front panel retaining screws. When the four retaining screws are removed press on the back of the front panel to press out the circuit board (the top cover must be removed to allow access to this circuit board).

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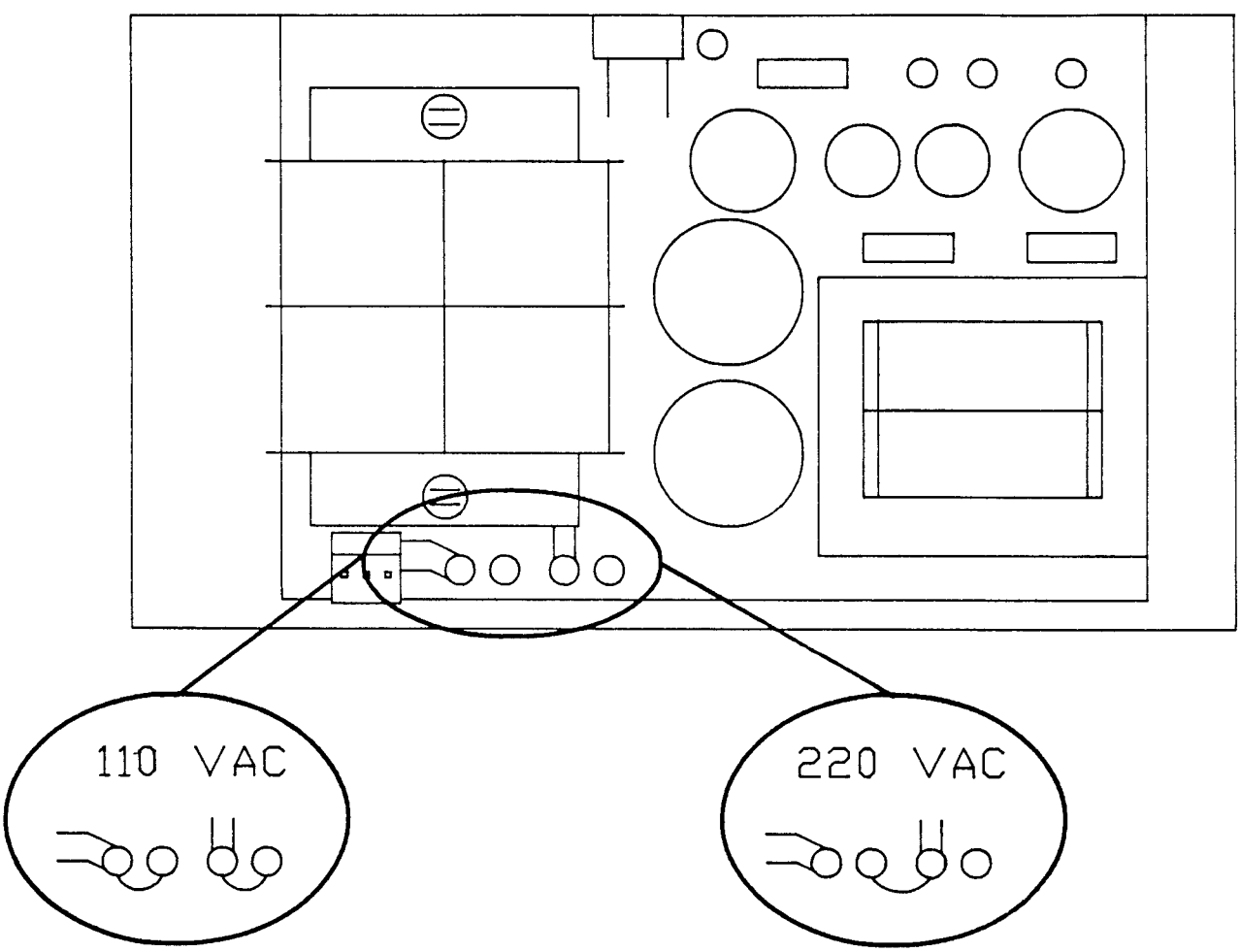


FIGURE 5-1 AC VOLTAGE SELECTION

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CHAPTER 6

OPTIONAL MODEL 1227 GPIB/IEEE-488 INTERFACE

SPECIFICATIONS AND INSTALLATION

6.1 Overview

This chapter describes the optional model 1227 GPIB/IEEE-488 interface which allows the LDT-5910 to be remotely programmed via the IEEE standard 488-1978 interface bus. For a description of how to program remotely refer to Chapter 3.

With the optional 1227 GPIB/IEEE-488 interface installed, the LDT-5910 may be controlled by most computers via the GPIB/IEEE-488 bus. When the 1227 interface receives any of its recognized commands from the GPIB bus it sends appropriate control information to the LDT-5910 main board microprocessor via an optically isolated serial interface. Ground, receive and transmit lines are optically isolated. In the case of interface messages such as DCL (device clear), GTL (go to local), and REN (remote enable), special ASCII characters are transmitted to the LDT-5910. For example, when the 1227 receives the bus command REN, it responds by sending the character string "Y1" to the LDT-5910 main board. This character string is then interpreted by the LDT-5910 as a remote enable command. Upon receipt of these characters, the LDT-5910 responds appropriately.

The 1227 interface receives device dependent commands, such as D0 (blank the display), G9 (get user defined message), or T20.0 (control to 20.0 C), as ASCII - strings and are simply passed to the LDT-5910 for interpretation and action. When the 1227 interface is instructed to talk it signals the LDT-5910 that data is required. The LDT-5910 then transmits the appropriate data back to the 1227 as a serial stream of ASCII characters. The 1227 then loads these characters onto the GPIB bus to complete the talk cycle.

6.2 Specifications

IEEE-488 BUS IMPLEMENTATION

General:	Implements talker/listener functions.
Interface Messages:	REN, DCL, LLO, GTL, SDC
Isolation:	Instrument is optically isolated from IEEE-488 bus.
Command Execution Time:	Approximately 40 msec.

POWER REQUIREMENTS

Isolated Supply:	+5 volts, 500 mA max.
Instrument Supply:	+5 volts, 100 mA max.

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6.3 Installation

Install the GPIB interface (model 1227) using the following procedure:

> Note: The 1227 GPIB/IEEE-488 interface board contains static sensitive parts. Handle the circuit board only by its edges and work at a static free work station.

a. Turn off the LDT-5910 and disconnect it from the AC line.

b. Remove the top cover of the 5910 by removing the two cover retaining screws located on either side of the instrument near the rear panel.

c. Remove the 5910 rear panel by unscrewing the four screws located in the corners of the panel.

d. Remove the aluminum cover plate from the rear panel of the 5910 to expose the cutouts for the GPIB connector and address selector switch.

e. Fasten the 1227 interface board onto the rear panel with the supplied GPIB connector retaining screws, lock washers and nuts. Center the GPIB connector and address selector switch in their respective panel cutout holes. Note that the 1227 interface board must be mounted upside down (components facing down) to be correctly installed.

f. Insert the supplied plastic fasteners into the each upper channel of the 5910's side rail to support the front of the GPIB board. Slide the support to a position approximately 4 3/8 inches from the back panel. (See Figure 6.1).

h. Screw the right angle brackets into the plastic side rail fasteners.

> Note: One face of the bracket has a threaded hole for the screws that hold the GPIB board to the brackets. Do not screw the threaded face of the bracket into the plastic fasteners.

Tighten the screw into the plastic side rail fastener to lock the support into place.

i. Install the ribbon cables from pin header J105 on the main circuit board to the GPIB board. When correctly installed the cables run in towards the center of the main circuit board (see Figure 6.1) without any twists.

j. Replace the LDT-5910 rear panel and attached GPIB interface board and replace the four retaining screws on the rear panel.

k. Screw the front of the GPIB board to the mounting brackets with the supplied 6-32 mounting screws.

l. Replace the top cover of the LDT-5910.

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Appendix A

The Steinhart-Hart Equation

Two terminal thermistors have a non-linear relationship between temperature and resistance. The resistance verses temperature characteristics for a family of similar thermistors is shown in figure A-1. It has been found empirically that the resistance verses temperature relationship for most common negative temperature coefficient (NTC) thermistors can be accurately modeled by a polynomial expansion relating the logarithm of resistance to inverse temperature. The Steinhart-Hart equation is one such expression and is given as follows:

$$1/T = A + B(\text{Ln } R) + C(\text{Ln } R)^3 \qquad \text{Equation 1}$$

Once the three constants A, B, and C are accurately determined, equation 1 introduces very small errors in the calculation of temperature even over wide temperature ranges. Table A.1 shows the results of using equation 1 to fit the resistance verses temperature characteristic of a common 10K ohm (at room temperature) thermistor. Equation 1 will produce temperature calculation errors of less than 0.01 C over the range -20 C to 50 C.

		-------Error T (°C)-------	
R[1]	T Actual	First Order Fit. Eq.1[2]	Third Order Fit Eq. 2[3]
97072	-20.00	-0.00	-0.32
55326	-10.00	0.00	-0.06
32650	0.00	-0.00	0.09
19899	10.00	-0.00	0.15
12492	20.00	-0.00	0.13
10000	25.00	0.00	0.08
8057	30.00	0.00	0.01
5326	40.00	0.00	-0.20
3602	50.00	-0.00	-0.50

Table A.1 Comparison of Curve Fitting Equations

---

[1] Resistance of a 10K, Fenwal UUA41J1 thermistor.

[2] constants A'=0.963 * 10^{-3}, B'=2.598 *10^{-4}

[3] Constants A=1.125 *10-3 (C1=1.125)
B=2.347 *10-3 (C2=2.347)
C=0.855 *10-7 (C3=0.855)

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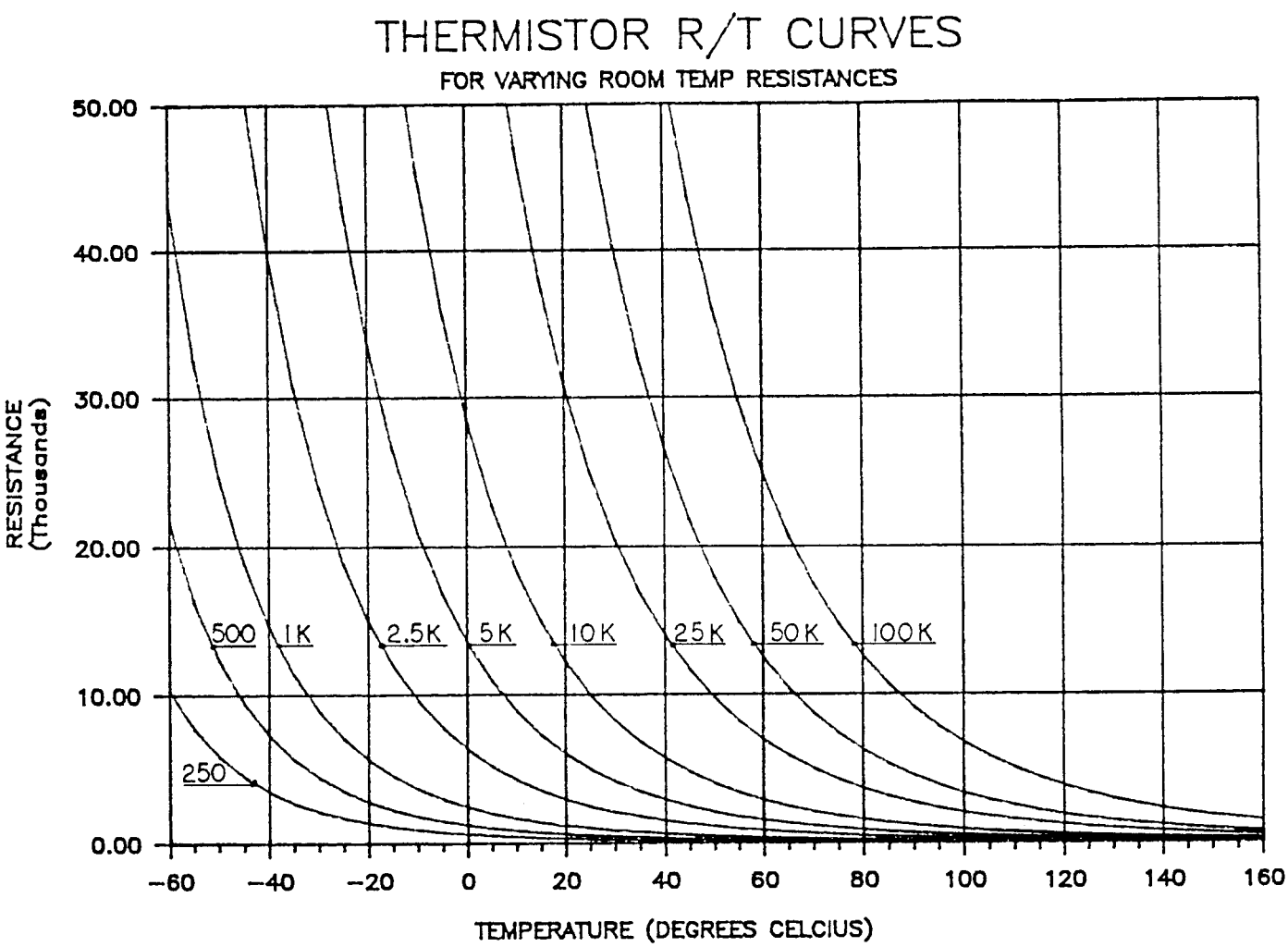


FIGURE A-1 THERMISTOR RESISTANCE VERSES TEMPERATURE

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In practice we have found that the constants A, B and C for virtually all common thermistors lie within a narrow range. Consequently, we have defined the constants C1, C2, C3 as follows:

$$C1 = A * 10^{+3}$$
$$C2 = B * 10^{+4}$$
$$C3 = C * 10^{+7}$$

The constants C1, C2, And C3 may all be expressed in the form n.nnn simplifying entry into the LDT-5910.

If high accuracy is not required, the Steinhart-Hart equation may be simplified to a first order polynomial:

$$1/T = A' + B' * \ln R \qquad \text{Equation 2}$$

This equation is easier to solve and often provides adequate results. Table A.1 also shows that the use of equation 2 introduces temperature errors of less than 0.5 °C over the range -20 C to 50 °C. Once the constants A' and B' are determined, the LDT-5910 is programmed with the following values of C1, C2 and C3:

$$C1 = A' * 10^{+3}$$
$$C2 = B' * 10^{+4}$$
$$C3 = 0.000$$

Table of Constants

We have tested or reviewed many thermistors and include the appropriate calibration constants for the temperature range -20 C to 50 C in most cases. Please contact ILX Lightwave Corporation if you require more information about these constants or would like other constants computed for you.

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Table A.2 Thermistor Constants

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

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Computer program

We have also included two computer programs that use a least squares curve fitting routine to determine the values of C1, C2 and C3. The programs, called STEIN3 and STEIN1, are written in IBM's advanced BASICA. STEIN3 calculates the values the coefficients C1, C2 and C3 using equation 1. STEIN1 calculates C1 and C2 using equation 2. Type one of these program into your computer.

Next you must create a data file for your thermistor that describes the resistance at various temperatures. The temperature verses resistance calibration data can be obtained from the thermistor manufacturer. Enter the resistance at various temperatures as data points into an ASCII file. You can write the data file on a word processor, but you must use non-document mode so special word processing characters are not inserted into the data file. Format the data with one temperature-resistance pair per line and at least one space separating the two numbers. Temperatures should be in centigrade and resistances in ohms. We recommend that you use at least twenty data points, uniformly spread over the intended range of use, for an accurate determination of the coefficients. Enter a -1 to signify the end of the resistance data and temperature data.

A small sample data file is included below as an example of the data format and end-of-data marker (R = -1).

Temperature	Resistance
-20	97072
-10	55326
0	32650
10	19899
20	12492
25	10000
30	8056.8
40	5326.4
50	3602.3
-1	-1

Run the STEIN3 or STEIN1 program. The best curve fitting values for C1, C2 and C3 will be displayed. Key these numbers into the LDT-5910. If the computer program supplies negative values for constants C2 or C3 then the temperature verses resistance data was bad or incorrectly entered.

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```
80 REM ********** STEIN1 **********
*
90 REM
92 REM     Rev: 3-11-87
94 REM
100 REM    Least squares fit program to find the thermistor coefficients
110 REM    C1 and C2 in the following equation:
120 REM
130 REM              1/T = C1 + C2 * (ln R)
140 REM
200 REM
210 REM  Variables:
220 REM
230 REM   T[i], R[i]      temperature and resistance data values.
240 REM
250 REM   Y[i] = 1/T[i]  the dependent variable (depends on R[i])
260 REM                    in the Steinhart - Hart equation (above).
270 REM
280 REM   X[i] = ln(R[I])  the value of the ith function of the independent
290 REM                    variable ln(R) (natural log of resistance)
330 REM
1000 DEFDBL A-Z
1010 DEFINT I, J, K, L
1020 DIM R[400], T[400], Y[400], X[400]
1025 C[3]=0
1030 PRINT "What is the data file name"; : INPUT D$
1040 OPEN "i", 1, D$
1050 REM    **** read and echo T(i), R(i) from the data file ****
1060 REM              (terminate read on R=-1)
1070 I=0
1080 PRINT "Data:"
1090 G$="Point     Temperature (Celsius)   Resistance (ohms)"
1100 H$=" ###          ######.##             #########.##"
1110 PRINT G$
1120 PRINT
1130 I=I+1
1140 INPUT #1, T(I), R(I)
1150 IF R(I)<0 THEN GOTO 1180
1155 X(I)=LOG(R(I)) : Y(I)=1/(T(I)+273.15)
1160 PRINT USING H$; I, T(I), R(I)
1170 GOTO 1130
1180 N=I-1
1190 CLOSE
1200 REM          **** accumulate sums ****
1205 SX=0 : SY=0 : SXY=0 : SXX=0
1210 FOR I = 1 TO N
1220 SX=SX+X(I)
1230 SY=SY+Y(I)
1240 SXY=SXY+X(I)*Y(I)
1250 SXX=SXX+X(I)*X(I)
1260 NEXT I
1300 REM          ****  print out results  ****
```


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```
1310 C[2]=(N*SXY-SX*SY)/(N*SXX-SX*SX)
1320 C[1] = (SY-C[2]*SX)/N
1620 PRINT
1630 G$="Key in:      C1          C2          C3"
1640 P$="          #.###       #.###       #.###"
1650 PRINT G$
1660 PRINT USING P$; C[1]*1000!, C[2]*10000!,C[3]
1700 '
1702 C1=INT(C[1]*1000000!)/1000000!
1704 C2=INT(C[2]*1E+07)/1E+07
1706 C3=0
1710 PRINT
1712 PRINT "                T          T           T"
1714 PRINT "     R        ACTUAL      CALC        ERROR"
1716 PRINT " ========   =========   ==========   ========="
1718 P$=   " ########    ####.##    ####.##      ####.##"
1720 FOR L=1 TO N
1730 X=LOG(R(L))
1740 TCALC=1/(C1+C2*X+C3*X*X*X)-273.15
1760 PRINT USING P$;R(L),T(L),TCALC,T(L)-TCALC
1780 NEXT L
```


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```
80 REM ********** STEIN3 **********
*
90 REM
92 REM    Rev: 3-11-87
94 REM
100 REM   Least squares fit program to find the thermistor coefficients
110 REM   C1, C2 and C3 in the Steinhart-Hart equation:
120 REM
130 REM          1/T = C1 + C2 * (ln R) + C3 * (ln R)**3
140 REM
150 REM Reference:
160 REM
170 REM   "Data Reduction and Error Analysis for the Physical Sciences"
180 REM       Philip R. Bevington (McGraw-Hill, New York, 1969)
190 REM            Library call no.: QA 278 B48
200 REM
210 REM Variables:
220 REM
230 REM   T[i], R[i]    temperature and resistance data values.
240 REM
250 REM   Y[i] = 1/T[i]  the dependent variable (depends on R[i])
260 REM            in the Steinhart - Hart equation (above).
270 REM
280 REM   X[n,i]        the value of the nth function of the independent
290 REM            variable R (resistance) evaluated at the ith
300 REM            data point R[i]
310 REM
320 REM       X[1,i] = 1 ;  X[2,i] = ln(R[i])  ;  X[3,i] = ln(R[i]) ** 3
330 REM
340 REM   c[j]          the value of the jth coefficient to be solved for
350 REM            in the expansion
360 REM
370 REM       Y[i] = c[1] * X[1,i] + c[2] * X[2,i] + c(3) * X[3,i]
380 REM
390 REM            which becomes the Steinhart - Hart equation
395 REM            which is the inverse of the alpha matrix
400 REM            with the above substitutions for Y[i] and X[n,i].
410 REM            c[j] corresponds to Bevington's a[j] vector
420 REM            in his eqn 8-26.
430 REM
440 REM   A[j,k]       Bevington's alpha matrix (j,k=1,2,3)
450 REM            and beta vector (j=4, k=1,2,3) (Bevington eqn 8-23).
460 REM
470 REM   E[j,k]       Bevington's epsilon (error) matrix (eqns 8-28, 8-30)

480 REM            and contains the uncertainties in the estimates
490 REM            of the c[j] coefficients. These uncertainties are
500 REM            the consequence of the scatter (errors) in the
510 REM            input temperature verses resistance data.
1000 DEFDBL A-Z
1010 DEFINT I, J, K, L
1020 DIM R[400], T[400], Y[400], X[4,400], A[4,3], B[3,3], E[3,3], C[3]
```


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```
1030 PRINT "What is the data file name"; : INPUT D$
1040 OPEN "i", 1, D$
1050 REM    **** read and echo T(i), R(i) from the data file ****
1060 REM              (terminate read on R=-1)
1070 I=0
1080 PRINT "Data:"
1090 G$="Point     Temperature (Celsius)   Resistance (ohms)"
1100 H$=" ###          ######.##              #########.##"
1110 PRINT G$
1120 PRINT
1130 I=I+1
1140 INPUT #1, T(I), R(I)
1150 IF R(I)<0 THEN GOTO 1180
1160 PRINT USING H$; I, T(I), R(I)
1170 GOTO 1130
1180 N=I-1
1190 CLOSE
1200 REM          **** calculate 4 x 3 matrix ****
1210 FOR I = 1 TO N
1220 H=LOG(R(I))
1230 X(1,I)=1
1240 X(2,I)=H
1250 X(3,I)=H*H*H
1260 REM       (subscript 4 corresponds to y[i] = X[4,i])
1270 X(4,I)=1/(T(I)+273.15)
1280 NEXT I
1290 REM   **** Calculate alpha (i=1 to 3) and beta (i=4) ****
1300 REM             (Bevington eqns 8-23)
1310 FOR I=1 TO 4 : FOR J=1 TO 3 : A(I,J)=0 : NEXT J : NEXT I
1320 FOR I=1 TO N : FOR J=1 TO 4 : FOR K=1 TO 3
1330 A(J,K)=A(J,K)+X(J,I)*X(K,I)
1340 NEXT K : NEXT J : NEXT I
1350 REM   **** Error matrix "E" = inverse of alpha (3x3 part of A) ****
1360 GOSUB 2010
1370 REM     **** Coefficients = beta (fourth column of A) x E ****
1380 REM                (eqn 8-26 of Bevington)
1390 FOR I=1 TO 3 : C(I)=0 : FOR J=1 TO 3
1400 C(I)=C(I)+E(I,J)*A(4,J)
1410 NEXT J : NEXT I
1420 SIGMA=0
1430 FOR I=1 TO N
1440 H=X(4,I)-C(1)*X(1,I)-C(2)*X(2,I)-C(3)*X(3,I)
1450 SIGMA=SIGMA+H*H
1460 NEXT I
1470 REM          **** sigma = mean square deviation ****
1480 REM                (Bevington eqn 8-29)
1490 SIGMA=SQR(SIGMA/(N-3))
1500 REM       **** print coefficients and estimated errors ****
1510 REM             (eqns 8-26 and 8-30 of Bevington)
1520 F$="##.####^^^^  +/- ##.##^^^^ )"
1530 PRINT
1540 PRINT "1/T = (";
```


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```
1550 PRINT USING F$; C(1), SIGMA*SQR(E(1,1))
1560 PRINT "    + (";
1570 PRINT USING F$; C(2), SIGMA*SQR(E(2,2));
1580 PRINT " * ln (R)"
1590 PRINT "    + (";
1600 PRINT USING F$; C(3), SIGMA*SQR(E(3,3));
1610 PRINT " * ln (R) ** 3"
1620 PRINT
1630 G$="Key in:      C1          C2          C3"
1640 P$="          #.####      #.####      #.###"
1650 PRINT G$
1660 PRINT USING P$; C[1]*1000!, C[2]*10000!, C[3]*1E+07
1700 '
1710 PRINT
1712 PRINT "              T          T           T"
1714 PRINT "    R       ACTUAL      CALC        ERROR"
1716 PRINT " ========  =========  ==========  ========="
1718 P$=   " ########    ####.##    ####.##     ####.##"
1720 FOR L=1 TO N
1730 X=LOG(R(L))
1740 TCALC=1/(C(1)+C(2)*X+C(3)*X*X*X)-273.15
1760 PRINT USING P$;R(L),T(L),TCALC,T(L)-TCALC
1780 NEXT L
1890 REM   ****************** program end ************************
1892 END
2000 REM      ************* Begin Subroutines ***************
2010 REM       **** Invert 3 x 3 matrix "A" by cofactors ****
2020 GOSUB 2160 : GOSUB 2120
2030 DET=SUM
2040 FOR K=1 TO 3 : FOR L=1 TO 3
2050 GOSUB 2160
2060 FOR J=1 TO 3 : B(J,L)=0 : B(K,J)=0 : NEXT J : B(K,L)=1
2070 GOSUB 2120
2080 REM       **** "E" = inverse = transpose of cofactor ****
2090 E(L,K)=SUM/DET
2100 NEXT L : NEXT K
2110 RETURN
2120 REM           **** 3 x 3 determinant routine ****
2130 SUM = B[1,1]*B[2,2]*B[3,3]+B[1,2]*B[2,3]*B[3,1]+B[1,3]*B[2,1]*B[3,2]
2140 SUM = SUM-B[1,1]*B[2,3]*B[3,2]-B[1,2]*B[2,1]*B[3,3]-B[1,3]*B[2,2]*B[3,1]
2150 RETURN
2160 REM      **** Copy matrix A onto "scratch" matrix B ****
2170 FOR I=1 TO 3 : FOR J=1 TO 3 : B(I,J)=A(I,J) : NEXT J : NEXT I
2180 RETURN
```


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Appendix B

Sensing Current and Thermistor Selection

Introduction

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-5910 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 below.

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

In the LDT-5910 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 A/D input voltage of the LDT-5910. Thermistor resistance and voltage are related through Ohms Law (V = I x R). The LDT-5910 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 LDT-5910. The LDT-5910 will over-range when the input voltage exceeds about 4.5 Volts. Figure B-1 graphically shows the lower temperature and upper - voltage limits for a typical 10 K ohm thermistor. The practical 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.

Sensing Current	Temperature Range
10 uA	-51 to 40 °C
100 uA	-10 to 100 °C

Temperature Resolution

You must also consider measurement resolution since the resolution decreases as the thermistor temperature increases. The LDT-5910 uses an A/D converter that can sense a voltage change as small as 1 mV (1 mV is roughly equal to 1 A/D - convertor step), to convert the input voltage to a digital number. The microprocessor then transforms the digital number to temperature using the Steinhart-Hart equation. A temperature change of one degree centigrade will be represented by

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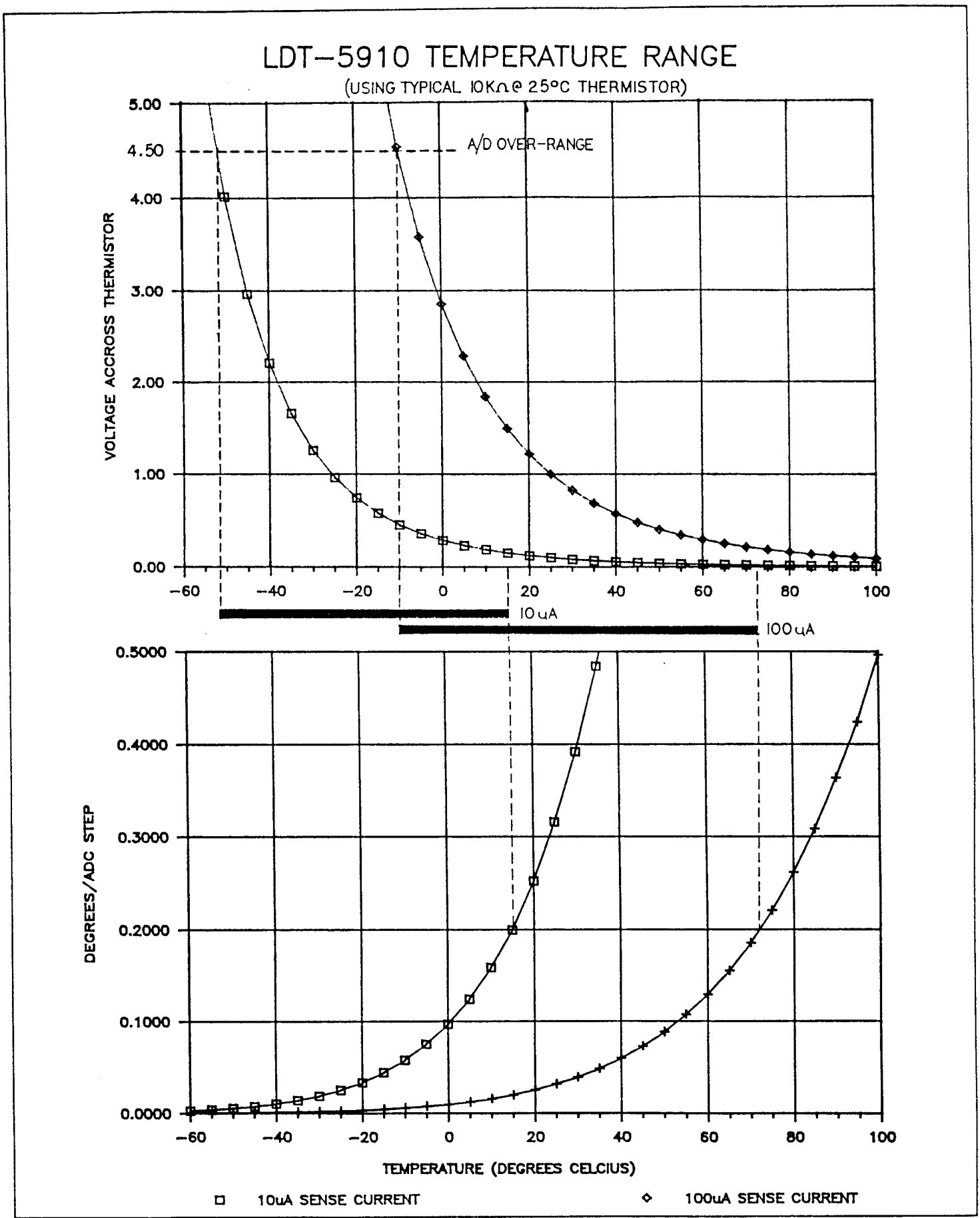


FIGURE B-1 THERMISTOR TEMPERATURE RANGE

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more A/D steps at a lower temperature than at a higher temperature because of the non-linear resistance of the thermistor. Resolution figures for a typical 10 K ohm thermistor are given below.

Temperature	Voltage at 10 uA	Resolution
-20 °C	56 mV/ °C	.019 °C/mV
25 °C	4.4 mV/ °C	.25 °C/mV
50 °C	1.4 mV/ °C	.8 °C/mV

For this thermistor a temperature change from -20 to -19 °C will be represented by 56 steps in the LDT-5910's A/D convertor (if supplied with 10 uA). The same thermistor will only change about 1.4 A/D steps from 49 to 50 °C !

The resolution you choose will impact the temperature displayed on the LDT-5910. If you want to read a certain temperature accurate to .2 °C, then you must set the current switch for that resolution. Since the thermistor is non-linear the resolution will also decrease as the temperature increases. The high temperature limit occurs when the temperature resolution drops below an acceptable level.

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 -10 °C you will need to set the switch to the 10 uA setting. With the current switch set to 10 uA the best resolution you will see will be a 0.2 °C temperature change. If, for example, the lower limit is 0 °C you can choose either setting, but there is a trade-off in terms of resolution. If you need 0.1 °C resolution you will have to change the setting of the current switch to 100 uA.

If you need high resolution over a narrow range, for a very accurate measurement, you can set the current setting for the maximum resolution. For example, at a high temperature of 20 °C, you need a measurement resolution of at least 0.05 °C. This resolution is within the range of either current switch setting, but at the 10 uA setting the resolution is only 0.2 °C while at the 100 uA setting the resolution is better than .05 °C. Set the switch to 100 uA.

Selecting and Using Thermistors

The type of thermistor you choose will depend primarily on the operating temperature range. These guidelines for selecting the range and resolution will apply to any thermistor. From figure B-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, 10 K thermistors are often a good choice for detector cooling applications where you want to operate at temperatures from -40 °C to room temperature. If you require a different temperature range or the accuracy you need can't be achieved with either switch setting, select another thermistor. Thermistor temperature curves, supplied by the manufacture, show the resistance verses temperature range for many other thermistors. ILX Lightwave Corporation will also offer help for your specific application.

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Appendix C

Schematic Diagrams

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