User's Guide

3A Current Source TE Module
LDC-3916558
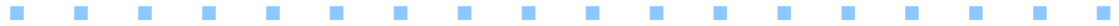
ILX Lightwave®
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INTRODUCTION AND SPECIFICATIONS

This chapter is an introduction to the LDC-3916558 3-Amp Temperature Control Module for the LDC-3916 or LDC-3908 Laser Diode Controller Mainframe. It contains unpacking information, instructions on how to install and apply power, and safety considerations and instructions. It also contains some maintenance information and specifications.

⚠ WARNING

If any of the following symptoms exist, or are even suspected, remove the LDC-3916558 Module from service. Do not use the module until trained service personnel can verify safe operation.

Visible damage

Severe transport stress

Prolonged storage under adverse conditions

Failure to perform intended measurements or functions

If necessary, return modules to ILX Lightwave for service and repair to ensure that safety features are maintained.

Product Overview

The 3916558 module is intended to be used within a LDC-3916 16-channel or LDC-3908 8-Channel Laser Diode Controller Mainframe. The module contains a single three ampere independent temperature controller that drives a thermoelectric cooler (TEC). The temperature controller features a bi-polar current driver that works with most TEC modules to deliver precise temperature control over a wide range of temperatures. The temperature controller operates using thermistor type temperature sensors only. The LDC-3916558 features a

TEC module voltage measurement, selection of thermistor current range, and control loop gain adjustment from 1 to 127.

Initial Inspection

When you receive your LDC-3916558 3-Amp Temperature Control Module, check for shipping damage immediately. Verify that the module has an ESD protective hood on the 15-pin D-sub and that it is enclosed in an ESD safe handling bag. Remember before handling the module to follow proper ESD safe handling procedures.

Installing the Module into the LDC-3916 or LDC-3908 Mainframe

If you are receiving this new module without an LDC-3916 or LDC-3908 Mainframe for installation into a previously purchased mainframe, follow the instructions below. If your system was configured at the factory with your desired modules, skip this section.

⚠ **CAUTION**

Static discharge can damage your new Temperature Controller Module. Be certain you use proper grounding procedures before you unpack and install your module(s) into the LDC-3916 or LDC-3908 Mainframe.

Inspect the module for any visible shipping damage that may have occurred before inserting the module into the mainframe. Pay special attention to the copper shielding material on the back edge of the module.

Be sure that the LDC-3916 or LDC-3908 Mainframe power is off before inserting or removing any module.

Unwrap the module from the anti-static bag it was packaged in.

Make sure the instrument the module is going into, either the LDC-3916 or the LDC-3908, is switched off. Insert the module into the desired slot from the rear. Each module is supported by two plastic card guides inside of the mainframe. Insert the module, 40-pin connector first, by lining up the edges of the module frame with the appropriate card guides (one on top and one on the bottom). Carefully slide the module into the mainframe slot until the connector is seated. You will have to push a little harder to seat the module.   The rear panel of the module should be flush with the mainframe when properly inserted. Fasten the module to the mainframe with two screws located at the top and bottom of the module rear panel.

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Specifications

Temperature Control[1]	
Temperature Control Range[2]:	-99°C to 150°C
Thermistor Setpoint (Resolution and Accuracy)[3]	
-20°C to 20°C	0.1 ^{o}C; $\pm$0.2^{o}C
20°C to 50°C	0.2 ^{o}C; $\pm$0.2^{o}C
Short Term Stability (1 hour)[4]:	<$\pm$0.007^{o}C
Long Term Stability (24 hours)[5]:	<$\pm$0.01^{o}C
Output Type:	Bipolar current source
Compliance Voltage:	8 VDC
Maximum Output Current:	3 A
Maximum Output Power:	24 W
Current Noise and Ripple[6]:	<2 mA rms
Current Limit Range:	0.1 to 3.10 A
Current Limit Set Accuracy:	$\pm$0.05 A
Control Algorithm:	Gain adjustable from 1 to 127
Temperature Sensor	
Types:	Thermistor (2-wire NTC)
Thermistor Sensing Current[7]:	10 uA/100 uA
Useable Thermistor Range:	25 to 450,000 Ω typical
User Calibration:	Steinhart-Hart, 3 constants
TEC Measurement (Display)	
Temperature	
Range[8]:	-99.9^{o}C to 199.9^{o}C
Accuracy:	$\pm$0.5^{o}C
Thermistor Resistance (10 uA setting)	
Range:	0.01 to 450.00 kΩ
Accuracy[9]:	$\pm$0.05 kΩ
Thermistor Resistance (100 uA setting)	
Range:	0.001 to 45.000 kΩ
Accuracy[10]:	$\pm$0.005 kΩ
TE Current Range:	-3.00 to 3.00 A
TE Current Accuracy:	$\pm$0.04 A

TE Current Resolution:	$\pm$0.01 A
Voltage Range:	-10.75 to 10.75 V
Voltage Resolution:	100 mV (1 mW through GPIB)
Voltage Accuracy[11]:	$\pm$70 mV ($\pm$20 mV through GPIB)

1. All values relate to a one-hour warm-up period
2. Software limits of range. Actual range possible depends on the physical load, thermistor type, and TEC module used.
3. Accuracy figures are quoted for a typical 10 kΩ thermistor and 100 uA current setting for -5°C to 50°C, and a typical 10kΩ thermistor and a 10 uA current setting for -20°C to -5°C. Accuracy figures are relative to the calibration standard. Both resolution and accuracy are dependent upon the user-defined configureation of the instrument.
4. Over any one-hour period, half-scale output, controlling an LDM-4412 mount @ 25°C, with 10kΩ thermistor, on 100 uA setting.
5. Over any 24-hour period, half-scale output, controlling an LDM-4412 mount @ 25°C, with 10kΩ thermistor, on 100 uA setting.
6. Measured at 2A output over a bandwidth of DC to 25 MHz.
7. Thermistor current software selectable by front panel or GPIB.
8. Software limits of display range.
9. Using a 100 kΩ thermistor, controlling an LDM-4412 mount of -30°C to 25°C.
10. Using a 10 kΩ thermistor, controlling an LDM-4412 mount over -5°C to 90°C
11. Voltage measurement accuracy while driving calibration load; accuracy is dependent upon load used.

In keeping with our commitment to continuous improvement, ILX Lightwave reserved the right to change specifications without notice or liability for such changes.

OPERATIONS

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This chapter introduces you to the operation of the LDC-3916558 front panel control functions. It shows you how to use the 3916558 to control a load temperature. It also gives instructions for connecting a load to a temperature controller's output. We recommend that you review the contents of this chapter at a minimum before operating your new LDC-3916558 3-Amp Temperature Control Module.

The 3916558 module contains a 3-Amp temperature controller.

The 3916558 is intended for use with Thermoelectric Cooler (TEC or Peltier) modules.

Connecting to the Temperature Controller

Use the 15-pin connectors on the rear panel of your 3916558 module to make connections to thermoelectric cooler (TEC) modules and their associated thermistors. There are connections provided for current drive and temperature sensor. Also provided are connections to earth ground (chassis) and to the modules' analog ground. The pinout diagram for this connector is shown in Figure 2.1.

Pins	Function
1,2	TE Module (+)
3,4	TE Module (-)
5,6	Earth Ground
7	Sensor (+)
8	Sensor (-)
9	Analog Ground
10	N/C
11	N/C
12	N/C
13	N/C
14	N/C
15	N/C
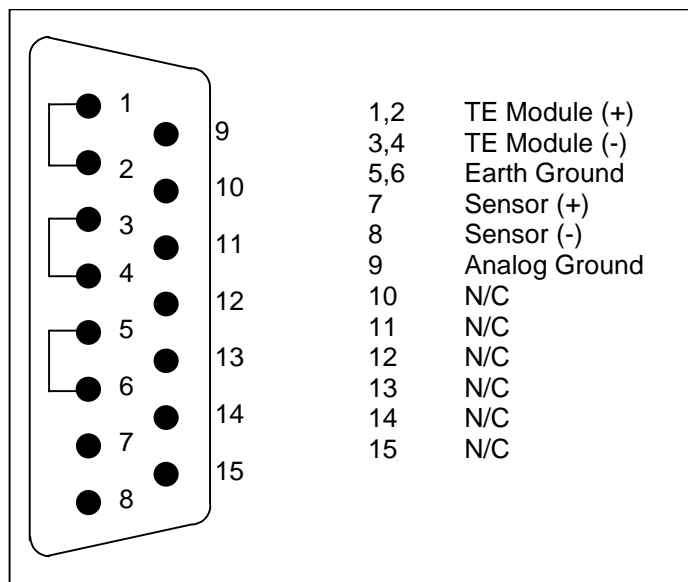
Figure 2.1 Rear Panel TEC Connector

Current will flow from pins 1 and 2 (connected internally) to pins 3 and 4 when the controller is trying to cool the load. This is referred to as "positive" current. Current will flow from pins 3 and 4 to pins 1 and 2 when the controller is trying to heat the load. Pin 5 and 6 are connected to the LDC-3916 or LDC-3908 chassis, which is connected to "earth ground." Sensor current (10 μA or 100 μA) flows from pin 7 to pin 8; a voltage will develop across a thermistor connected to these pins. Analog Ground is provided at pin 9 as a convenient reference when making measurements or troubleshooting a system, but it is not normally required. Pins 10-15 are reserved by ILX Lightwave for diagnostic purposes and must not be connected.

TEC Grounding Considerations

The TEC Module pins are isolated from chassis ground, allowing either output terminal to be connected to earth ground at the user's option.

⚠ CAUTION

For the TEC connector, if any one terminal pin is grounded, then no other terminal pin should be grounded. Do NOT connect Sensor (-) to TEC Module (- or +). Damage to the instrument and devices will occur.

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Operating the Temperature Controllers from the Front Panel

This section describes how to operate the LDC-3916558 3-Amp Temperature Controller from the front panel of either the LDC-3916 or LDC-3908 mainframe. It begins by reviewing the front panel operations and continues by showing you an example. For a more detailed explanation of the front panel keys, see either the LDC-3916 or LDC-3908 Mainframe manual.

General Front Panel Operation
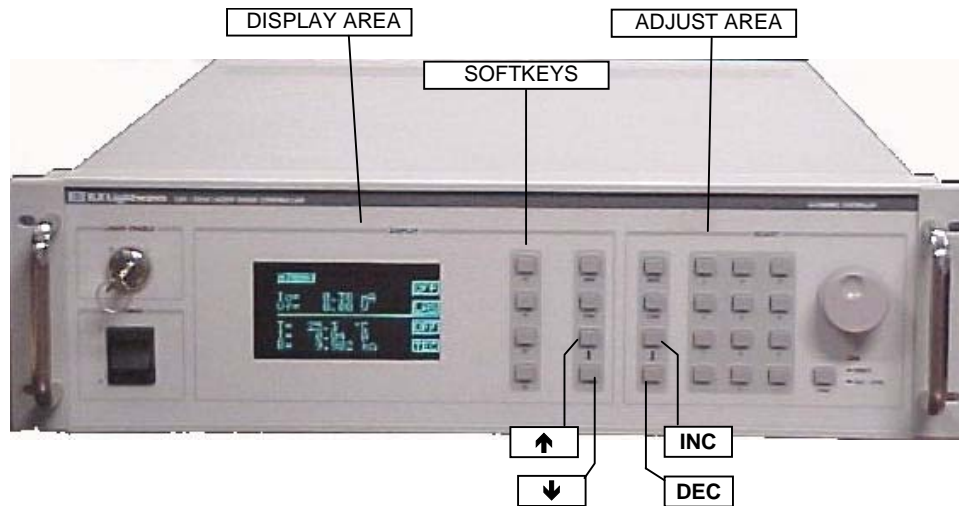
Figure 2.2 3916 Front Panel

The two areas of interest on the front panel are the DISPLAY area and the ADJUST area. The DISPLAY area contains the display screen and various keys that allow you to select a menu and parameters within that menu.

The keys labeled F1, F2, F3, and F4 have several functions depending which page is displayed. The boxed text on the right of the screen are the functions associated with these softkeys. In the lower right corner of the DISPLAY area are the UP (↑) and DOWN (↓) ARROW hardkeys. Most of the menus have adjustable parameters. You adjust the parameters using the ↑ or ↓ hardkeys.

The ADJUST section contains keys used to adjust the value of a parameter once selected. Set the value of a parameter using the numeric keypad (along with the ENTER key), the ADJUST knob, or the INC (↑) and DEC (↓) keys in the lower left corner of the ADJUST section.
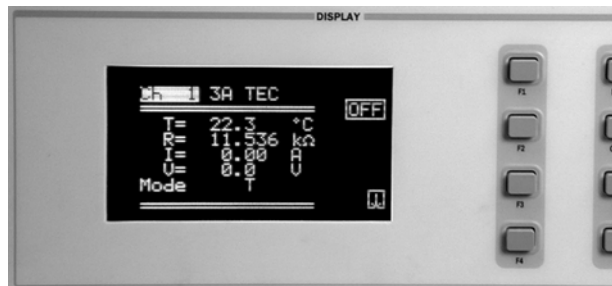
Example Setup

The 3916558 temperature controller has four pages (menus) of information.

Suppose you need to maintain the temperature of a laser package at 15.5 °C . Your laser is in a package that comes equipped with an internal TEC module and a thermistor.

To set up the temperature controller:

- Select constant-temperature control mode
- Enter the temperature setpoint of 15.5 C
- Select the sensor current range
- Enter the appropriate thermistor constants
- Set the control loop gain
- Set appropriate high temperature limit and TEC module current limits.

To access any of the TEC information pages you must start with the "Channel" menu. The most direct way is to press the CHAN key located directly below the MAIN key in the upper right corner of the DISPLAY area.

The Channel menu allows you to change channels (modules) by rotating the ADJUST knob, turn the temperature controllers on or off, and access each of the TEC's menus. To get to the TEC's first menu, press the F2 softkey: it is "attached" to the "TEC" box in the Channel menu. The next menu is the TEC page 1 menu.

Figure 2.3 Channel Menu

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In the TEC page 1 menu, you can set the Temperature setpoint (TSet), the high temperature limit (TLim), and the control mode (Mode). This page also displays measured temperature (T), TE module current (I), and measured TEC module voltage (V). You can also turn the controller on or off from this page.

To enter the temperature set point, press the ↓ hardkey until the TSet parameter is highlighted. Enter 15.5 using the keypad, and press Enter. Note: whenever you use the keypad to enter a parameter value, you must press Enter within three seconds or the parameter will revert to its previous value. Now press the ↓ hardkey until the TLim parameter is highlighted. Enter 40.0 using the numeric keypad. Now press the ↓ hardkey until the Mode parameter is highlighted. Press the INC hardkey in the ADJUST area until "T" is displayed.
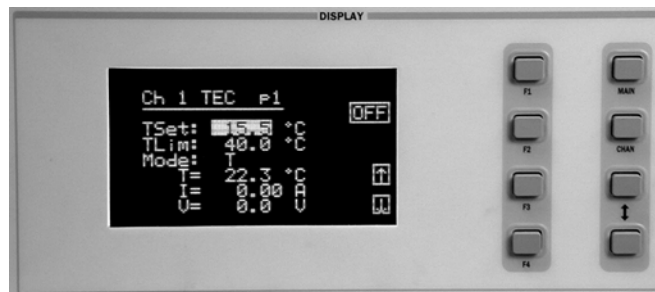
Figure 2.4 TEC p1 Menu

From the TEC page 1 menu, press the F4 softkey: it is attached to the "down-arrow" box on the page 1 menu. Now you will see the TEC page 2 menu.
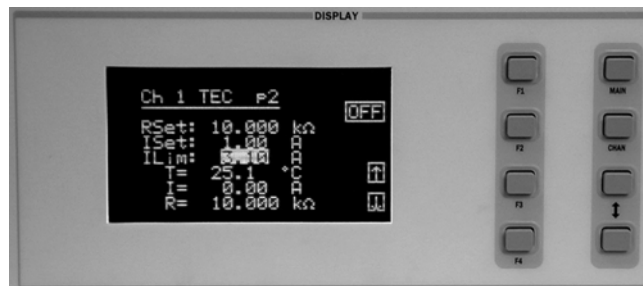
Figure 2.5 TEC p2 Menu

In the TEC page 2 menu, you can set the constant resistance setpoint, the constant current setpoint, and the current limit. Press the ↓ hardkey until the ILim parameter is highlighted. Enter 3.0 using the numeric keypad. The RSet parameter is for constant resistance control mode, and the ISet parameter is for constant current mode.
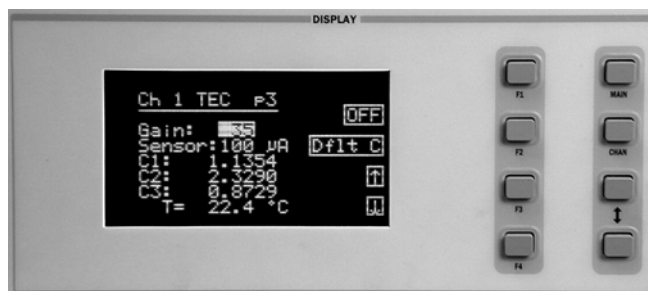
Figure 2.6 TEC p3 Menu

In the TEC page 3 menu, press the   hardkey until the Gain parameter is highlighted. If you're not sure what the best gain setting should be, a safe first choice is 30. If you want the controller to drive to the setpoint faster, enter a higher value. For this example, enter the number 35. Now press the ↓ hardkey until the Sensor parameter is highlighted. For now, press the INC hardkey in the ADJUST area until 100 μA is displayed. The other parameters you can enter from this page are the Steinhart-Hart coefficients for the particular thermistor that you are using to measure temperature. If it's installed in a laser package, the coefficients may be available in the package documentation. You can restore the default values by pressing the F2 softkey. The defaults are approximate values for the typical 10 kΩ thermistor.

Figure 2.7 TEC p4 Menu

From the TEC page 3 menu, press the F4 softkey: it is attached to the "down-arrow" box on the page 3 menu. Now you will see the TEC page 4 menu. In the TEC page 4 menu, you can configure the TEC to turn off a laser current source in a different channel that has any of the modules shown in Table 2.1. The TEC will then turn off an external laser if the temperature limit is exceeded or if the TEC fails in anyway. Highlight the Channel parameter and turn the knob (or press the INC hardkey) to select the desired channel number, All to choose all channels, or None so that the TEC will not turn off any laser current sources.

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Note: The only channel numbers that will appear are channels in which a controllable laser source resides. Next, highlight the Output parameter and turn the knob (or press the INC hardkey) to select laser source output 1 or 2 (refer to Table 2.1), Both to choose both outputs, or None so that the TEC will not turn off either laser current source output. In modules with 2 laser sources, output 1 is the top source and output 2 is the bottom source.

Table 2.1 TEC Controllable Laser Sources

3916 Module	Firmware Version	Number of Laser Source Outputs
3916371	v2.03 or greater	1
3916372	v2.03 or greater	1
3916374	v2.03 or greater	1
3916376	v2.03 or greater	1
3916332	v1.03 or greater	2
3916334	v1.03 or greater	2
3916336	v1.03 or greater	2
3916338	v1.06 or greater	1

You are now finished setting up the TEC to control temperature to 15.5 C. Connect the load and turn on the temperature controller. From any of the three TEC pages p1, p2, p3 or p4, you can turn on the output by pressing the F1 softkey, associated with the "OFF" box in each page. Notice that the text inside the box changes to "ON." The text box reports the controller's on/off status.

Note: To check the firmware version in any module, select the correct channel number in the CHAN menu, then press the following keys in this order:

+/   .   **Enter**

For information regarding firmware upgrades, contact ILX Customer Support.

Guidelines

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

Choosing Control Mode

In the preceding example, you configured a controller to maintain a load at a constant temperature. The 3916558 controller uses a thermistor to measure temperature. A negative temperature coefficient (NTC) thermistor is a device whose resistance decreases as its temperature increases. The sense-current that the controller provides through the thermistor results in a voltage across the thermistor. This voltage is used as a feedback signal by the 3916558's control loop to maintain a constant temperature.

In both constant-temperature and constant-resistance modes, the quantity that is maintained constant by the controller is the thermistor resistance. In constant temperature mode, the 3916558 converts the temperature setpoint to a thermistor resistance setpoint.

The 3916558 uses the Steinhart-Hart equation to convert a temperature to a resistance. The equation describes the nonlinear resistance vs. temperature characteristics of typical thermistors. Calibrating a thermistor consists of measuring its resistance at various temperatures, and fitting these measured data to the Steinhart-Hart equation. The resulting coefficients C1, C2, and C3 effectively describe the thermistor.

If you need to know the precise temperature of your load, you must use a calibrated thermistor, and enter its Steinhart-Hart coefficients C1, C2, and C3 in the page 3 menu. If the exact temperature is not crucial, you can use the default constants provided by the 3916558. However, the 3916558's temperature accuracy specifications apply only to a calibrated thermistor with C1, C2, and C3 entered.

In effect, constant temperature control mode is the same as constant resistance mode, but the temperature setpoint TSet is converted to a resistance setpoint. (RSet, the constant-resistance setpoint, is not affected by TSet.) If you prefer to avoid that conversion, or if you do not know your thermistor's coefficients, but you know the thermistor resistance at your desired operating point, then constant-resistance mode is an option for you.

Another control mode that is available in the 3916558 is constant-current mode. In general, the amount of heat a TEC module pumps depends on its drive current. If you have a situation where a constant heat load must be removed or added, then you might consider using constant current mode.

Setting Gain

The control circuit in the 3916558's temperature controller includes a "proportional" section. The amount of current provided by this circuit is proportional to the difference between the measured temperature (resistance) and the setpoint temperature (resistance). The proportionality constant of this circuit is the Gain setting in the page 3 menu. A higher value in this setting will cause more current to flow when the load temperature differs from the setpoint temperature, thus causing a quicker correction.

More gain is not always better, though, as the thermal mass of the load may cause a situation where the load temperature oscillates about the setpoint. Selecting the proper gain for your particular application is normally an empirical procedure, with heat load, thermal mass, maximum current, desired settling time, and allowable overshoot all playing a part.

A common method for selecting the gain to get the fastest temperature settling time is the following: set the gain to 30, turn on the output and allow the load to settle, then increase the gain until the load temperature oscillates about the setpoint. Then decrease the gain by a few points until the oscillations cease.

The control circuit also includes an integrating section. The longer the load temperature is different from the setpoint, the more current the integrating section contributes. An integrating term is indispensable in a system that has inertia, such as thermal mass. The integrating circuit is not adjustable.

Setting Sensor Current

You can select a thermistor sense current of 10 μA or 100 μA in the page 3 menu. When deciding which current (and thermistor) to use, keep in mind the following principles:

1   To ensure measurement accuracy, the voltage across the thermistor must not exceed 5 V.

2   To improve control responsiveness, the thermistor voltage variations that result when the load temperature deviates from the setpoint should be as large as possible.

Using 10 A as the sense current will allow you to use a maximum thermistor resistance of ~ 500 kΩ. The 100 μA setting allows an ~ 50 kΩ maximum.

To see why maximizing the voltage variation is an issue, refer to Figure 2.8, which shows resistance as a function of temperature for a thermistor. The values shown were selected for simplicity in this example, and may not reflect real thermistor values.
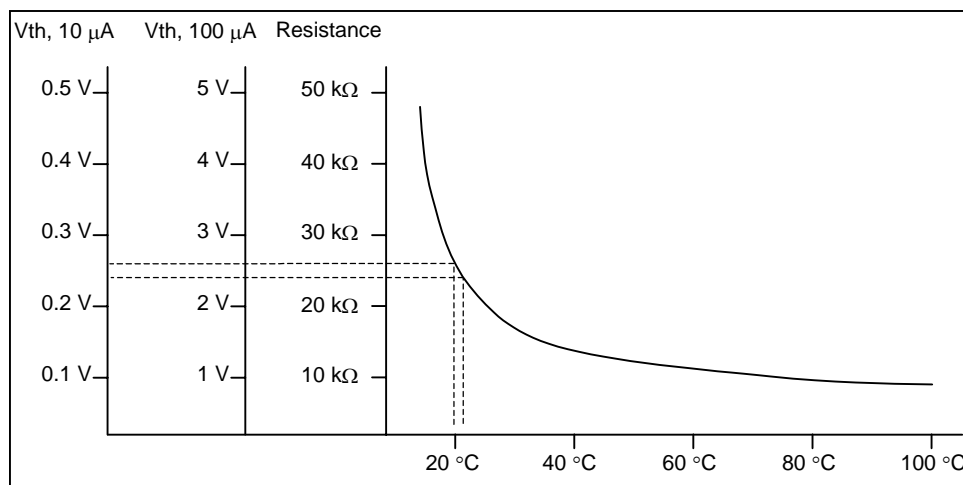
Figure 2.8 Example Thermistor Resistance vs. Temperature

Suppose you want to use the thermistor in Figure 2.8 to control a load to 20°C. At 20°C, the thermistor's resistance is 25 kΩ. Deviations of 1°C from 20°C will cause resistance variations of about 2 kΩ. If you use the 10 μA setting, there will be 20 mV of feedback to the control circuit. Using the 100 μA setting will provide 200 mV of feedback. The larger feedback signal means that the temperature will be more tightly controlled.

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

If you do not have the option of selecting a thermistor, use the following guideline: If your desired setpoint results in a thermistor resistance of less than 50 kΩ, use the 100 μA setting. Otherwise, use the 10 μA setting.

Setting Safety Limits

TEC modules can be damaged by excessive current, and module manufacturers will typically specify a maximum safe operating current for their module. The 3916558 controller provides a current limit feature (ILim) that allows you to set the maximum current that the controller will supply. The ILim setting is in the page 2 menu; its units are Amperes.

It is normal for the controller to be in current limit, especially when the load temperature is far from the setpoint. An indication, "ILim," will appear on the screen when the controller is in a current-limit condition.

If the load you are cooling generates more heat than the controller and TEC module can remove, the load will eventually heat up. In fact, if the TEC module's heat sink becomes heat saturated, the TEC current may actually start heating the load due to the resistance of the module. This situation is sometimes referred to as "thermal runaway," and can cause a load to become damaged.

To help avoid thermal runaway damage, the 3916558's controller provides a high-temperature limit setting (TLim). When the load temperature exceeds the TLim setting, the 3916558 will turn off the TEC current and generate an error. The TLim setting is in the page 1 menu. Using GPIB, you can disable the high-temperature limit from turning off the controller. See Chapters 3 and 4 for more information about disabling or enabling conditions that will turn off the controller.

Default Settings

When you select Default from the Recall menu, the 3916558 module will return to the following settings:

Table 2.2 3916558 Default Settings

Output	Off
Mode	Constant-Temperature
Temperature setpoint (TSet)	$22^{o}C$
TEC current setpoint (ISet)	1.0A
Current limit (ILim)	1.0A
Temperature limit (TLim)	$80.0^{o}C$
Resistance setpoint (RSet)	$10k\Omega$
Gain	3
Sensor Current	100 uA
C1	$1.125 \ (x \ 10^{-3})$
C2	$2.347 \ (x \ 10^{-4})$
C3	$0.855 \ (x10^{-7})$

TEC Error Indicators

The 3916558 Controller indicates general TEC operational error conditions. When an error occurs, the Error Indicator Code will appear on the Status page, the Chan page, or the respective channel's setup pages. The Error Indicator Code will clear when you exit any page where it appears. Error Indicator codes are summarized in Table 2.3. Some of these errors can be disabled using GPIB. See Chapter 4 for more information.

Table 2.3 TEC Error Indicators

Error Number	Error Condition	Probable Cause
E402	Open Sensor	An open circuit has been detected in the thermistor connections. Check the connections to the thermistor and to pins 7 and 8 on the 15-pin connector.
E403	TE Module Open	An open circuit has been detected in the TEC module connections. Check the wires and connections to the TEC module, and to pins 1, 2 and 3, 4 on the controller's 15-pin connector.
E404	Current Limit	The controller reached the current limit, and the "current limit" bit of the Output Off Enable register has been set using GPIB.
E405	Voltage Limit	The output driver has reached its voltage limit and the "voltage limit" bit of the Output Off Enable register has been set using GPIB.
E407	Temperature Limit	The measured temperature has reached the high-temperature limit setting.
E409	Sensor Changed	The sensor current was changed while the output was on, and the "Sensor Changed" bit of the Output Off Enable register has been set using GPIB.
E410	Tolerance error	The output dropped out of tolerance, and the "Tolerance" bit in the Output Off Enable register has been set.
E415	Sensor Shorted	The measured thermistor resistance is less than 25Ω, and the "Sensor Shorted" bit in the Output Off Enable register has been set.
E416	Temperature Conversion error	The temperature setpoint could not be converted to a valid control setting. This can happen if the Steinhart-Hart constants are invalid.
E435	Mode Changed	The TEC mode was changed while the TEC output was on.

The errors that are enabled in the "Output Off Enable" register by default at power-up are Open Sensor, TEC Module Open, Temperature Limit, and Sensor Shorted. The Output Off Enable register is not saved at power-down.

REMOTE OPERATIONS

Almost everything that you can do from the front panel can also be done remotely. In fact, more features and information are available through the remote interface than are available from the front panel. For example, using the Enable:Outoff command, you can set up the module so that it will turn off if it goes into current limit. You cannot do that from the front panel. The following sections show you the fundamentals of operating your LDC-3916558 module remotely through the GPIB or RS-232 interfaces.

Remote Configuration

Refer to either the LDC-3916 or LDC-3908 Instruction Manual Chapter 3, "Operating in Remote Control" for information concerning setup of GPIB or RS-232 remote communications. That section also describes the use of IEEE 488.2 common commands, LDC-3916/LDC-3908 mainframe commands, and syntax.

LDC-3916558 3-AMP Temperature Control Module Command Set

The LDC-3916558 3-Amp Temperature Controller has its own module-specific command set, separate from the commands for the LDC-3916/LDC-3908 mainframe (see either the LDC-3916 or LDC-3908 Instruction Manual Chapter 3 "Operating in Remote Control"). Figure 3.1 shows all of the commands that are usable by the LDC-3916558 module in conjunction with the LDC-3916 and LDC-3908.

(root)

: TEC

*CAL?	ALLCOND?	MODERR?
*CLS	ALLEVE?	MODIDN?
*ESE	BEEP	MODPUD
*ESE?	BEEP?	MODPUD?
*ESR?	CHAN	STATMENU:LINE*n*:?
*IDN?	CHAN?	STATMENU:LINE*n*:TEMP
*OPC	CHECKSUM?	STATMENU:LINE*n*:RES
*OPC?	DELAY	STATMENU:LINE*n*:ITE
*PSC	ERR?	STATMENU:LINE*n*:TEV
*PSC?	MENU	(*n* = 1 or 2)
*PUD	MES	
*PUD?	MES?	
*RCL	RAD	
*RST	RAD?	
*SAV	SECURE	
*SRE	TERM	
*SRE?	TERM?	
*STB?	TIME?	
*TST?	TIMER?	
*WAI		

:CONST
:CONST?
:COND?
:EVE?
:GAIN
:GAIN?
:ITE
:ITE?
:LASOFF
:LASOFF?
:MODE?
:OUT
:OUT?
:R
:SEN
:SEN?
:SYNCI?
:SYNCR?
:SYNCT?
:SYNCV?
:T
:T?
:TOL
:TOL?
:V?

:ENAB
|
:COND
:COND?
:EVE
:EVE?
:OUTOFF
:OUTOFF?

:LIM
|
:ITE
:ITE?
:THI
:THI?

:MODE
|
:ITE
:R
:T

:SET
|
:ITE?
:R?
:T?

:CONV
|
:R
:R?
:T
:T?

:CAL
|
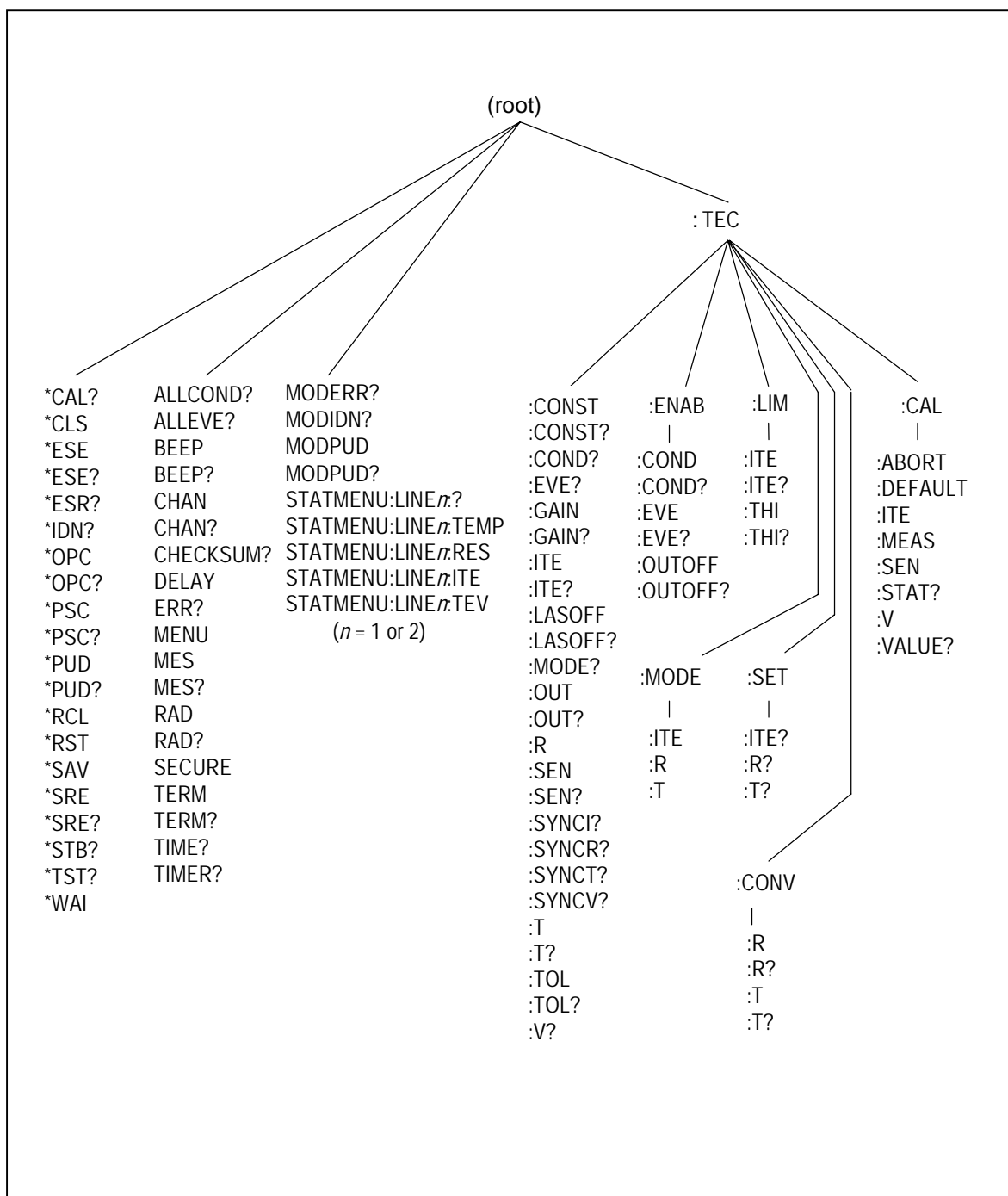:ABORT
:DEFAULT
:ITE
:MEAS
:SEN
:STAT?
:V
:VALUE?

Figure 3.1 LDC-3916558 3-Amp Temperature Controller Command Path Structure

LDC-3916558 3-Amp Temperature Controller Often Used Commands

The complete command set of the LDC-3916558 3-Amp Temperature Control module is listed in chapter 4 of this manual. Within the command set, however, are a few commands that have been found to be frequently used. These commands are listed in Table 3.1.

Table 3.1 LDC-3916558 Often Used Commands

Name	Parameters	Function	Example
CHAN	1	Sets the channel number for further commands.	chan 1
ERR?	none	Returns "Mainframe" errors generated since the last query followed by a binary indication of modules with errors.	err?
MODERR?	none	Returns module errors generated since the last error query (to that module).	moderr?
TEC:			
TEC:MODE:T	none	Selects the constant-temperature control mode.	tec:mode:t
TEC:T	1	Sets the constant-temperature mode setpoint.	tec:t 25.6
TEC:LIM:THI	1	Sets the high temperature limit.	tec:lim:thi 100.0
TEC:LIM:ITE	1	Sets the current limit.	tec:lim:ite 1.1
TEC:SEN	1	Sets the thermistor current (10 μA or 100 μA).	tec:sen 1
TEC:GAIN	1	Sets the control loop gain.	tec:gain 40
TEC:OUT	1	Turns the temperature controller on or off.	tec:out on
TEC:T?	none	Returns the measured temperature.	tec:t?

Table 3.1 illustrates the minimum set of settings that must be entered for proper operation of a temperature controller in the LDC-3916558: control mode, setpoint, high-temperature limit, current limit, sensor type, and control loop gain.

Command Timing and Completion

All commands for the LDC-3916558 module are sequential. The "Tolerance" feature can be used to notify a controller that a device's controlled temperature has settled to its setpoint.

Status Reporting

Refer to either the LDC-3916 or LDC-3908 Laser Diode Controller ("Mainframe") Instruction Manual, Chapter 3 "Operating in Remote Control," for more detailed information on standard status structures, and mainframe-related commands.

The following sections discuss the LDC-3916558 module-dependent aspects of status reporting, including the "OUTOFF" commands and queries. The Output Off Register is used to specify the conditions that will force a temperature controller to turn off.

Status Registers

The temperature controller in an LDC-3916558 has its own Condition register and Event register. These registers indicate the existence or occurrence of conditions or events of interest. An example of a condition is "Current drive is in current limit." An example of an event is "Current drive went into current limit." A program running on a host controller may poll the device (i.e. TEC) on the module loaded into the LDC-3916 or LDC-3908 mainframe, to determine if a condition exists or an event happened that may be of interest or that may constitute a problem.

Alternatively, a controller program may set up the modules to report only conditions or events of interest when they occur. The controller program can then simply read the mainframe's All-Condition or All-Event registers (using the ALLCOND? and ALLEVE? queries) to determine if any interesting situations exist, and then only poll the module that has indicated the situation. When a selected condition exists in a module, the mainframe's ALLCOND register has the bit corresponding to that module set. When a selected event has occurred in a module, the bit corresponding to that module is set in the ALLEVE register.

Each channel of the LDC-3916 and LDC-3908 may contribute to the "ALLCOND" and "ALLEVE" registers. For the 3916558 module, the enabled conditions of the temperature controller are logically ORed, and the summary is passed to the appropriate bit of the ALLCOND register (see Figure 3.2). Likewise, the enabled events of the temperature controller are logically ORed, and the summary is passed to the appropriate bit of the ALLEVE register (see Figure 3.3). By "appropriate bit" we mean the bit corresponding to the channel number: bits 0-15 correspond to modules in channels 1-16 or bits 0-7 corresponding to modules in channels 1-8.

Furthermore, you can set up the mainframe so that when a situation of interest occurs in one or more modules, the mainframe generates an SRQ (Service Request) to the host controller.

For example, you may want the LDC-3916 or the LDC-3908 to interrupt the host controller in the event of TEC's temperature going out of tolerance. As Figure 3.3 shows, bit 9 of TEC's Event register will be set when the temperature goes into or

out of tolerance. To enable that event to be reported, set bit 9 in TEC's Enable Event register using the command "TEC:ENAB:EVE 512". This allows an In Tolerance event to be passed to the ALLEVE register in either the 3916 or 3908 mainframe. You can monitor the ALLEVE status by using the "ALLEVE?" query, and you can monitor the summary using the "*STB?" query. To generate the SRQ (interrupt) for our example, you must also set the Service Request Enable Register, using "*SRE 1", to allow the ALLEVE summary to generate the interrupt.
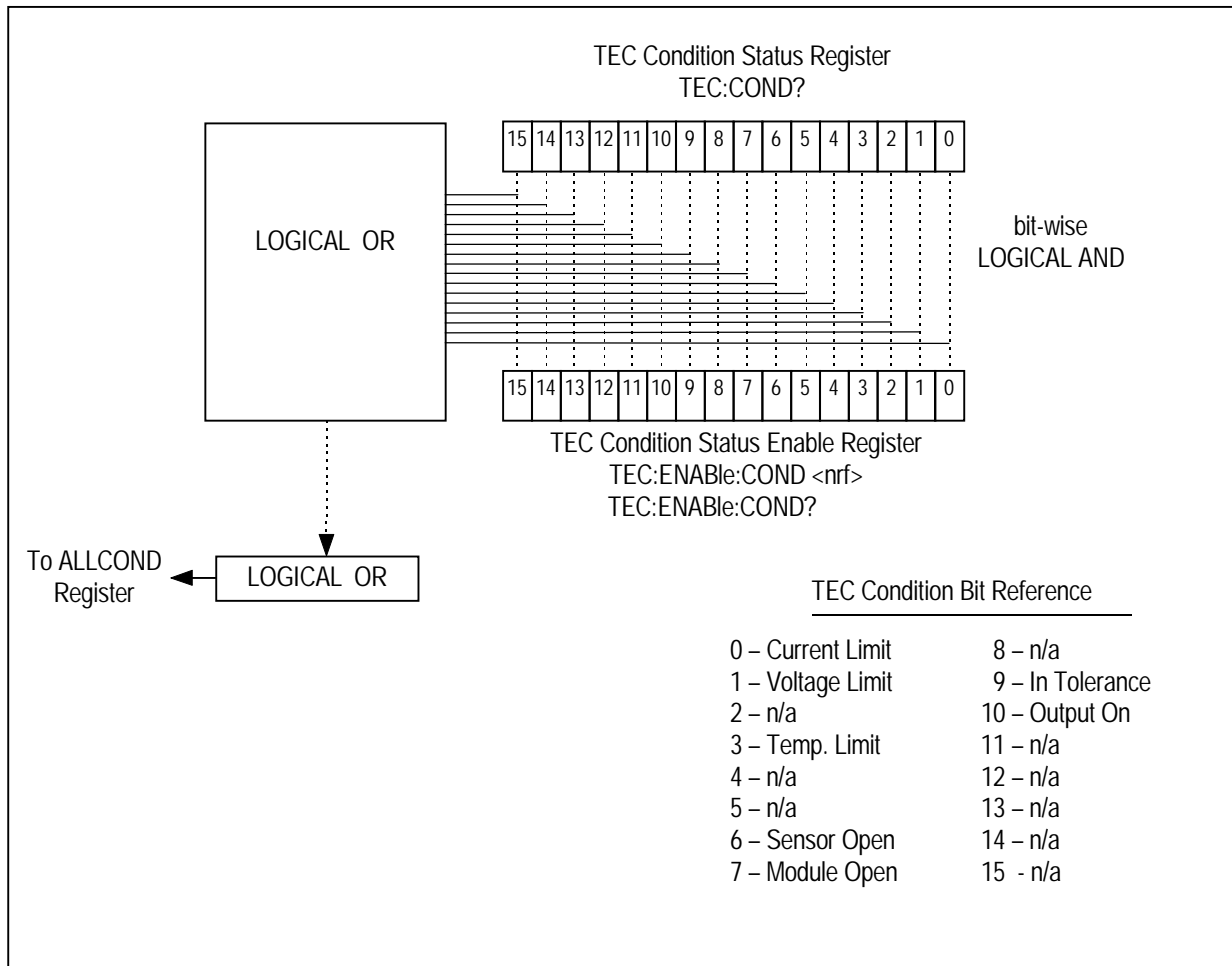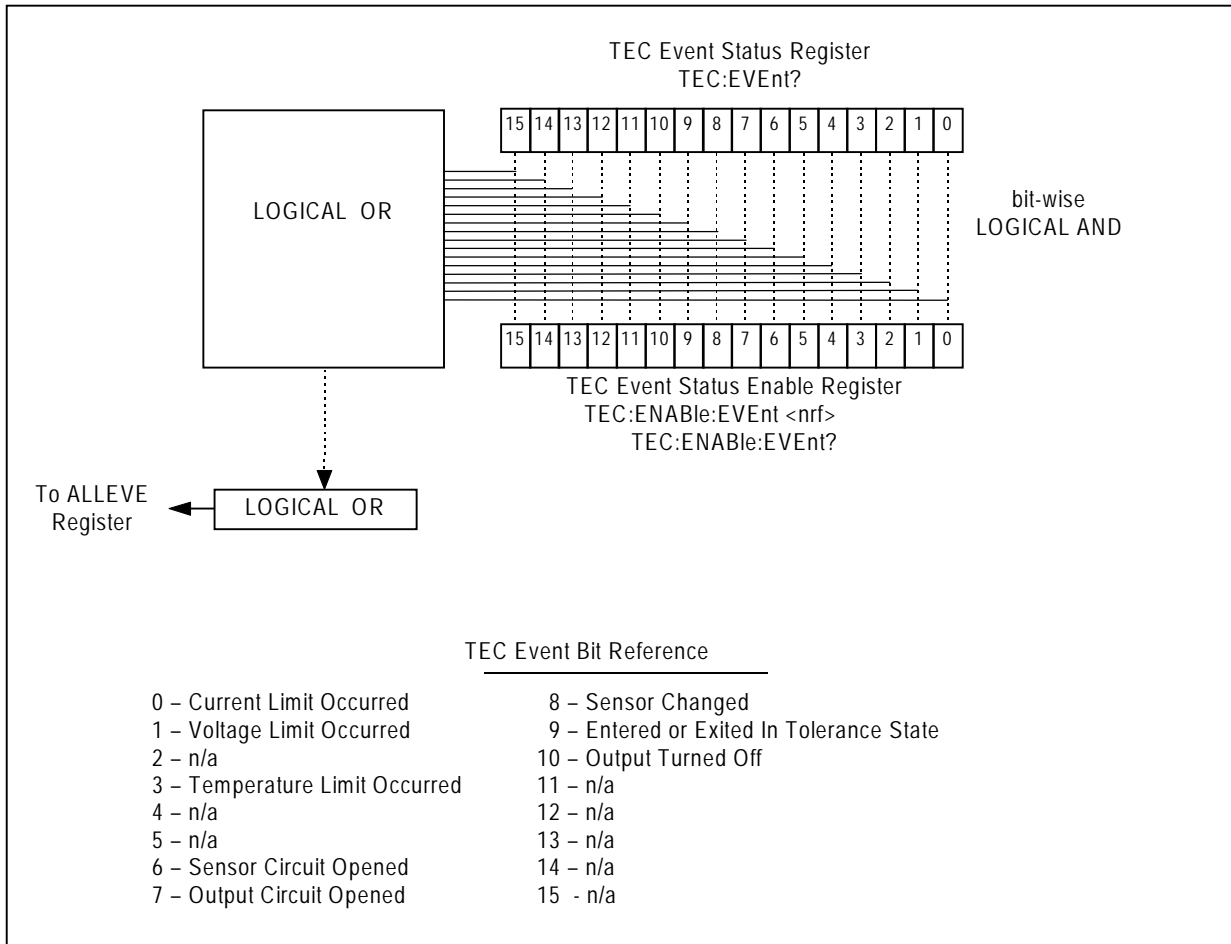

Figure 3.2 LDC-3916558 Status Condition Registers

The bits in the module's Condition Register reflect as closely as possible the state of the instrument. These bits are therefore dynamic: they are set or cleared as conditions come or go.

TEC Event Status Register
TEC:EVEnt?

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

LOGICAL OR

bit-wise
LOGICAL AND

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

TEC Event Status Enable Register
TEC:ENABle:EVEnt <nrf>
TEC:ENABle:EVEnt?

To ALLEVE
Register

LOGICAL OR

TEC Event Bit Reference

0 – Current Limit Occurred
1 – Voltage Limit Occurred
2 – n/a
3 – Temperature Limit Occurred
4 – n/a
5 – n/a
6 – Sensor Circuit Opened
7 – Output Circuit Opened

8 – Sensor Changed
9 – Entered or Exited In Tolerance State
10 – Output Turned Off
11 – n/a
12 – n/a
13 – n/a
14 – n/a
15 - n/a

Figure 3.3 LDC-3916558 Event Status Registers

The bits in a module's Event Registers are "sticky": when an event occurs, the corresponding bit will remain set until the user reads the Event Register.

Output Off Registers

The Output Off Enable Registers allow you to specify the conditions that cause the temperature controllers' outputs to be automatically turned off. The events and conditions that may be selected to turn off the outputs are shown in Table 3.2.

Table 3.2 LDC-3916558 TEC Output Off Register Contents

Bit Number	Condition	Default Value
0	Current Limit	0 (Disabled)
1	Voltage Limit	0
2	N/A	0
3	Temperature Limit	1 (Enabled)
4	N/A	0
5	N/A	0
6	Sensor Open	1
7	Module Open	1
8	Sensor Changed	0
9	Not in Tolerance	0
10	Sensor Shorted	1
11	N/A	0
12	N/A	0
13	N/A	0
14	N/A	0
15	N/A	0

The default (factory) settings for the TEC Output Off registers are also shown in Table 3.2. The default contents of each register are 1224 (decimal). The contents of the Output Off registers are not affected by the *PSC (Power-On Status Clear) command.

Error Messages

This section contains descriptions of the errors that are specific to the LDC-3916558 modules. These are the error codes that the module reports in response to the "MODERR?" query. Refer to either the LDC-3916 or the LDC-3908 ("Mainframe") Instruction Manual, Chapter 3, for a list of LDC-3916 and LDC-3908 mainframe error codes and descriptions (the codes returned in response to the "ERR?" query).

During remote operation, the recommended method for error testing is as follows. First read the system errors and module error summary with the "ERR?" query. This will allow you to error-check the LDC-3916 and the LDC-3908 as a whole. If any module errors are present, the corresponding bit of the module error summary will be set. For example, suppose the 3916 responds to an "ERR?" query with the string "0,0000000001100000". The "0" to the left of the comma indicates that there are no mainframe errors, and the binary representation to the right of the comma indicates that there are errors on channels 7 and 6. (Module 16 is on the left, module 1 is on the right, for the 3908, there are only 8 bits after the comma). Read the module errors using the "MODERR?" query. For example, "Chan 7;Moderr?" will return the errors in module 7, and "Chan 6;Moderr?" will return any errors in module 6. For more information on LDC-3916 and LDC-3908 mainframe errors, refer to the LDC-3916 or the LDC-3908 Instruction Manual, Chapter 3.

Error Code	Explanation
E-103	Length of arbitrary block is different from expected length
E-104	Parameter is an undefined numeric type
E-105	Parameter has an invalid exponent
E-106	A digit was expected in the parameter but was not found
E-114	Specified arbitrary block length is invalid
E-123	Command is not found
E-126	Wrong number of parameters for command
E-201	Parameter value out of range
E-202	Error in conversion of parameter type
E-203	Command is a "secure" command, but secuire commands are disabled
E-204	Suffix is invalid
E-205	Expected Boolean parameter is invalid
E-206	Error in conversion to signed 16-bit integer
E-207	Error in conversion to unsigned 16-bit integer
E-208	Error in conversion to signed 32-bit integer
E-209	Error in conversion to unsigned 32-bit integer

Error Code	Explanation
E-210	Error in conversion to floating-point number
E-211	Error in conversion to character pointer
E-212	Error in conversion to byte pointer
E-214	Response is too long to output
E-222	Set value is over range
E-223	Set value is under range
E-226	Error in arbitrary block specification
E-402	Open Sensor caused TEC to turn off
E-403	Open Module (Open Circuit) caused TEC to turn off
E-404	Current Limit caused TEC to turn off
E-405	Voltage Limit caused TEC to turn off
E-407	Temperature Limit caused TEC to turn off
E-409	Sensor Change caused TEC to turn off
R-410	Out-of-Tolerance condition caused TEC to turn off
E-415	Sensor Shorted caused TEC to turn off
E-416	New setting resulted in invalid TEC setpoint
E-601	Internal error: recalled bin has incorrect checksum (settings to not match bin)
E-602	Internal error: task synchronization error
E-620	Internal error: resource unavailable
E-621	Internal error: message undeliverable to task
E-622	Internal error: could not send message to mainframe
E-623	Internal error: could not convert setting to valid setpoint
E-710	Internal error: AC Power Low error detected
E-711	Internal error: AC Power Low error detected
E-712	Internal error: Over-temperature error found on internal sensor
E-713	Internal error: Power brown-out error detected
E-714	Internal error: Writing to display
E-802	Calibration error: Measurement entered before calibration was ready
E-803	Calibration error: Invalid sensor specified for calibration

COMMAND REFERENCE

This chapter is a guide to all of the device-dependent commands for the LDC-3916558 3-Amp Temperature Control Module. This chapter is divided into two parts. The first part contains an overview of the remote commands used by the LDC-3916558 . The second part contains all of the LDC-3916558 commands in alphabetical order.

Table 4.1 lists the commands for the LDC-3916558 modules.

GPIB Commands

Table 4.1 LDC-3916 Device-Dependent Commands

Name	Parameters	Function
STATMENU:LINE*n*?	NONE	Returns the name of the measurement that is displayed on line *n* of the status menu. (*n* can be either 1 or 2)
STATMENU:LINE*n*:TEMP	NONE	Sets line *n* of the status menu to display TEC temperature
STATMENU:LINE*n*:ITE	NONE	Sets line *n* of the status menu to display TEC current
STATMENU:LINE*n*:RES	NONE	Sets line *n* of the status menu to display thermistor resistance
STATMENU:LINE*n*:TEV	NONE	Sets line *n* of the stus menu to display TEC forward voltage
TEC:CAL:ABORT	none	Aborts calibration
TEC:CAL:DEFAULT	none	Stores default calibration values for selected calibration
TEC:CAL:ITE	none	Selects ITE calibration
TEC:CAL:MEAS	1	Enters an actual (measured) value during calibration
TEC:CAL:SEN	1	Selects thermistor (temperature sensor) calibration
TEC:CAL:STAT?	none	Queries the status of calibration
TEC:CAL:VALUE?	1	Queries a calibration value; for use at factory only
TEC:COND?	none	Queries the value of the Condition Status Register
TEC:CONST	3	Enters the Steinhart-Hart coefficients
TEC:CONST?	none	Queries the values of the Steinhart-Hart coefficients
TEC:CONV:R	1	Converts a resistance (kΩ) to temperature ($^\circ$C)
TEC:CONV:R?	0 or 1	Returns the equivalent temperature ($^\circ$C) of the last conversion
TEC:CONV:T	1	Converts a temperature ($^\circ$C) to resistance (kΩ)
TEC:CONV:T?	0 or 1	Returns the equivalent resistance (kΩ) of the last conversion
TEC:ENAB:COND	1	Enters the value for the Condition Status Enable Register
TEC:ENAB:COND?	none	Queries the contents of the Condition Status Enable Register
TEC:ENAB:EVE	1	Enters the value for the Event Status Enable Register
TEC:ENAB:EVE?	none	Queries the contents of the Event Status Enable Register
TEC:ENAB:OUTOFF	1	Enters the value for the Output Off Enable Register
TEC:ENAB:OUTOFF?	none	Queries the contents of the Output Off Enable Register

Name	Parameters	Function
TEC:EVE?	none	Queries the contents of the Event Status Register
TEC:GAIN	1	Sets the control loop gain
TEC:GAIN?	none	Queries the control loop gain setting
TEC:ITE	1	Enters the constant-current setting
TEC:ITE?	none	Queries the measure output current
TEC:LIM:ITE	1	Enters the Current Limit setting
TEC:LIM:ITE?	none	Queries the Current Limit setting
TEC:LIM:THI	1	Enters the Temperature Limit setting
TEC:LIM:THI?	none	Queries the Temperature Limit setting
TEC:LASOFF	2	Enters the channel and source of the laser to turn off
TEC:LASOFF?	none	Returns the channel and source of the laser to turn off
TEC:MODE:ITE	none	Selects constant-current control mode
TEC:MODE:R	none	Selects constant-thermistor resistance control mode
TEC:MODE:T	none	Selects constant-temperature control mode
TEC:MODE?	none	Queries the control mode
TEC:OUT	1	Turns the output on or off
TEC:OUT?	none	Queries the state of the output: on or off
TEC:R	1	Enters the constant-thermistor resistance setting
TEC:R?	none	Queries the measured thermistor resistance
TEC:SEN	1	Selects sensor (thermistor) type: low or high resistance
TEC:SEN?	none	Queries the selected sensor type
TEC:SET:ITE?	none	Queries the constant-current setpoint
TEC:SET:R?	none	Queries the constant-resistance setpoint
TEC:SET:T?	none	Queries the constant-temperature setpoint
TECSYNCI?	NONE	Synchronized measurement; returns the TE current in amps
TECSYNCR?	NONE	Synchronized measurement; returns the thermistor resistance in kΩ
TECSYNCT?	NONE	Synchronized measurement; returns the thermistor temperature in ^{o}C
TECSYNCV?	NONE	Synchronized measurement; returns the measured TE voltage in volts
TEC:T	1	Enters the constant-temperature setpoint
TEC:T?	none	Queries the measured temperature
TEC:TOL	2	Enters the tolerance parameters

Name	Parameters	Function
TEC:TOL?	none	Queries the tolerance parameters
TEC:V?	none	Queries the measured TE voltage
MODERR?	none	Returns the error codes (up to 10) from the module
MODIDN?	none	Returns identification data from the module
MODPUD	1	Used at factory to set product information
MODPUD?	none	Returns factory-set product information

LDC-3916558 Device-Dependent Commands

This section contains all of the device-dependent commands for the LDC-3916558 3-Amp Temperature Control Modules, listed in alphabetical order. Sub-sections for each path are presented, listing the commands that are legal for that path.   See Chapter 3, Figure 3.1 for the command path tree structure.

Figure 4.1 shows the format for the commands.

Command Path:Name
Required letters are shown in upper case; lower case letters are optional.

Front Panel/
Remote Execution
A solid box means the command can be executed in that mode. Command mnemonics in front panel (local) mode may vary.

Command Description

Syntax Diagram
(For Remote Commands)

Parameters
Tells what parameters are expected, and their type.

An <**nrf value**> refers to a flexible numeric notation (IEEE488.2). Integer, exponential, or floating point may be used with the decimal radix. Alternate radices may be selected in remote operation.

Points of Interest
Has special information about the command.

Examples
Shows typical statements using the command.

■   Front Panel

■   Remote

TEC:LIMit:ITE

The TEC1:LIMit:ITE command sets TEC1's current limit value.

SYNTAX DIAGRAM

PARAMETERS   An <nrf value> that represents the TEC1 limit current, in A.

POINTS OF   The current limit is in effect in all modes of
INTEREST   operation.

In local operation, the limit current is entered by selecting the ILIM parameter in the CHANNEL:TEC1 menu.

EXAMPLES   "Tec1:Lim:ITE 0.9" - action: the TEC1 current limit is set to 0.9 A.

Figure 4.1 Command Description Format

The following pages contain a reference for the device-dependent commands of the LDC-3916558 3-Amp Temperature Control module. It contains useful information for remote operation of the module.

STATMENU:LINE*n*:

FRONT PANEL

REMOTE

The STATMENU:LINE*n*: command path is used to get to the selected channel's status menu display selection commands. (*n* can be either 1 or 2).

The following commands may be reached directly from the STATMENU:LINE*n*: command path.

STATMENU:LINE*n*:TEMP

STATMENU:LINE*n*:ITE

STATMENU:LINE*n*:RES

STATMENU:LINE*n*:TEV

STATMENU:LINE*n*?

FRONT PANEL

REMOTE

The STATMENU:LINE*n*? query returns the name of the measurement that is currently being displayed on line *n* of the status menu. (*n* can be either 1 or 2).
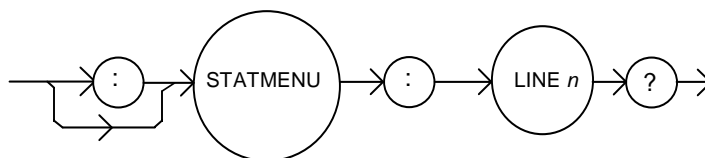
| Parameters | None. The response is character data which represents the measurement that is currently being displayed on line 1 of the selected channel's portion of the status menu. |
| Notes | The possible responses are: |

1: "TEMP" tec temperature

2: "ITE" tec current

3: "RES" thermistor resistance

4: "TEV" tec forward voltage

The default condition of the status menu displays tec temperature (TEMP) on line 1 and tec current (ITE) on line 2.

Examples   "STATMENU:LINE1?" - response: displays the last used command on line 1.

STATMENU:LINE*n*:TEMP

The STATMENU:LINE*n*:TEMP command sets the measurement that is to be displayed on line *n* of the status menu to tec temperature (TEMP)..
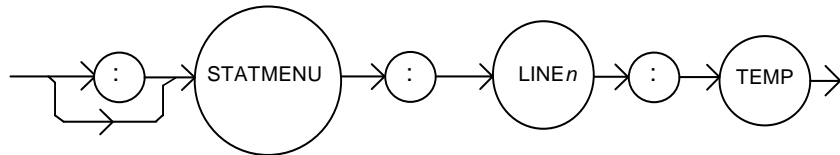
Parameters	None.
Notes	The default condition of the status menu displays tec temperature (TEMP) on line 1 and tec current (ITE) on line 2.
Examples	"STATMENU:LINE1:TEMP" - response: tec temperature is displayed on line 1 of the status menu.

STATMENU:LINE*n*:ITE

The STATMENU:LINE*n*:ITE command sets the measurement that is to be displayed on line *n* of the status menu to tec current (ITE).
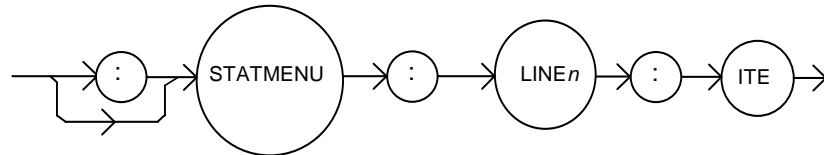
Parameters	None.
Examples	"STATMENU:LINE1:ITE" - response: tec current is displayed on line 1 of the status menu.

STATMENU:LINE*n*:RES

The STATMENU:LINE*n*:RES commands sets the measurement that is to be displayed on line n of the status menu to thermistor resistance (RES).
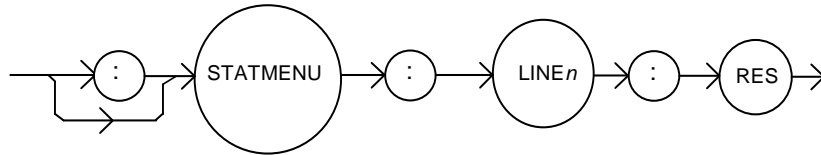
Parameters   None.

Examples   "STATMENU:LINE1:RES" - response: thermistor resistance is displayed on line 1 of the status menu.

STATMENU:LINE*n*:TEV

The STATMENU:LINE*n*:REV command sets the measurement that is to be displayed on line n of the status menu to tec forward voltage (TEV).
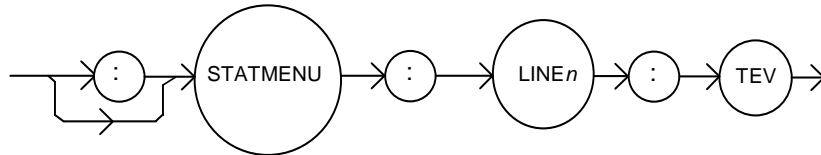
Parameters   None.

Examples   "STATMENU:LINE1:TEV" - response: tec forward voltage is displated on line 1 of the status menu.

TEC

The TEC: command path is used to access the LDC-3916558 3-Amp Temperature Controller's TEC commands. The following command paths may be reached from the TEC: command path.

TEC:CAL: **TEC:ENABle:**   **TEC:LIMit:**   **TEC:MODE:**   **TEC:SET**

The following commands may be reached directly from the TEC: command path.

TEC:COND?	**TEC:ITE?**	**TEC:SYNCI?**
TEC:CONST	**TEC:LASOFF?**	**TEC:SYNCR?**
TEC:CONST?	**TEC:MODE?**	**TEC:SYNCT?**
TEC:CONV:R	**TEC:OUT**	**TEC:SYNCV?**
TEC:CONV:T	**TEC:OUT?**	**TEC:T**
TEC:EVEnt?	**TEC:R**	**TEC:T?**
TEC:GAIN	**TEC:R?**	**TEC:TOL**
TEC:GAIN?	**TEC:SEN**	**TEC:TOL?**
TEC:ITE	**TEC:SEN?**	**TEC:V?**

TEC:CAL:

FRONT PANEL

REMOTE

The TEC:CAL: command path is used to access the selected module's TEC calibration commands..

The following commands may be reached directly from the TEC:CAL: command path.

TEC:CAL:ABORT	TEC:CAL:DEFAULT	TEC:CAL:ITE
TEC:CAL:MEAS	TEC:CAL:SEN	TEC:CAL:STATUS
TEC:CAL:V	TEC:CAL:VALUE?	

TEC:CAL:ABORT

FRONT PANEL

REMOTE

The TEC:CAL:ABORT command is used to exit the selected module's TEC calibration procedure without changing the calibration values.
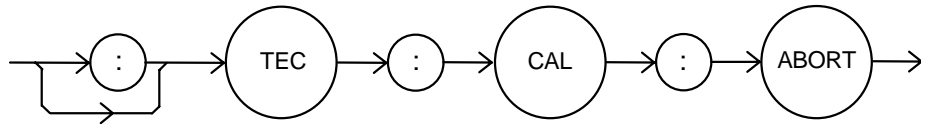
Parameters   None.

Notes   If this command is issued while the LDC-3916558 3-Amp Temperature Controller is in a TEC calibration, the calibratio will be terminated and the module will operate with the same calibraiton values as before the calibration mode was started

This command is intended for use after a false or invalid calibration measurement is entered, or to exit calibration mode before any measurements have been entered.

Examples   "TEC1:CAL:ABORT" - action: the module exits calibration mode.

TEC:CAL:DEFAULT

The TEC:CAL:DEFAULT command sets all of the selected module's TEC calibration constants to default values.
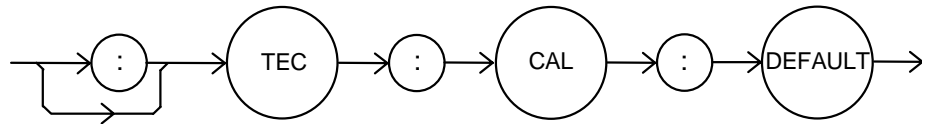
Parameters   None.

Notes   This command should only be used in the case in that the calibration has become corrupted and circumstances make calibration impossible. Measurements and setpoints on the selected module's TEC1 are not guaranteed to meet accuracy specifications after this command is issued. Accuracy will remain unspecified until calibration is performed on the module.

WARNING: **This command will set ALL of the module's TEC calibration constants to their default values.**

Examples   "TEC:CAL:Default" - action: the selected module sets all of its TEC calibration constants to their default values.

TEC:CAL:ITE

The TEC:CAL:ITE command is used to initiate the calibration procedure for the selected module's TEC current setpoint, current measurement, and current limit.
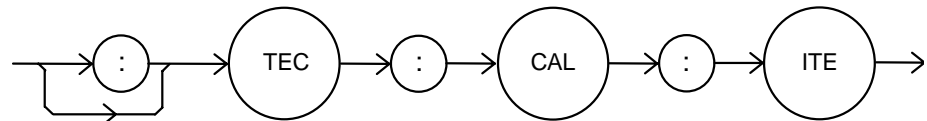
Parameters   None.

Notes   This is a service related command. Calibration mode should not be entered unless the user has the proper measurement equipment in place. See the Service Reference portion of this manual for complete calibration instructions.

After this command is issued, the selected module will enter ITE calibration mode.

Examples   "TEC:CAL:ITE" - action: the selected module enters calibration mode for TEC current.

TEC:CAL:MEAS

The TEC:CAL:MEAS command is used to enter measured value during the selected module's TEC calibration procedure.
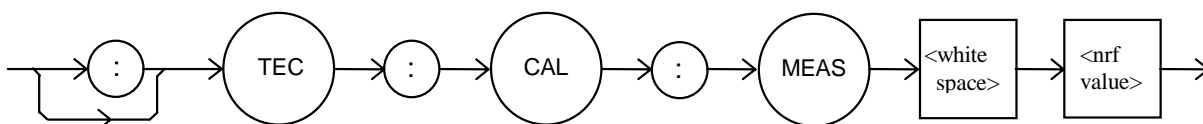
Parameters   An <nrf value> that represents the measured value expected for the present TEC calibration state.

Notes   See the Service Reference portion of this manual for complete calibration instructions.

Examples   "TEC:CAL:MEAS 1.01" - action: the module uses the value 1.01 for the required measurement value.

TEC:CAL:SEN

The TEC:CAL:SEN command is used to initiate the calibration procedure for the selected module's TEC sensor (thermistor).
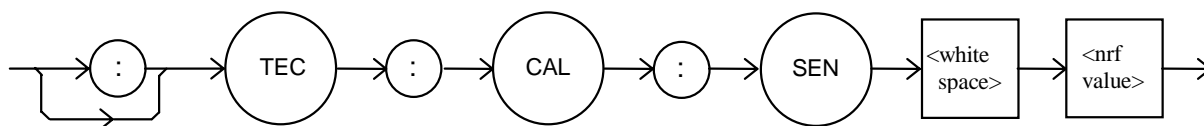
Parameters   An <nrf value> representing the thermistor sense current value: 1 = 100 μA, 2 = 10 μA.

Notes   This mode calibrates thermistor resistance measurements. Both thermistor current settings must be calibrated separately.

After this command is issued, the selected module will enter thermistor calibration mode. See the Service Reference portion of this manual for complete calibration instructions.

Examples   "TEC:CAL:SEN 1" - action: the selected module enters calibration mode for 100 μA thermistor current calibration.

TEC:CAL:STATus?

The TEC:CAL:STATus? query is to determine whether the selected module is ready for a calibration value.

: → TEC → : → CAL → : → STAT → ?
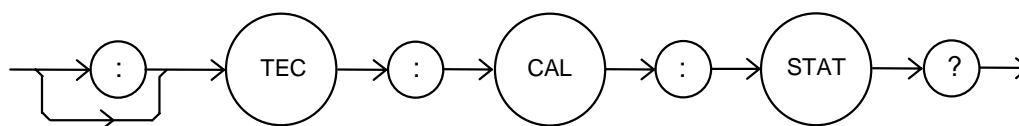
Parameters	None. The response will be an <nrf value>; 0 = Not Ready for Measurement; 1 = Ready for Measurement; 2 = Calibration Completed; 3 = Calibration Aborted
Notes	If the calibration is aborted, the status value will remain "3" until a calibration is started again.
Examples	"TEC:CAL:STAT?" - response: 1, means the module is ready for a calibration measurement to be entered using the "TEC:CAL:MEAS" command.
	"TEC:CAL:STAT?" - response: 2, means the module has completed calibration.
	"TEC:Cal:Stat?" - response: 0, means the module is not yet ready for the TEC calibration measurement value to be entered.

TEC:CAL:V

The TEC:CAL:V command is used to initiate the calibration procedure for the selected module's TEC TE voltage measurement.

: → TEC → : → CAL → : → V
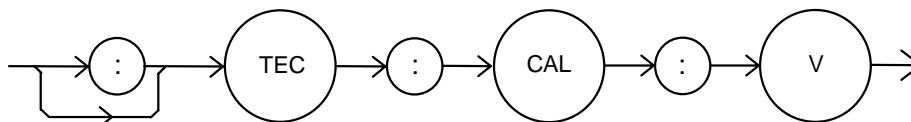
Parameters	None.
Notes	This mode calibrates the TE voltage measurement.
	After this command is issued, the selected module will enter voltage measurement mode. See the Service Reference portion of this manual for complete calibration instructions.
Examples	"TEC:CAL:V" - action: the selected module enters calibration mode for TE voltage.

TEC:CAL:VALUE?

The TEC:CAL:VALUE? query is used at the factory only.

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TEC:COND?

The TEC:COND? query returns the contents of the selected module's TEC Condition Status register.
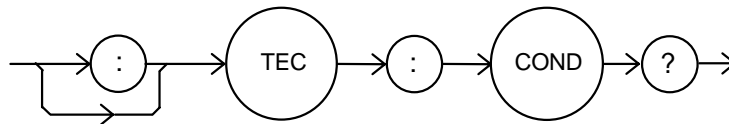
Parameters   None. The response is the sum of the following:

1	Current Limit	256	N/A
2	Voltage Limit	512	In Tolerance
4	N/A	1024	Output On
8	Temperature Limit	2048	N/A
16	N/A	4096	N/A
32	N/A	8192	N/A
64	Sensor Open	16384	N/A
128	Open Circuit	32768	N/A

Notes   The bits in this register reflect as closely as possible the actual state of the module. They will change as conditions in the module change. To be sure you detect the occurrence of a condition, it may be appropriate to read the Event Status Register (TEC:EVE?).

You can set up the module to automatically report selected conditions to the 3916 and the 3908 Status Byte. Specify the conditions that are reported using the Condition Status Enable Register (TEC:ENABLE:COND). See the Status Reporting section of the 3916 or 3908 manual for more details.

Examples   "TEC:COND?" - response: 1024, means that the TEC Output is on.

"TEC:COND?" - response: 1025, means that the TEC Output is on (1024) and the output is in current limit (1).

TEC:CONST

The TEC:CONST command sets the Steinhart-Hart coefficients for the selected module's TEC thermistor.
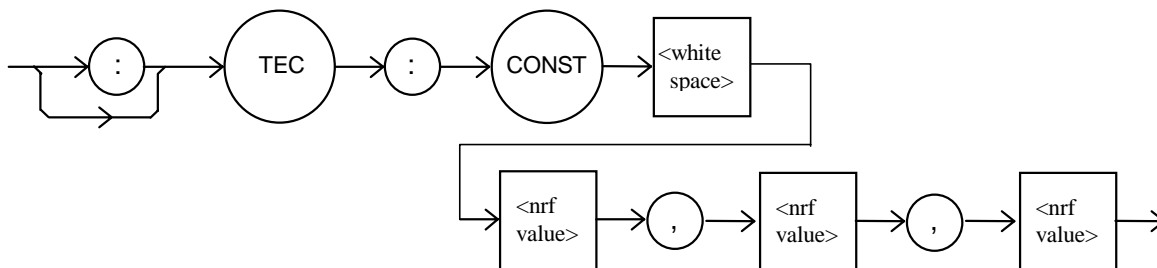
Parameters	Three <nrf values> are required. The first one represents C1, the second is C2, and the third is C3. The range for all three constants is -99.999 to 99.999. The module scales each value by an exponential value that is appropriate for that constant's part in the Steinhart-Hart equation.
Notes	If any one of the values is less than -99.999, and under-range error will be generated. Values over 99.999 will cause an over-range error. In either case, non of the constants will be modified. A thermistor's Steinhart-Hart coefficients are typically supplied by the thermistor manufacturer.
Examples	"TEC:CONST 0.9,1.2,2.3" - action: sets the selected module's TEC Steinhart-Hart coefficients to C1 = 0.9, C2 = 1.2, C3 = 2.3.

TEC:CONST?

The TEC:CONST? query returns the values of the selected module's Steinhart-Hart coefficients..
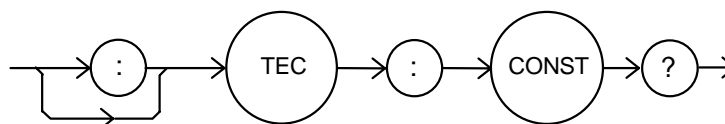
Parameters	None. The response data represents the values of C1, C2 and C3, in that order.
Notes	These values are pre-scaled so that the exponential value is not given. The actual value of C1 is scaled by 10E-3, C2 by 10E-4, and C3 by 10E-7.
Examples	"TEC:CONST?" - response: 0.9,1.1,2.2: C1, C2, and C3 are 0.9, 1.1, and 2.2.

TEC:CONV:R

The TEC:CONV:R command converts thermistor resistance (kΩ) to temperature (^{o}C).
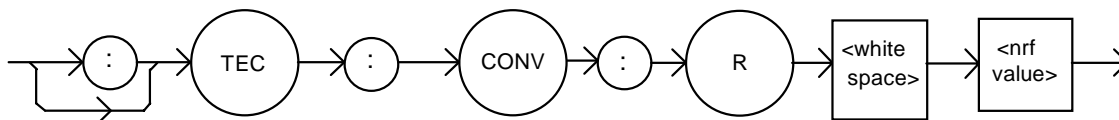
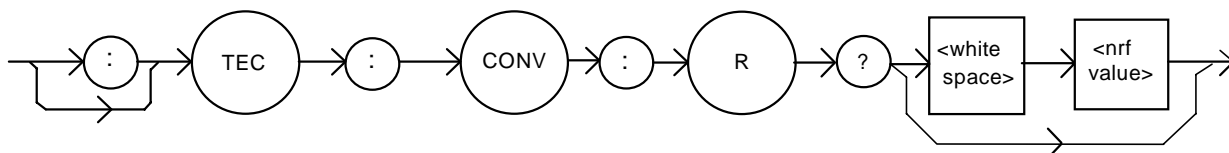| Parameters	An <nrf value> that corresponds to a resistance in kΩ.
Notes	The selected channel's Steinhart-Hart constants C1, C2 and C3 are used to convert resistance (kΩ) to temperature (^{o}C).
Examples	"TEC:CONV:R 12.456" - 12.456 kΩ is converted to temperature and saved in memory.

TEC:CONV:R?

The TEC:CONV:R? query converts thermistor resistance (kΩ) to temperature (^{o}C) and returns the value of the most recent conversion..

Parameters	Either no parameter or an <nrf value> that corresponds to a resistance in kΩ.
Notes	The calibration constants C1, C2 and C3 are used to convert resistance to temperature..
Examples	"TEC:CONV:R?" - returns: a value that corresponds to the temperature of the most recent conversion.
"TEC:CONV:R? 12.789" converts 12.789 kΩ to temperature and returns a number that corresponds to temperature in ^{o}C.

TEC:CONV:T

The TEC:CONV:T command converts temperature (^{o}C) to thermistor resistance (kΩ)..
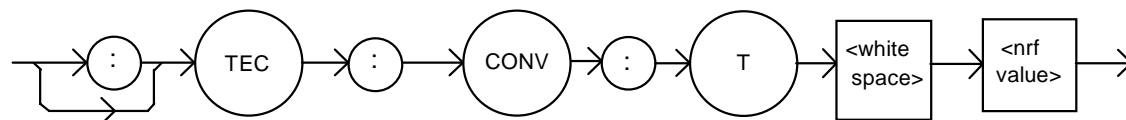
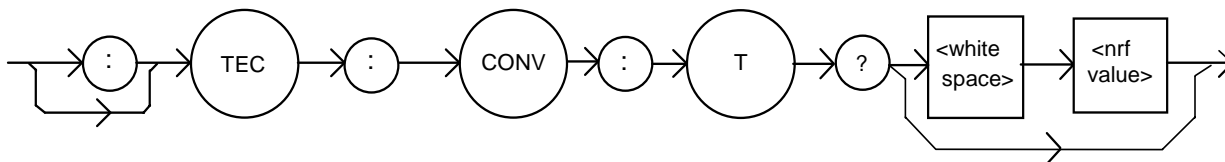| Parameters	An <nrf value> that corresponds to a temperature in ^{o}C.
Notes	The selected channel's Steinhart-Hart constants C1, C2 and C3 are used to convert temperature (^{o}C) to resistance (kΩ).
Examples	"TEC:CONV:T 25.6" - 25.6 ^{o}C is converted to resistance and saved in memory.

TEC:CONV:T?

The TEC:CONV:T? query converts temperature (^{o}C) to thermistor resistance (kΩ) and returns the value of the most recent conversion..

```
: ──▶ TEC ──▶ : ──▶ CONV ──▶ : ──▶ T ──▶ ? ──▶ <white space> ──▶ <nrf value> ──▶
```

Parameters	Either no parameters or an <nrf value> that corresponds to a temperature in ^{o}C.
Notes	The calibration constants C1, C2 and C3 are used to convert temperature to resistance.
Examples	"TEC:CONV:T?" - returns: a number that corresponds to the resistance value of the most recent conversion.
	"TEC:CONV:T? 35.5" converts 35.5 ^{o}C to resistance and returns a number that corresponds to resistance in kΩ.

TEC:ENABle:

The TEC:ENABle: command path us used to access the selected module's TEC status enable commands and queries.

The following commands may be reached directly from the TEC:ENABle: command path.

TEC:ENABle:COND	TEC:ENABle:COND?
TEC:ENABle:EVEnt	TEC:ENABle:EVEnt?
TEC:ENABle:OUTOFF	TEC:ENABle:OUTOFF?

TEC:ENABle:COND

The TEC:ENABle:COND command sets the selected module's TEC Condition Status Enable register. The bits in this register determine the bits in the TEC Condition Status register that are summarized in the 3916 Status Byte.
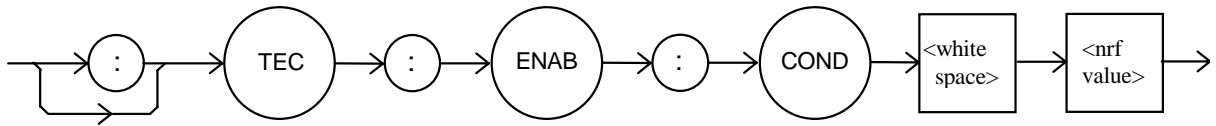
: → TEC → : → ENAB → : → COND → <white space> → <nrf value> →

Parameters   An <nrf value> whose sum represents the enabled bits:

1	Current Limit	256	N/A
2	Voltage Limit	512	In Tolerance
4	N/A	1024	Output On
8	Temperature Limit	2048	N/A
16	N/A	4096	N/A
32	N/A	8192	N/A
64	Sensor Open	16384	N/A
128	Open Circuit	32768	N/A

Notes   This register can be read using the TEC:ENABle:COND? query. See the Status Reporting section of the 3916 or the 3908 manual for more information regarding condition reporting.
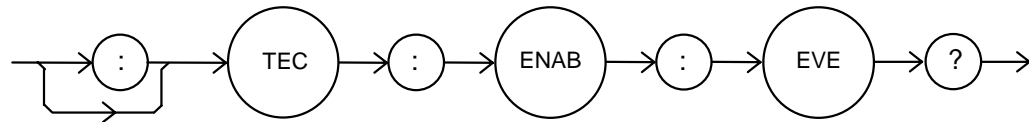
Examples   "TEC:ENAB:COND 9" - action: the only conditions from the selected module that will be reported to the 3916 or the 3908 Status Byte are the Temperature Limit (8) and Current Limit (1) conditions.

`TEC:ENABle:COND?`

The TEC:ENABle:COND? query returns the value of the selected module's TEC Condition Status Enable register.
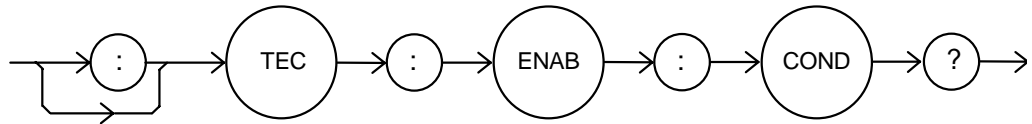
Parameters   None. The response is the sum of the following:

1	Current Limit	256	N/A
2	Voltage Limit	512	In Tolerance
4	N/A	1024	Output On
8	Temperature Limit	2048	N/A
16	N/A	4096	N/A
32	N/A	8192	N/A
64	Sensor Open	16384	N/A
128	Open Circuit	32768	N/A

Notes   The selected module's enabled TEC conditions can be set by using the TEC:ENABle:COND command. The TEC condition status can be monitored by the TEC:COND? query.

Examples   "TEC:ENAB:COND?" - response: 640, means that only the following two conditions will be reported (in summarized form) to the 3916's Status Byte: In Tolerance (512) and Open Circuit (128).

TEC:ENABle:EVEnt

The TEC:ENABle:EVEnt command sets the selected module's TEC Event Status Enable register. The bits in this register determine the TEC events that are summarized in the 3916 or the 3908.
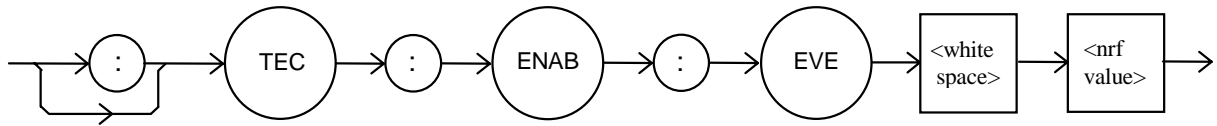
Parameters An <nrf value> whose sum represents the events that are enabled:

1	Current Limit Occurred	256	Sensor Type was Changed While Output was On
2	Voltage Limit Occurred	512	In Tolerance Condition was Entered or Exited
4	N/A	1024	Output Turned Off
8	Temperature Limit Occurred	2048	N/A
16	N/A	4096	N/A
32	N/A	8192	N/A
64	Sensor Circuit Opened	16384	N/A
128	Output Circuit Opened (Open Circuit)	32768	N/A

Notes The contents of this register are read with the TEC:ENABle:EVEnt? query. Events can be monitored using the TEC:EVE? query. See the Status Reporting section of the 3916 or the 3908 manual for more information regarding event reporting.

Examples "TEC:ENAB:EVENT 136" - action: only the "Open Circuit" (128) and "Temperature Limit" (8) events will be reported (in summarized form) to the 3916 or the 3908's Status Byte.

TEC:ENABle:EVEnt?

The TEC:ENABle:EVEnt? query returns the contents of the selected module's TEC Event Status Enable register.

Parameters   None. The response is the sum of the following:

1	Current Limit Occurred	256	Sensor Type was Changed While Output was On
2	Voltage Limit Occurred	512	In Tolerance Condition was Entered or Exited
4	N/A	1024	Output Turned Off
8	Temperature Limit Occurred	2048	N/A
16	N/A	4096	N/A
32	N/A	8192	N/A
64	Sensor Circuit Opened	16384	N/A
128	Output Circuit Opened (Open Circuit)	32768	N/A

Notes   This register is set using the TEC:ENABle:EVEnt command. The selected module's TEC event status can be monitored by the TEC:EVEnt? query.

Examples   "TEC:ENAB:EVE?" - reponse: 512, means that the "Tolerance Changed" event is the only event that the selected module's TEC will report to the 3916 or the 3908 Status Byte.

TEC:ENABle:OUTOFF

The TEC:ENABle:OUTOFF command sets the selected module's TEC Output Off Enable register. The bits in this register specify the conditions that will cause TEC to automatically turn off.

Parameters   An <nrf value> whose sum represents the enabled bits:

1	Current Limit	256	Sensor Changed
2	Voltage Limit	512	Not in Tolerance
4	N/A	1024	Sensor Shorted
8	Temperature Limit	2048	N/A
16	N/A	4096	N/A
32	N/A	8192	N/A
64	Sensor Open	16384	N/A
128	Module Open (Open Circuit)	32768	N/A

Notes   Read this register using the TEC:ENABle:OUTOFF? query. The factory default value ofor this register is 1224: the conditions that will cause the output to shut off are Sensor Shorted, Module Open, Sensor Open, and Temperature Limit (1024+128+64+8).

WARNING: If you set bit 9 in this register, the output will shut off whenever the controlled temperature is out of tolerance (specified using the "TOL" command). If the tolerance conditions do not include the ambient temperature, you will not be able to turn on the output. You should wait until the temperature is within your tolerance specification before setting this bit.

Examples   "TEC:ENAB:OUTOFF 72" - action: sets the selected module's TEC Output-Off enable register so that either a Sensor Open (64) or Temperature Limit (8) condition will cause the TEC output to be turned off.

`TEC:ENABle:OUTOFF?`

The TEC:ENABle:OUTOFF? query returns the contents of the selected module's TEC OUtput Off Enable register.

```
 :  →  TEC  →  :  →  ENAB  →  :  →  OUTOFF  →  ?
```

Parameters   None. The response is the sum of the following:

1	Current Limit	256	Sensor Changed
2	Voltage Limit	512	Not in Tolerance
4	N/A	1024	Sensor Shorted
8	Temperature Limit	2048	N/A
16	N/A	4096	N/A
32	N/A	8192	N/A
64	Sensor Open	16384	N/A
128	Module Open (Open Circuit)	32768	N/A

Notes   This register can be set by using the TEC:ENABle:OUTOFF command.

Examples   "TEC:ENAB:OUTOFF?" - response: 8, means that the selected module's TEC Temperature Limit is the only condition that will cause the TEC output to be turned off.

TEC:EVEnt?

The TEC:EVEnt? query returns the contents of the selected module's TEC Event Status register.

Parameters   None. The response is the sum of the following:

1	Current Limit Occurred	256	Sensor Type was Changed While Output was On
2	Voltage Limit Occurred	512	In Tolerance Condition was Entered or Exited
4	N/A	1024	Output Turned Off
8	Temperature Limit Occurred	2048	N/A
16	N/A	4096	N/A
32	N/A	8192	N/A
64	Sensor Circuit Opened	16384	N/A
128	Output Circuit Opened (Open Circuit)	32768	N/A

Notes   The events in this register will not be reported to the 3916 or the 3908's Status Byte unless they are selected using the TEC:ENABle:EVEnt command. The event status register is only cleared when it is read, or in response to a *CLS command.

Examples   "TEC:EVE?" - response: 131, means that an "Output Circuit Opened" event (128), a "Voltage Limit Occurred" event (2), and a "Current Limit Occurred" event (1) have occurred since the last TEC:EVEnt? query.

TEC:GAIN

The TEC:GAIN command sets the selected module's TEC control loop gain.
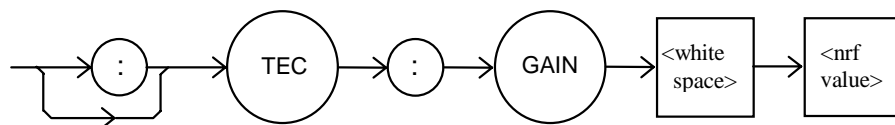
Parameters   An <nrf value> between 1 and 127, that represents the gain. The value will be rounded to the nearest integer.
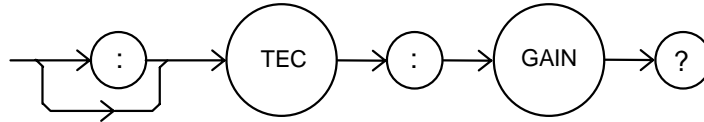
Notes   An error is generated if the value is invalid or not between 1 and 127.

Examples   "TEC:GAIN 40" - action: sets the selected module's TEC control loop gain to 40.

TEC:GAIN?

FRONT PANEL
REMOTE

The TEC:GAIN? query returns the value of the selected module's TEC control loop gain.

```
: → TEC → : → GAIN → ?
```

Parameters   None. The response is an integer value between 1 and 127.

Notes   The optimum gain to use depends on the characteristics of the device you are controlling.

Examples   "TEC:GAIN?" - response: 33, means the selected module's measured TEC control loop gain is set to 33.

TEC:ITE

FRONT PANEL
REMOTE

The TEC:ITE command sets the selected module's TEC constant-current setpoint.

```
: → TEC → : → ITE → <white space> → <nrf value>
```
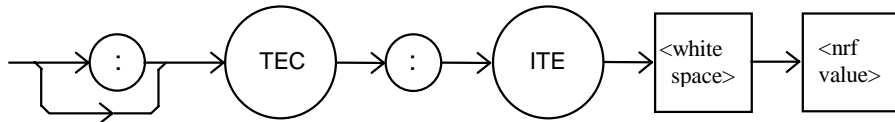
Parameters   An <nrf value> representing the ITE setpoint, in Amps.

Notes   This command will modify the ITE setting regardless of control mode, but the setting will only be used in constant-current mode. This setting is read using the TEC:SET:ITE? query. In constant-temperature or constant-resistance mode, the 3916558 applies a positive current to cool a device. A negative current is assumed to heat a device.

Examples   "TEC:ITE 0.6" - action: sets the selected module's TEC ITE setpoint to 0.6 Amps.

TEC:ITE?

FRONT PANEL
REMOTE

The TEC:ITE? query returns the value of the selected module's measure TEC current.

```
: → TEC → : → ITE → ?
```
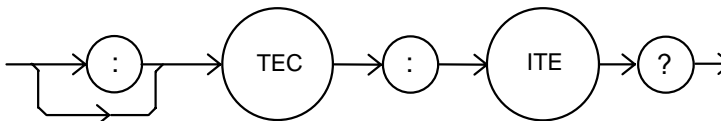
Parameters   None. The response is an <nrf value> representing the measured ITE current, in Amps.

Notes   Response is the selected module's measured TEC output current, regardless of control mode. This measurement is updated approximately once every 600 msec.

Examples   "TEC:ITE?" - response: 0.7, means the selected module's measure TEC output current it -0.7 A.

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TEC:LASOFF

The TEC:LASOFF command configures the TEC to turn off an external laser current source.
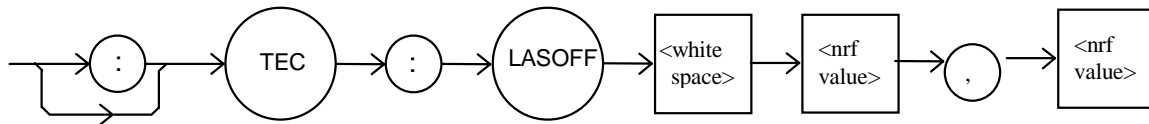

Parameters Two <nrf values> are required. The first represents channel number of the laser module, and the seond represents the laser source output. The range of the channel number is 0 through 17, where 0=NONE and 17=all channel. The range for the laser source output number is 0 to 3, where 0=NONE and 3=BOTH.

Examples "TEC:LASOFF 1,3" - action: sets the TEC to turn off both laser outputs of channel 1.

"TEC:LASOFF 1,2" - action: sets the TEC to turn off the number two output of channel 1.

"TEC:LASOFF 17,3" - action: sets the TEC to turn off all outputs of all the channels.

"TEC:LASOFF 0,0" - action: sets the TEC not to turn off any laser output in any channel.

TEC:LASOFF?

The TEC:LASOFF? query returns the channel number and output of the laser the TEC module is configure to turn off.
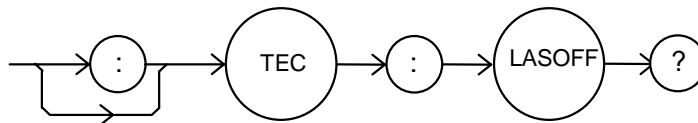
Parameters None. The response data represents the channel number and output of the laser to turn off.

Examples "TEC:LASOFF?" - response: 1,2: the TEC is configure to turn off channel 1, source 2.

"TEC:LASOFF?" - response: 17,3: the TEC is configured to turn off all channels and all outputs.
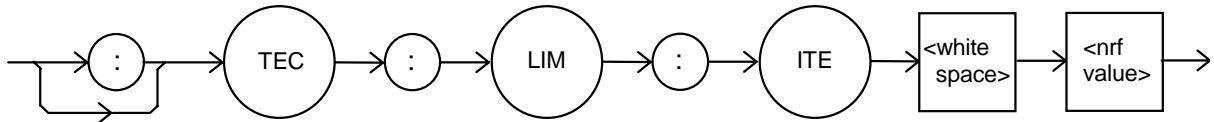
TEC:LIMit:

The TEC:LIMit: command path is used to access the selected module's TEC limit commands.

The following commands may be reached directly from the TEC:LIMit command path.

TEC:LIMit:ITE   TEC:LIMit:ITE?

TEC:LIMit:THI   TEC:LIMit:THI?

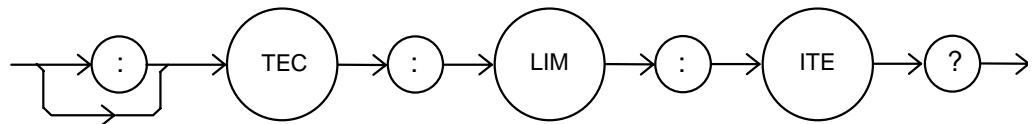## `TEC:LIMit:ITE`

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REMOTE

The TEC:LIMit:ITE command sets the selected module's TEC current limit value.

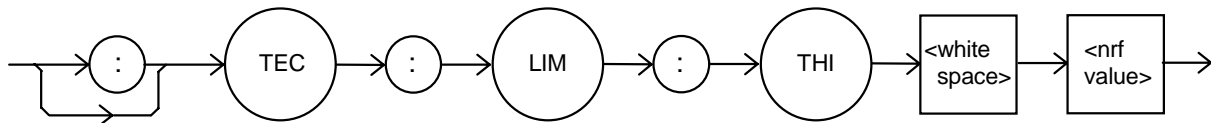| Parameters | An <nrf value> that represents the selected module's TEC limit current, in Amps. |
| Notes | The current limit parameter must be a positive value. It is applied to both positive and negative current drives. |
| Examples | "TEC:LIM:I 0.8" - action: the selected module's TEC current limit is set to 0.8 A. |

`TEC:LIMit:ITE?`

FRONT PANEL
REMOTE

The TEC:LIMit:ITE? query returns the value of the selected module's TEC current limit setting.

Parameters	None. The response is an <nrf value>.
Notes	The current limit is in effect in all control modes.
Examples	"TEC:LIM:I?" - response: 0.9, means the selected module's TEC current limit is 0.9 A.

`TEC:LIMIT:THI`

FRONT PANEL
REMOTE

The TEC:LIMit:THI command sets the selected module's TEC high temperature limit value.


Parameters	An <nrf value> that represents the selected module's TEC high temperature limit, in degrees Celsius.
Notes	By default, the TEC output is turned off when the measured temperature exceeds this setting. This feature can be disabled by clearing bit 3 in the Output Off Enable Register, using the TEC:ENABle:OUTOFF command. The range for the temperature limit is 0 to 199.9 $^{\circ}$C.
Examples	"TEC:LIM:THI 87.5" - action: the selected module's TEC temperature limit to 87.5 $^{\circ}$C.

TEC:LIMit:THI?

The TEC:LIMit:THI? query returns the value of the selected module's TEC high temperature limit setting.
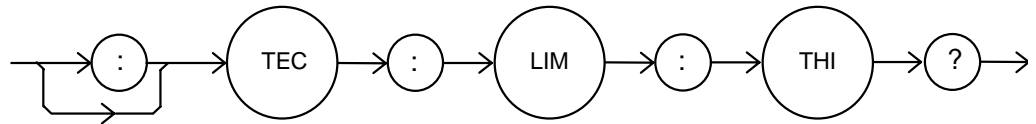
Parameters	None. The response is an <nrf value>.
Notes	High temperature limit is valid for all modes of operation. There is no low temperature limit.
Examples	"TEC:LIM:THI?" - response: 92.0, means the selected module's TEC high temperature limit is 92.0 $^{\circ}$C.

TEC:MODE:

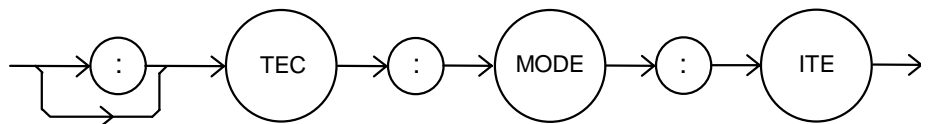The TEC:MODE: command path is used to access the selected module's TEC mode selection commands.

The following commands may be reached directly from the TEC:MODE: command path.
TEC:MODE:ITE   TEC:MODE:T   TEC:MODE:R

TEC:MODE:ITE

The TEC:MODE:ITE command selects constant current mode for the selected module's TEC.
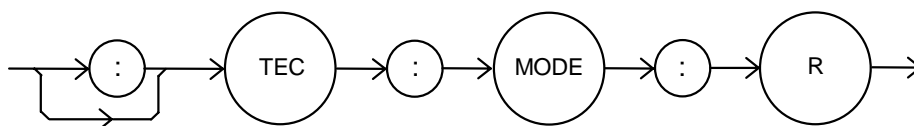

Parameters	None.
Notes	In this mode, TE current is kept constant, regardless of variations in load temperature.
Examples	"TEC:MODE:ITE" - action: selects constant-TE current control mode.

TEC:MODE:R

The TEC:MODE:R command selects constant thermistor resistance mode for the selected module's TEC.

```
  ┌──┐
──┤: ├──→ ( TEC ) ──→ ( : ) ──→ ( MODE ) ──→ ( : ) ──→ ( R ) ──→
  └──┘
```
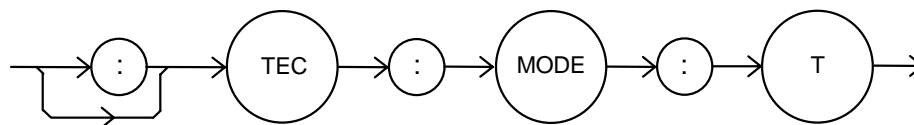
Parameters   None.

Notes   Since thermistor resistance is a function of temperature, this mode also controls load temperature. It bypasses the use of the Steinhart-Hart conversion for setpoint calculation. This allows control of the load temperature in cases where a thermistor's resistance at a desired temperature is know, but its Steinhart-Hart coefficients are not known.

Examples   "TEC:MODE:R" - action: selects constant thermistor resistance control mode.

TEC:MODE:T

The TEC:MODE:T command selects constant temperature mode for the selected module's TEC.

```
  ┌──┐
──┤: ├──→ ( TEC ) ──→ ( : ) ──→ ( MODE ) ──→ ( : ) ──→ ( T ) ──→
  └──┘
```

Parameters   None.

Notes   Constant temperature mode is the most frequently used control mode. Changing control modes causes the selected module's TEC to be turned off.
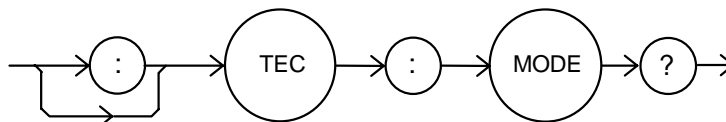
Examples   "TEC:MODE:T" - action: selects constant temperature control mode for the selected module's TEC temperature controller.

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TEC:MODE?

The TEC:MODE? query returns the selected module's TEC control mode.


Parameters　None. The response is a character response representing the control mode. The possible responses are "T", "R", and "ITE" (without quotes).

Notes　Constant current mode is sometimes useful in a multi-stage TEC system, or in a system where the heat load is constant and well known.

Examples　"TEC:MODE?" - response: T, means that the selected module's TEC is in constant temperature control mode.

TEC:OUTput

The TEC:OUTput command turns the selected module's TEC output on or off.
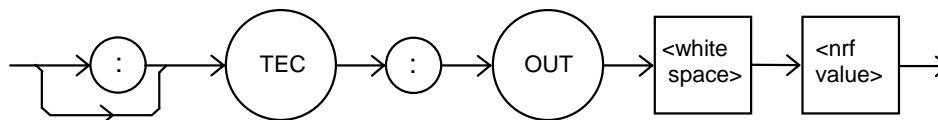
Parameters　An <nrf value>; 1 = on, 0 = off.

Notes　After the selected module's TEC output is turned on, it may be useful to wait until the output is stable before performing further operations, but it is not necessary. The character strings "OFF" and "ON" may be used in place of "0" and "1".

Examples　"TEC:OUT 1" - action: turns the selected module's TEC output on.

"TEC:OUT OFF" - action: turn off the selected module's TEC.

`TEC:OUTput?`

The TEC:OUTput? query returns the selected module's TEC output state.
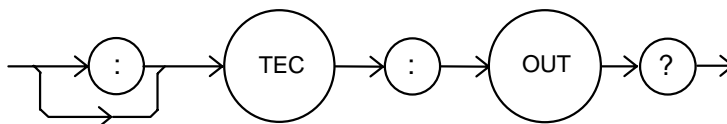
Parameters	None. The response is an <nrf value>.
Notes	Although the output is on, the output may not have reached the set point value. The output should always be off when connecting or disconnecting cables to the output connector.
Examples	"TEC:OUT?" - response: 0, means that the selected module's TEC is off.
	"TEC:OUT?" - response: 1, means that the selected modules' TEC is turned on.

`TEC:R`

The TEC:R command sets the selected module's TEC constant-resistance setpoint.
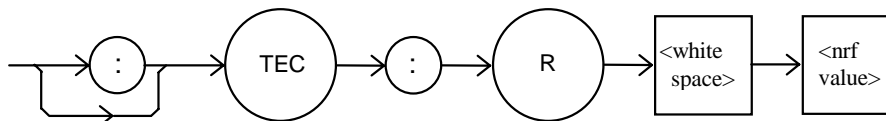
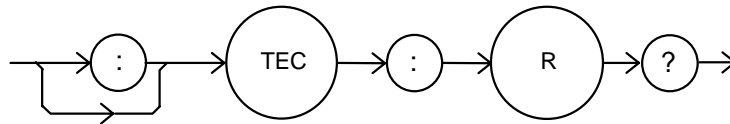| Parameters	None. The response is an <nrf value> representing the measured thermistor resistance, in kΩ.
Notes	This setting is always stored when the command is valid, but it is only used when the TEC is in constant-resistance mode. This setting is read using the TEC:SET:R? query.
Examples	"TEC:R 15" - action: sets the selected module's TEC constant-resistance setpoint to 15 kΩ.

`TEC:R?`

The TEC:R? query returns the value of the selected module's TEC measured thermistor resistance.


Parameters   None. The response is an <nrf value> representing the measured thermistor resistance, in kΩ.

Notes   Response is the selected module's measured thermistor resistance, regardless of control mode. This measurement is updated approximately once every 600 msec.

Examples   "TEC:R?" - response: 16.7, means the selected module's measured TEC thermistor resistance is 16.7 kΩ.

`TEC:SENsor`

The TEC:SEN command sets the selected module's TEC thermistor sense current.
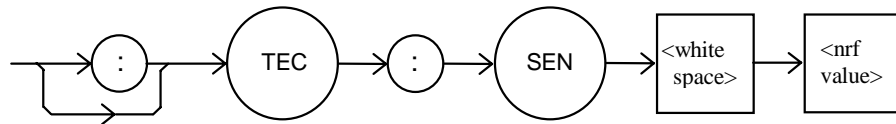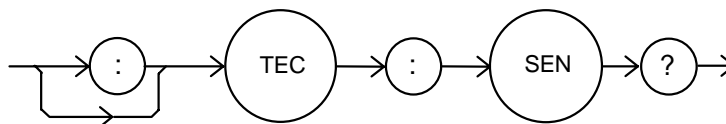

Parameters   An <nrf value> representing the desired thermistor sense current. 1 represents 100 μA, 2 represents 10 μA.

Notes   The sense current is applied through the thermistor, and the resulting voltage is measured by the 3916558 module. The measured voltage range is 0-5 V. The best sense current to use depends on the expected thermistor resistance at the setpoint. In general, use 100 μA for a resistance less than 50 kΩ, and 10 μA for larger values. The largest possible voltage swing in the vicinity of the setpoint will result in the best stability.

Examples   "TEC:SEN 1" - action: sets the selected module's TEC thermistor current to 100 μA.

TEC:SEN?

The TEC:SEN? query returns the selected module's TEC thermistor sense current.

Parameters None. The response is an <nrf value> representing the sense current. 1 represents 100 μA, 2 represents 10 μA.

Notes The sensor current is always applied, regardless of the control mode.

Examples "TEC:SEN?" - response: 1 means that the sense current is 100 μA.

TEC:SET:

The TEC:SET: command path is used to access the selected module's TEC set point queries.

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

TEC:SET:ITE?　　　　TEC:SET:R?　　　　TEC:SET:T?

TEC:SET:ITE?

The TEC:SET:ITE? query returns the selected module's TEC constant-current setpoint.
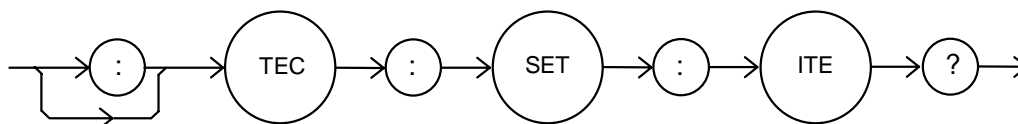
Parameters None. The response is an <nrf value> that represents the selected module's constant ITE set point value, in Amps.

Notes The ITE set point is only in effect when the operating mode is ITE.

Examples "TEC:SET:ITE?" - response: -0.5, means the selected module's TEC output current set point is -0.5 A.

TEC:SET:R?

The TEC:SET:R? query returns the selected module's TEC constant thermistor resistance set point.

```
:  →  TEC  →  :  →  SET  →  :  →  R  →  ?  →
```
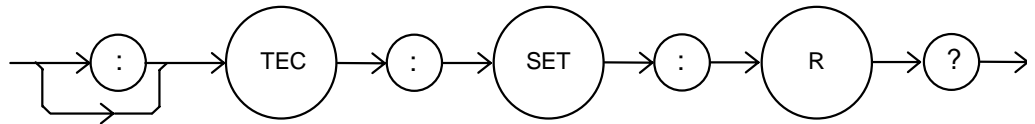
Parameters   None. The response is an <nrf value> that represents the selected module's constant resistance set point value, in kΩ.

Notes   The constant-thermistor resistance set point is only in effect when the operating mode is R.

Examples   "TEC:SET:R?" - response: 19.6, means the selected module's TEC resistance set point is 19.6 kΩ.

TEC:SET:T?

The TEC:SET:R? query returns the selected module's TEC constant temperature setpoint.

```
:  →  TEC  →  :  →  SET  →  :  →  T  →  ?  →
```
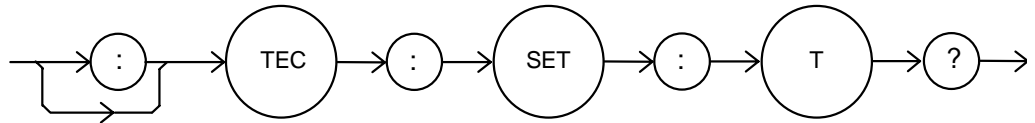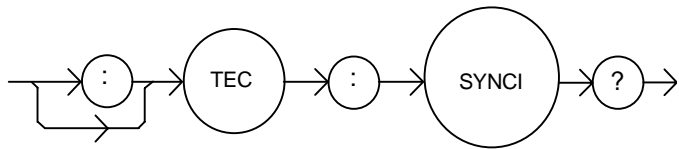
Parameters   None. The response is an <nrf value> that represents the selected module's constant temperature set point value, in ^{o}C.

Notes   The constant-temperature setting is only in effect when the operating mode is T.

Examples   "TEC:SET:T?" - response: 17.3, means the selected module's TEC temperature setting is 17.3 ^{o}C.

`TEC:SYNCI?`

The TEC:SYNCI? query returns the selected channel's measured TE current, in Amps.

Parameters   None. The response is an <nrf value> representing current in Amps.

Notes   This is a "synchronized" measurement: the TEC measurement system is connected to the current measure signal when this query is received. A current measurement is made, and the result is returned as the response. After the measurement is made, the measurement system result is returned as the response. After the measurement is made, the measurement system returns to its normal function, switching between the various signals and measuring them.

The response time to this query is from 200 to 250 msec, but the measurement is made as soon as the query is received. In contrast, the TEC:ITE? query returns immediately, but the measurement can be up to 600 msec old.

Examples   "TEC:SYNCI?" - response: 1.3, means the measured TE current is 1.3A.

`TEC:SYNCR?`

The TEC:SYNCR? query returns the selected channel's measured thermistore resistance in kΩ.
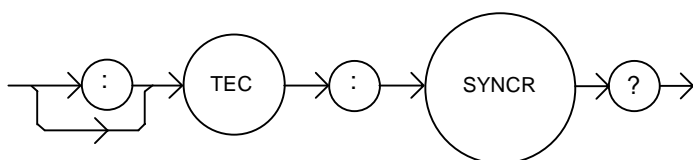
Parameters   None. The response value is an <nrf value> representing resistance in kΩ.

Notes   This is a "synchronized" measurement: the TEC measurement system is connected to the thermistor resistance-measure signal when this query is received. A resistance measurement is made, and the result is returned as the response. After the measurement is made, the measurement system returns to its normal function, switching between the various signals and measuring them.

The response time to this query is from 200 to 250 msec, but the measurement is made as soon as the query is received. In contrast, the TEC:R? query returns immediately, but the measurement can be up to 600 msec old.

Examples   "TEC:SYNCR?" - response: 10.543, means the measured thermistor resistance is 10.543 kΩ.

TEC:SYNCT?

The TEC:SYNCT? query returns the selected channel's measured thermistor temperature in °C.
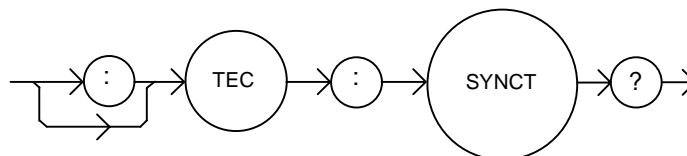

Parameters — None. The response value is an <nrf value> representing temperature in oC.

Notes — Temperature is derived from the thermistor resistance measurement. This is a "synchronized" measurement: the TEC measurement system is connected to the thermistor resistance-measure signal when this query is received. A resistance measurement is made, the temperature is calculated, and the result is returned as the response. After the measurement is made, the measurement system returns to its normal function, switching between the various signals and measuring them.

The response time to this query is from 200 to 250 msec, but the measurement is made as soon as the query is received. In contrast, the TEC:T? query returns immediately, but the measurement can be up to 600 msec old.

Examples — "TEC:SYNCT?" - response: 17.9, means the measured thermistor temperature is 17.9 °C.

TEC:SYNCV?

The TEC:SYNCV? query returns the selected channel's measured TE forward voltage, in Volts.
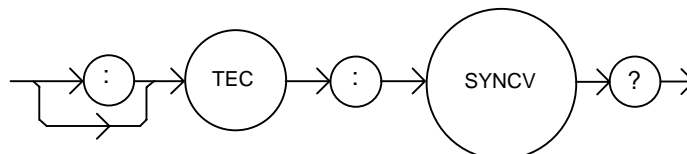
Parameters — This is a "synchronized" measurement: the TEC measurement system is connected to the voltage-measure signal when this query is received. A voltage measurement is made and the result is returned as the response. After the measurement is made, the measurement system returns to its normal function, switching between the various signals and measuring them.

The response time to this query is from 200 to 250 msec, but the measurement is made as soon as the query is received. In contrast, the TEC:V? query returns immediately, but the measurement can be up to 600 msec old.

Examples — "TEC:SYNCV?" - response: 1.9, means the measured forward voltage is 1.9V.

TEC:T

The TEC:T command sets the selected module's TEC constant-temperature setpoint.

```
  :  →  TEC  →  :  →  T  →  <white space>  →  <nrf value>
```
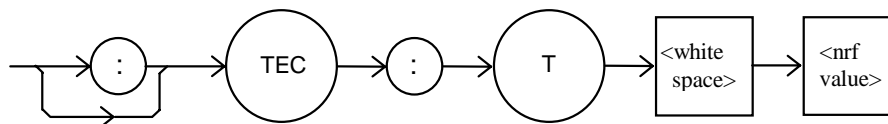
Parameters   An <nrf value> representing the constant temperature setting, in ^oC.

Notes   This setting is always stored when the command is valud, but it is only used when the TEC is in constant temperature mode. This setting is read using the TEC:SET:T? query.

Examples   "TEC:T 12" - action: sets the selected module's TEC temperature setpoint to 12^oC.

TEC:T?

The TEC:T? query returns the value of the selected module's TEC measured temperature.

```
  :  →  TEC  →  :  →  T  →  ?  →
```

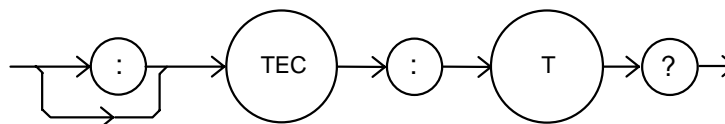Parameters   None. The response is an <nrf value> representing the measured temperature, in ^oC.

Notes   The measured temperature is calculated from the measured thermistor resistance using the Steinhart-Hart equation and the Steinhart-Hart coefficients entered using the TEC:CONST command. This measurement is updated approximately once every 600 msec.

Examples   "TEC:T?" - response:13.1 means the selected module's measured TEC temperature is 13.1 ^oC.

TEC:TOLerance

The TEC:TOLerance command sets the selected module's TEC tolerance settings.

```
  :  →  TEC  →  :  →  TOL  →  <white space>  →  <nrf value>  →  ,  →  <nrf value>
```
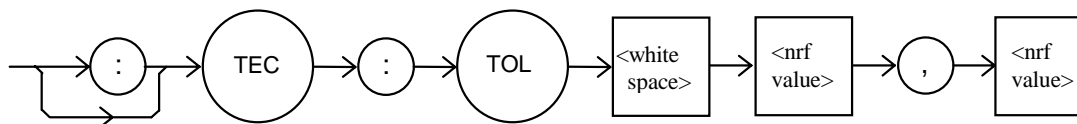
Parameters   Two <nrf values>. The first represents the tolerance window, the second represents the required time duration. When the controlled quantity (temperature, resistance, or current) is within the tolerance window for the required time duration, the load is said to be "In Tolerance". A bit in the Condition Status Register is set whenever this condition exists.

Notes   The range of the first parameter, the tolerance window, is 0.1 to 10.0. The units of this parameter depends on the control mode. In constant temperature mode, the units of the

tolerance window are ^{o}C. In constant resistance mode, the window units are kΩ. In constant current mode, the window is in Amps.

The default tolerance parameters are 0.2 and 5. This corresponds to 0.2 ^{o}C (or 0.2 kΩ, or 0.2 A) for five seconds.

WARNING If the tolerance window is set too tight for the system, the output may never reach tolerance.

Examples "TEC:TOL 0.5,10" - action: sets the selected module's TEC tolerance window to 0.5 for 10 seconds.

`TEC:TOL?`

The TEC:TOL? query returns the values of the selected module's TEC tolerance window.
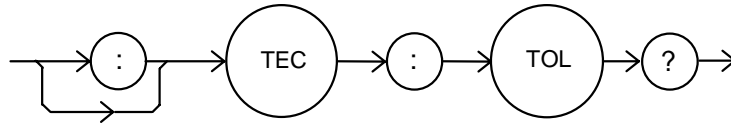
Parameters None. The response is two <nrf values> representing the tolerance parameters, as described in the TEC:TOL command description.

Notes Measurements are updated approximately every 600 msec. This means that the smallest effective tolerance duration is 0.6 seconds.

Examples "TEC:TOL?" - response: 1,10 means the selected module's TEC tolerance parameters are 1 and 10. If the control mode is constant temperature, this means the tolerance units are 1°C and 10 seconds.

`TEC:V?`

The TEC:V? query returns the selected module's TEC measured TE voltage.
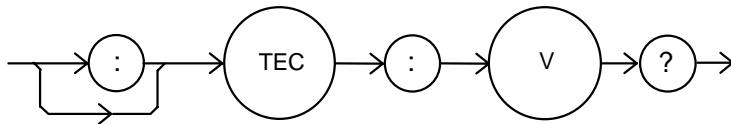
Parameters None. The response is an <nrf value> representing the measured TE voltage, in Volts.

Notes This measurement is updated approximately once every 600 msec.

Examples "TEC:V?" - response: 3.4 means the selected module's TEC measured TE voltage is 3.4 V.

TROUBLESHOOTING
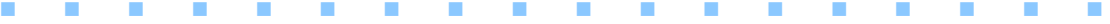
This chapter describes calibration of your LDC-3916558 3-Amp Temperature Control Module. Descriptions of the required test instruments, calibration conditions, and the detailed procedures for calibration of the instrument's Temperature Controllers are included. A troubleshooting guide is also offered for common failure symptoms. This chapter is divided into three major sections: Local (front panel) calibration, remote (through the GPIB Interface) calibration, and a troubleshooting guide.

ILX Lightwave Corporation provides in-house and on-site calibration services for ILX instruments. Most ILX instruments require yearly calibration to ensure performance to published specifications. ILX factory calibrations employ NIST traceable measurement instrumentation, and our calibration engineers and technicians use automated test equipment to accurately and efficiently capture and record calibration data. An original certificate of calibration authenticity is provided with all instrument calibrations, and a detailed report showing any pre-calibration out-of-tolerance conditions is available upon request. Calibration turn-times are normally five business days or less. On-site calibrations can be performed around your production schedule, night or day, seven days a week. Please call ILX Customer Support at (800) 459-9459 for information about calibrating your instrument.

Calibration Overview

You must perform several calibrations to completely calibrate the 3916558. The calibration consists of calibrating the temperature sensors, the TE bipolar current source, and the TE load voltage measurement. The current limit is calibrated internally by the instrument, using measurements supplied by the user, as part of the calibration process.

Your 3-Amp Temperature Controller must be calibrated while installed in an LDC-3916 or an LDC-3908 mainframe with the case closed. They should be calibrated every 12 months or whenever performance verification indicates that calibration is necessary, such as differences between set point and measurement display values that exceed the accuracy specification. Calibrate the instrument under laboratory conditions. ILX Lightwave recommends calibration at 23°C ± 1.0 °C. When necessary, however, the 3916558 3-Amp Temperature Controllers may be calibrated at their intended use temperature if this is within the specified operating temperature range of 0 - 40°C.

The LDC-3916558 should be allowed to warm up for at least 1 hour at half-power before calibration.

Recommended Equipment

Recommended test equipment for calibrating the LDC-3916558 3-Amp Temperature Control module 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.

Description	Manufacturer/Model	Specification
DMM	Agilent 3457A	DC Amps (@1.0A): +0.02% Resistance (@ 10W): 0.02% 0.1 mA or 0.1 mV resolution

Table 5.1 Recommended Test Equipment

It will be necessary to connect various loads to the outputs of the module for the calibration procedure. The devices required for the calibration loads are listed in Table 5.2.

Temperature Sensor (Thermistor) Calibration	
10 μA setting	50 kΩ resistor, 1% 1/4 W 400 kΩ resistor, 1% 1/4 W
100 μA setting	4 kΩ resistor, 1% 1/4 W 40 kΩ resistor, 1% 1/4 W
Current Source Calibration	1Ω, 50W resistor, low TCR
Voltage Measurement Calibration	5Ω, 50W resistor, low TCR

Table 5.2 Required Calibration Components

Local Calibration of the 3916558 3-Amp Temperature Controllers

Thermistor Calibration

The following procedure is for calibrating the 100 μA and 10 μA thermistor current sources so that the thermistor resistance measurement for these ranges will meet the stated accuracy specifications.

a Install the module into a 3916 or a 3908 mainframe. Turn on the mainframe and allow it to warm up for at least one hour.

b Using the multimeter, measure and record the exact resistance of your metal film resistors. You should know the precise resistance of the resistors to at least 1Ω.

Note: For best accuracy in your calibration, a four-point probe resistance measurement is recommended.   After connecting the probe to the calibration resistor, wait at least thirty seconds before recording the resistance value. Heat from your fingers can change the value of the resistance.

c Enter the 10 μA sensor calibration mode by pushing the (DISPLAY) MAIN front panel button, then the Sys. Config soft key, then the Cal. soft key, then the Cal TEC soft key, then the Therm10 Cal soft key. The module's 10 μA calibration screen will appear.

d Press the Start soft key. The internal calibration procedure will begin, and the screen will prompt you to connect a 50 kΩ resistor.

e Connect a resistor of approximately 50 kΩ (you should know the exact resistance value to at least 1) to the TE connector's sensor pins (pins 7 and 8). Allow the measurement to settle for at least 10 seconds.

f Enter the exact resistance value in kΩ into the "RReal" adjust field, and press Enter. Be sure not to enter more than 7 characters, including the decimal point. After an internal calibration, the screen will now prompt you to attach a 400 kΩ resistor.

g Connect a resistor of approximately 400 kΩ (again you should know the exact value to within 1Ω), and allow the measurement to settle for at least 30 seconds. \

h Enter the exact resistance value into the "RReal" adjust field, and press Enter. The internal calibration procedure will make its calculations, and when it has finished it will indicate so on the screen.

Follow a similar procedure for the 100 μA sensor calibration, except use the Therm100 Cal soft key, and use a 4 kΩ and a 40 kΩ resistor.

ITE Current Calibration

The following procedure is for calibrating the TE current source. The internal calibration procedure sets the current to two negative values and two positive values. You must enter the exact current that you measure at each of these points. The internal procedure will then use this information to calibrate the current source setpoint, measurement, and limit circuits.

a   With the output off, connect a 1Ω, 50 W resistor across the TEC output terminals (TE Module (+), pins 1 & 2; and TE Module (-), pins 3 & 4). Positive current flows from the module (+) pins to the module (-) pins.

b   Connect a calibrated DMM across the load resistor. You will be calculating TE current (ITE) in the following manner using Ohm's Law:

I = E / R

where E is the accurately measured voltage across the resistor, R is the accurately measured load resistance, and I is the calculated current in Amps. ILX recommends a 4-point probe resistance measurement.

Note: We recommend that the load resistor be temperature-controlled during the calibration. The current may be measured directly using an ammeter with a range of at least 3.5 A, and accurate to within ±0.01 A. Connect the ammeter in series with a load resistor of value no more than 1Ω .

c   Enter the ITE calibration mode by pushing the (DISPLAY) MAIN front panel button, then the Sys. Config soft key, then the Cal. soft key, then the Cal TEC soft key, then the ITE Cal soft key. The module's ITE calibration screen will appear.

d   Press the Start soft key. The internal calibration procedure will turn on the output and drive the TE current to approximately 90% of its negative output range. Allow the current to settle for at least 10 seconds.

e   Calculate or measure the actual current to within 0.01 A and enter the value (in Amps) into the "IReal" adjust area, press (ADJUST) ENTER. Be sure to include the minus sign, and do not enter more than five characters, including the minus sign and decimal point. If you do enter more than five characters, and as a result the minus sign no longer appears on the left side of the display, press the (ADJUST) CLEAR button and re-enter the value. Otherwise the internal calibration procedure will either abort, or produce an incorrect calibration.

f   Repeat this process for the next three values of current that the internal procedure sets. The next three current settings are approximately 30% of negative output range, then 30% of positive output range, and finally 90% of positive output range. Allow the current to settle for at least 10 seconds at each step.

After you have entered the last actual current, the internal calibration procedure will perform the calibration for the current setpoint, measurement, and limit circuits. The screen will then display a message indicating that the calibration has finished.

TE Voltage Calibration

The following procedure is for calibrating the TE voltage measurement. The internal calibration procedure sets the current to a negative value and a positive value. You must enter the exact voltage that you measure at both of these points. The internal procedure will then use this information to calibrate the voltage measurement circuit.

a   With the output off, connect a 5 Ω, 50 W resistor across the TEC output terminals (TE Module [+], pins 1 & 2; and TE Module [-], pins 3 & 4).

b   Connect a calibrated voltmeter across the load resistor.

c   Enter the TE voltage calibration mode by pushing the (DISPLAY) MAIN front panel button, then the Sys. Config soft key, then the Cal. soft key, then the Cal TEC soft key, then the TE Volts Cal soft key. The module's TE Volts calibration screen will appear.

d   Press the Start soft key. The internal calibration procedure will turn on the output and drive the TE current to approximately 33% of its negative output range. Allow the current to settle for at least 10 seconds.

e   Measure the voltage across the load resistor to within 0.01 V and enter the value in Volts into the "VReal" adjust area. Press (ADJUST) ENTER. Be sure to include the minus sign, and do not enter more than five characters, including the minus sign and decimal point. If you do enter more than five characters, and as a result the minus sign no longer appears on the left side of the display, press the (ADJUST) CLEAR button and re-enter the value. Otherwise the internal calibration procedure will either abort, or produce an incorrect calibration.

After you have entered the first voltage, the internal cal procedure will set the output current to approximately 33% of positive output range. Measure the voltage across the load resistor, enter this measurement in the "VReal" adjust area, and press (ADJUST) ENTER. The internal cal procedure will calibrate the TE voltage measurement circuit, and the screen will display a "Completed" message.

Remote Calibration of the 3916558 3-Amp Temperature Controllers

The LDC-3916558 3-Amp Temperature Control Modules can be calibrated remotely using the GPIB Interface. All of the required calibration commands are listed in Table 4.1 in Chapter 4. The procedures below are general guidelines for writing a program to calibrate your instrument

Thermistor Calibration

The following procedure is for remotely calibrating the 100 μA and 10 μA thermistor current sources so that the thermistor resistance measurements for these ranges will meet the stated accuracy specifications.

a   Install the module into a 3916 or a 3908 mainframe. Turn on the mainframe and allow it to warm up for at least one hour.

b   Using the multimeter, measure and record the exact resistance of your metal film resistors. You should know the exact resistance of the resistors to at least 1Ω .

Note: For best accuracy in your calibration, a four-point probe resistance measurement is recommended.   After connecting the probe to the calibration resistor, wait at least thirty seconds before recording the resistance value. Heat from your fingers can change the value of the resistance.

c   Connect a resistor of approximately 50 k to the TE connector's sensor pins (pins 7 and 8).

d   Begin the 10 μA sensor calibration by sending the following command over GPIB:

TEC:CAL:SEN 2.

This starts the internal 10 μA sensor calibration procedure.   Allow the measurement to settle for at least 10 seconds.

e   Check to see if the internal cal procedure is ready for a measurement: send the following query to the module:

TEC:CAL:STATUS?

The cal procedure is ready for a measurement if it returns the value "1". Query the status until the value that is returned is "1".

f   Enter the exact resistance value (that you previously measured) in k of the first resistor by sending the following command:

TEC:CAL:MEAS (value in kΩ)
e.g. TEC:CAL:MEAS 45.678

Note: The internal cal procedure will store the measured value that you enter and briefly change its measurement status to "0" to indicate that it is not yet ready for another measurement.

g   Connect the 400 kΩ resistor and allow the measurement to settle for at least 10 seconds.

h   Check to see if the internal cal procedure is ready for a measurement: send the following query to the module:

TEC:CAL:STATUS?

The cal procedure is ready for a measurement if it returns the value "1". Query the status until the value that is returned is "1".

When the status query returns "1", enter the value of the second resistor:

i   Enter the exact resistance value (that you previously measured) in kΩ of the second resistor by sending the following command:

TEC:CAL:MEAS (value in kΩ)
e.g. TEC:CAL:MEAS 398.877

The internal cal procedure will now complete the calibration of the 10 μA sensor measurement circuit. It indicates that it is finished by responding to the status query with the value "2".

Follow the same procedure for the 100 μA sensor calibration, except use the following command to start the cal:

TEC:CAL:SEN 1

For the 100 A sensor calibration, use 4 kΩ for the first resistor and 40 kΩ for the second.

ITE Current Calibration

The following procedure is for remotely calibrating the TE current source. The internal calibration procedure sets the current to two negative values and two positive values. You must measure the current at each of these points and send the measurements to the module over GPIB. The internal procedure will then use this information to calibrate the current source setpoint, measurement, and limit circuits.

a   With the output off, connect a 1 *, 50 W resistor across the TEC output terminals (TE Module [+], pins 1 & 2, and TE Module [-], pins 3 & 4).

b   Connect a calibrated DMM across the load resistor. You will be calculating TE current (ITE) in the following manner using Ohm's Law:

$I = E / R$

where E is the accurately measured voltage across the resistor and R is the accurately measured load resistance. I is the calculated current in Amps. A 4-point probe resistance measurement is recommended.

Note: We recommend that the load resistor be temperature-controlled during the calibration.

The current may be measured directly using an ammeter with a range of at least 3.5 A and accurate to within 0.01 A. If you use the ammeter approach, you should connect the ammeter in series with a load resistor with a nominal value of 1Ω .

c   Begin the ITE calibration by sending the following command over GPIB:

TEC:CAL:ITE

The internal cal procedure will begin by setting the TE output current to approximately 90% of its negative full range. Allow the current to settle for at least 10 seconds.

d   Check to see if the internal cal procedure is ready for a measurement by sending the following query to the module:

TEC:CAL:STATUS?

The cal procedure is ready for a measurement if it returns the value "1". Query the status until the value that is returned is "1".

e   Enter the measured current in Amps by sending the following command:

TEC:CAL:MEAS (current in Amps)
e.g. TEC:CAL:MEAS -1.45

The internal cal procedure will store the measured value that you enter, and briefly change its measurement status to "0" to indicate that it is not yet ready for another measurement. This will occur after each time a new measurement is entered.

f   The controller will set the output current to approximately 30% of its negative output range. Allow the current to settle for at least 10 seconds.

g Check to see if the internal cal procedure is ready for the second measurement. Send the following query to the module:

TEC:CAL:STATUS?

The cal procedure is ready for a measurement if it returns the value "1". Query the status until the value that is returned is "1".

h Enter the second actual measured TE current:

TEC:CAL:MEAS (current in Amps)
e.g. TEC:CAL:MEAS -0.43

i The controller will set the output current to approximately 30% of its positive output range. Allow the current to settle for at least 10 seconds.

j Check to see if the internal cal procedure is ready for the third measurement. Send the following query to the module:

TEC:CAL:STATUS?

The cal procedure is ready for a measurement if it returns the value "1". Query the status until the value that is returned is "1".

k Enter the third actual measured TE current:

TEC:CAL:MEAS (current in Amps)
e.g. TEC:CAL:MEAS 0.45

The controller will set the output current to approximately 90% of its positive output range. Allow the current to settle for at least 10 seconds.

l Check to see if the internal cal procedure is ready for the fourth measurement. Send the following query to the module:

TEC:CAL:STATUS?

The cal procedure is ready for a measurement if it returns the value "1". Query the status until the value that is returned is "1".

m Enter the fourth actual measured TE current:

TEC:CAL:MEAS (current in Amps)
e.g. TEC:CAL:MEAS 1.47

After you have entered the last measured current, the internal calibration procedure will perform the calibration for the current setpoint, measurement, and limit circuits. The cal procedure will set the status to the value "2" to indicate that it has finished.

TE Voltage Calibration

The following procedure is for remotely calibrating the TE voltage measurement circuit. The internal calibration procedure sets the current to two values. You must measure the voltage at each of these points and send the measurements to the module over GPIB. The internal procedure will then use this information to calibrate the TE voltage measurement circuit.

a   With the output off, connect a 5 Ω, 50 W load resistor across the TEC output terminals (TE Module [+], pins 1 & 2; and TE Module [-], pins 3 & 4).

b   Connect a calibrated voltmeter across the load resistor. Begin the TE voltage calibration by sending the following command over GPIB:

   TEC:CAL:V
   The internal cal procedure will begin by setting the TE output current to approximately 33% of its negative full range. Allow the current to settle for at least 10 seconds.

c   Check to see if the internal cal procedure is ready for the measurement. Send the following query to the module:

   TEC:CAL:STATUS?
   The cal procedure is ready for a measurement if it returns the value "1". Query the status until the value that is returned is "1".

d   Enter the actual measured TE voltage:

   TEC:CAL:MEAS (voltage in Volts)
   e.g. TEC:CAL:MEAS -2.91

   Note: The internal cal procedure will store this value and briefly change its measurement status to "0" to indicate that it is not yet ready for another measurement. This will occur after each time a new measurement is entered.

e   The controller will set the output current to approximately 33% of its positive output range. Allow the current to settle for at least 10 seconds.

f   Check to see if the internal cal procedure is ready for the measurement. Send the query to the module:

   TEC:CAL:STATUS?
   The cal procedure is ready for a measurement if it returns the value "1". Query the status until the value that is returned is "1".

g   Enter the actual measured TE voltage:

   TEC:CAL:MEAS (voltage in Volts)
   e.g. TEC:CAL:MEAS 2.85

   After you have entered the second measured voltage, the internal calibration procedure will perform the calibration for the voltage measurement circuit. The cal procedure will then set the status to the value "2" to indicate that it has finished.

This ends the calibration guide.

Troubleshooting Guide

This section is a guide to troubleshooting the 3916558 3-AMP Temperature Controller Modules. Some of the more common symptoms are listed here, and the appropriate troubleshooting actions are given. We recommend that you start at the beginning of this guide. Read the symptom descriptions, and follow the steps for the corrective actions that apply. If you encounter problems that are beyond the scope of this guide, contact your ILX Lightwave customer service representative.

Symptom	Corrective Actions
LDC-3916 or LDC-3908 unit will not power up.	Check AC power line voltage and power cord connection. Check fuse on instrument back panel.
Power on, but outputs have been shut off. Instrument may be "locked up" or instrument resets itself.	This may occur if the instrument loses power (AC line) briefly or line voltage drops below specification. If instrument is "locked up", power it off and then on to restart.
Power on, but no TE current output.	Check the load connections and operating mode.
Power on, but temperature is not controlled.	If SENSOR OPEN indication, check the sensor connections. Check that the proper sensor current range is selected. The 10 μA setting is required if the thermistor resistance is more than 50 kΩ. Check that C1, C2, and C3 are the correct values for your thermistor. Check that the GAIN setting is not too low and that the ILim value is not too low for your thermal load.
Unable to adjust output or parameter.	Ensure that the desired parameter is highlighted. Ensure that you are not trying to set TSet to a higher value than TLim, or ISet higher than ILim.
Output goes off intermittently.	Check that the AC power cord connection is secure. Power line dropouts may reset the unit and when power is restored, the output will be off. check the TE module connections. A high impedance on the TE load can cause the output to exceed the compliance voltage momentarily. If enabled with GPIB, this condition will shut off the output. There are other events or conditions that will turn the output off if enabled with GPIB. See the Operating in Remote Control portion of this manual for more information. Check the sensor connections at the module and the load. Changing control modes whil the output is on will turn the output off.