Model 3040 Temperature Controller
User's Manual

Certificate No.: FM 27207

Newport Corporation, Irvine, California, has been certified compliant with ISO 9002 by the British Standards Institution.

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EC DECLARATION OF CONFORMITY

Model 3040 Temperature Controller

We declare that the accompanying product, identified with the "CE" mark, meets all relevant requirements of Directive 89/336/EEC and Low Voltage Directive 73/23/EEC.

Compliance was demonstrated to the following specifications:

EN50081-1 EMISSIONS:
Radiated and conducted emissions per EN55011, Group 1, Class A

EN50082-1 IMMUNITY:
Electrostatic Discharge per IEC 1000-4-2, severity level 3
Rated Emission Immunity per IEC 1000-4-3, severity level 2
Fast Burst Transients per IEC 1000-4-4, severity level 3
Surge Immunity per IEC 1000-4-5, severity level 3

IEC SAFETY:
Safety requirements for electrical equipment specified in IEC 1010-1.

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1. General Information

1.1 Introduction

This chapter describes the features, options, accessories, and specifications of the Model 3040.

1.2 Product Overview

PRODUCT FEATURES

- ❑ GPIB/IEEE 488.2 and RS-232C Interfaces
- ❑ Temperature Controller (TEC)
  - Model 3040: 32 Watt (4A/8V), ultra stable bipolar output
  - Thermistor, AD590, LM335, and Pt RTD sensors

High Power Temperature Controller Fulfills All Your Thermo Electric (TE) Cooling Needs

The 32 Watt Temperature Controller is offered to meet your most demanding TE cooling needs. It may be operated in one of three modes:

- Constant Temperature
- Constant Resistance
- Constant TE Current

Short term stability is better than 0.0005°C while long term stability is better than 0.001°C. Four sensor types are compatible with this TEC:

- Thermistors
- AD590 series
- LM335 series
- 100Ω Platinum RTDs

With the sensor's calibration constants, the actual temperature is displayed in °C on the front panel.

GPIB/IEEE-488.2 and RS232 Interfaces Gives Power to Remotely Control and Collect Data.

For ultimate control a GPIB/IEEE-488.2 interface is available. All control and measurement functions are accessible via the GPIB interface. In addition, standard serial RS-232C ports allow simpler interfacing to a PC.

1.3 Available Options and Accessories

Model 3040 Advanced Temperature Controller

3040	Temperature Controller (32 W)

Accessories

300-02	Temperature Controller Cable
300-04	Temperature Controller/Mount Cable
300-16	10.0 kΩ thermistor (± 0.2°C)
300-22	AD592CN IC Sensor
35-RACK	Rack Mount Kit

Newport Corporation also supplies temperature controlled mounts, lenses, and other accessories. Please consult with your representative for additional information.

1.4 Safety Terms and Symbols

1.4.1 Terms

The following safety terms are used in this manual:

The **WARNING** heading in this manual explains dangers that could result in personal injury or death.

The **CAUTION** heading in this manual explains hazards that could damage the instrument.

In addition, a **NOTE** heading gives information to the user that may be beneficial in the use of this instrument.

1.4.2 Symbols

The following symbols are used in this manual and on the instrument:

○	Power Off
		Power On
⚠	Refer to the documentation.
⏚	Earth Ground

1.5 General Warnings and Cautions

The following general warning and cautions are applicable to this instrument:

WARNING

This instrument is intended for use by qualified personnel who recognize shock hazards or laser hazards and are familiar with safety precautions required to avoid possible injury. Read the instruction manual thoroughly before using, to become familiar with the instrument's operations and capabilities.

WARNING

The American National Standards Institute (ANSI) states that a shock hazard exists when probes or sensors are exposed to voltage levels greater then 42 VDC or 42V peak AC. Do not exceed 42V between any portion of the Model 3040 (or any attached detector or probe) and earth ground or a shock hazard will result.

CAUTION

There are no serviceable parts inside the Model 3040. Work performed by persons not authorized by Newport Corporation may void the warranty. For instructions on obtaining warranty repair or service please refer to Chapter 8 of this manual.

C H A P T E R 2

2. System Operation

2.1 Introduction

This chapter describes how to operate the 3040 temperature controller.

2.2 Installation

CAUTION

Although ESD protection is designed into the 3040, operation in a static-fee work area is recommended.

2.2.1 AC Power Considerations

The 3040 can be configured to operate at a nominal line voltage of 100, 120, 220, or 240 VAC. Normally, this is done at the factory and need not be changed before operating the instrument. However, be sure that the voltage setting is correct on the power input and correct fuses are installed per chapter 6 before connecting to an AC source. The 3040 is shipped set for 120 VAC and a caution sticker is placed on the input power connector.

CAUTION

Do not exceed 250VAC on the line input.

Do not operate with a line voltage that is not within ±10% of the line setting. Too low of an input voltage may cause excessive ripple on the DC supplies. Too high of an input voltage will cause excessive heating.

WARNING

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

2.2.2 Tilt-Foot Adjustment

The 3040 has front legs that extend to make it easier to view the LCD display. To use them, place the 3040 on a stable base and rotate the legs downward until they lock into position.

2.2.3 Rack Mounting

The 3040 may be rack mounted by using a 3040 rack mount kit. All rack mount accessory kits contain detailed mounting instructions.

2.2.4 Ventilation Requirements

Rear panel area needs 2 to 4 inches of clearance for air circulation.

2.2.5 Power-Up Sequence

Setup input power connector switch to desired voltage, then connect 3040 to AC power source. With the 3040 connected to an AC power source, set the power switch to "**I**" to supply power to the instrument and start the power-up sequence.

During the power-up sequence, the following takes place. For about 5 seconds an initialization screen is displayed. The software version is displayed in the lower left corner of the screen. During this time a self-test is performed to ensure that the 3040 hardware and software are communicating. If the 3040 cannot successfully complete this test, an error message will be displayed.

After this test, the 3040 is configured to the state it was in when the power was last shut off and displays the Main screen.

2.2.6 Quick Start

After the power-on sequence is complete, the 3040 goes to the Main screen. To set up the TEC, press the **MENU** button, then select TEC Setup Menu. The up and down cursor keys will allow the selection of all the TEC parameters, using the cursor keys and the dial set the parameter values. When finished, return the TEC to the Main screen by pressing the MENU button.

Enter the desired set point value using the cursor keys or the dial. Press the **TEC On** key to operate the TEC. The LED illuminates to indicate TEC operation. To turn the TEC off, press the **TEC On** key again.

2.3 Introduction to the 3040 Front Panel

2.3.1 Model 3040

Described below are the functions of each area of the Model 3040 front panel, as shown in Figure 1.

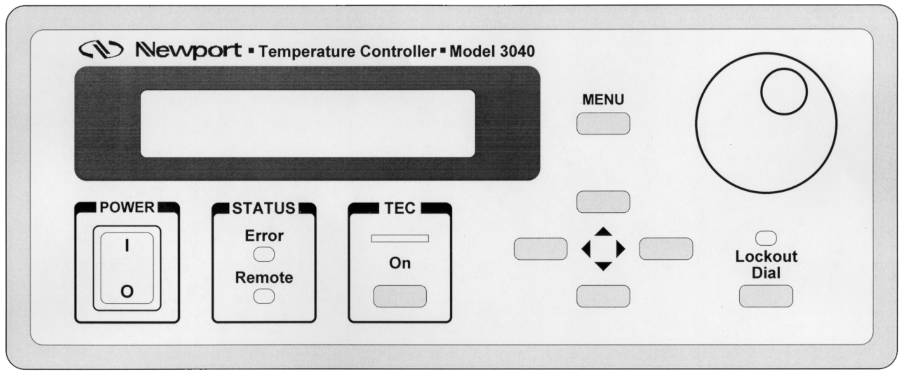

Figure 1 - Model 3040 Front Panel

1. **Power On/Off Switch** - Switches on/off the AC power to the unit.
2. **Error LED** - Indicates that an error has occurred. Instrument will also display the error message on the LCD display. See chapter 9 for additional information on errors.
3. **Remote LED** - Indicator will light to show when the unit is being computer controlled. See section 2.4.1 for additional information on remote mode.
4. **TEC On LED** - Indicates TEC output is on.
5. **TEC On Button** - Turns the TEC output on/off.
6. **Cursor Control Keys** - Moves cursor up or down between editable data fields. The left arrow decrements values in numerical entry fields, or as a previous choice in a multi-choice entry field. The right arrow increments values in numerical entry fields, or as a next choice in multi-choice entry fields. See section 2.4.1.3 for a description of data fields.
7. **MENU Key** - Switches to the main menu from any screen in the system (see section 2.4.3).
8. **Lockout Dial Key** - Used to enable/disable use of the dial.
9. **Lockout Indicator LED** - Indicates Dial is locked out.
10. **Dial** - Used to continuously vary certain parameters. The dial has an acceleration factor that causes the rate of change to increase as the dial is turned faster. Turning slowly allows for a fine adjustment at the smallest displayed decimal place.

2.4 General Operation

2.4.1 Display Elements

The Model 3040 uses a character display to depict information about the current state of the system. The display can be broken down into four basic elements: static fields, non-editable data fields, editable data fields, and soft key labels.

2.4.1.1 Static Fields

Static fields are elements on the display which do not change from moment to moment. These can include screen titles and error messages.

2.4.1.2 Non-Editable Data Fields

Non-editable data fields are used mainly to display read back information, such as temperature. These fields can have a prefix or suffix label, such as "**Ts=**" or "**A**", and are periodically updated by the system.

2.4.1.3 Editable Data Fields

Editable data fields are used for TEC and system settings such as current set point, temperature set point, display contrast, etc. An editable field has three distinct display states: focused, non-focused, and read-only.

The focused state indicates that the field has the input "focus." When a field has the focus, a right pointing arrow (→) is placed to the left of the field. Any keyboard entry or dial adjustment will be applied to the field, and only one field at a time on the display can have focus. Move between fields using the up and down arrow keys.

The non-focused state indicates that the field is editable, but does not currently have the focus. These fields are indicated with a right pointing triangle (‣) to the left of the field. Using the up and down arrows, focus can be moved to these fields.

When the editable data field is in the read-only state, it looks and acts exactly like a non-editable data field. Like the non-editable data field, it cannot have focus, and the up or down arrow keys will skip over the field. This state is used primarily to lockout specific data elements from front panel change when the Model 3040 is in remote mode. Any RS-232 communication will place the unit in remote mode, and editable fields that are protected during remote operations change to the read only state.

2.4.1.3.1 Changing Data Fields

A data field can only be changed from the front panel when the field is the focus. Some fields are numeric-based, such as current set point or temperature limits. Other fields are multi-choice fields, such as Yes/No fields. Both types are changed with the left and right arrows or the dial.

2.4.1.4 Controls

There are certain functions in the 3040, such as saving and recalling bins, that require a "button push". Because the 3040 has no additional buttons to do this function, it uses a "soft button". A soft button is similar to an edit field, but instead of selecting a value with the left and right arrow keys when the field is selected, the left and right arrow keys function as custom defined buttons for as long as that field is selected.

For example, the return to local function is not a setting or value, but a state of operation. A soft button for return to local might look like this:

```
→Local       →      Set
```

When this field is selected, as in this example, pressing the right arrow key would set the unit to local mode. There are also elements on the 3040 which us the left arrow as well, such as this example:

```
→Save ← Bin → Recall
```

In this case, pressing the left arrow key will save the bin information, while pressing the right arrow key would recall the bin information.

2.4.2 Main Screen

The system main screen is shown below, and is discussed in detail in section 3.4.1 and later. The screen is displayed after power on initialization, and its displayed elements will depend on the mode of operation. In this example, the unit is in constant temperature mode, displaying the temperature set point, current read back, and temperature read back.

```
→Ts=  25.00 °C  OutT
  T=  23.95  I= 0.00
```

Figure 2 - Main Screen

2.4.3 Menu Structure

The 3040 has a simple menu structure for changing the operation settings, such as limits, communications parameters, and so forth. Each menu group has settings accessible by first pressing the **MENU** button, then using the cursor keys to navigate through the menus. When discussing the menu items within a menu, all the items are shown in a single box.

NOTE
The 3040 display is a two line display, therefore only two elements will be visible at a time.

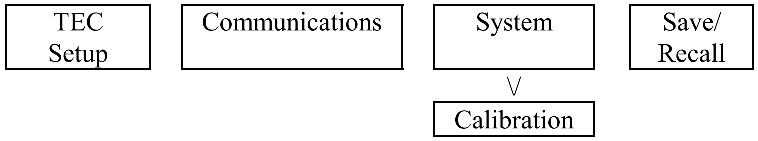

Figure 3 - Model 3040 Menu Groups

2.4.3.1 TEC Setup Menu

The TEC Setup Menu is covered in section 3.4.2, and covers settings that pertain to the operation of the TEC.

2.4.3.2 Communications Menu

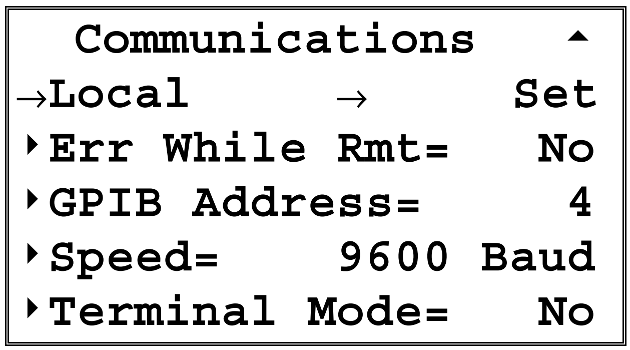

Figure 4 - Communications Menu

The Communications menu contains the setup parameters for GPIB and RS-232C communications.

The **Local** soft button will return the 3040 to local mode after being controlled over GPIB or RS-232C.

Error messages may appear on the display when error conditions occur which force the output off or reflect hardware errors in the 3040. Display of error messages on the 3040 screen may be disabled while in remote mode by setting **Err While Rmt** to **No**. Errors will continue to accumulate in the error queue, but will not be displayed on-screen.

GPIB Address selects the device address on the GPIB bus. The allowed range is 1 to 31.

Speed controls the speed of the RS-232C interface. The allowed speeds are 300, 1200, 2400, 4800, 9600, 19200, and 38400. The parity is NONE, and data bits are 8.

Terminal Mode controls the system prompt when communicating over the RS-232C interface. See the section on terminal mode in the *Computer Interfacing Manual*.

2.4.3.3 System Menu

The system configure menu controls basic operation of the 3040 system.

```
    System Setup   ▲
→Display=        T/I
▸ontrast=       11 %
▸Brightness=  100 %
▸Lockout Dial=   No
▸Audible beep=  Yes
▸Key Rate=     Fast
▸Dial Rate=    Fast
▸Calibrate →Execute
```

Figure 5 - System Configure Menu

Display controls which elements are displayed on the second line of the main screen. Possible options are T/I (temperature and current), T/V (temperature and voltage), V/I (voltage and current), and T/V/I (temperature voltage and current).

Brightness varies the back lighting intensity. **Contrast** is used to optimize the viewing angle.

Audible Beep controls the system's audible beeper. The beeper indicates errors, invalid data entry, and other situations where the 3040 needs to alert the user.

Lockout dial disables the unit's dial. This is the same as pressing the **Lockout Dial** key on the front panel.

Key Rate - this controls the speed at which, when a key is held down, it repeats. Settings are **Slow**, **Medium**, and **Fast**. Slow is the default setting.

Dial Rate - like the **Key Rate** setting, this controls the acceleration of the dial as it is turned. Settings are **Slow**, **Medium**, and **Fast**. Slow is the default setting.

Calibrate->Execute gains access to the Calibration menu. See section 2.4.3.3.1 for additional information on the calibration menu.

2.4.3.3.1 Calibration Menu

The calibration menu is used to access the 3040 calibration functions. Only qualified persons who fully understand the calibration procedure should perform these calibrations. Each of the calibration procedures are described in detail in Chapter 7.

```
    Calibration     ▲
→Cal         →    Ite
‣Cal       →   Sensor
‣Set    →    RTD Null
‣Set        →  T Null
```

Figure 6 - Calibration Menu

Because these are soft buttons, to use any of the calibration or set functions, first select the function, then press the right arrow key.

For each of the Cal functions, see the following sections:

Ite calibration: section 7.2.11.
Sensor calibration: section 7.2.2 and forward.

The **Set RTD Null** function is used to calibrate out the resistance of the cable when using RTD sensors. See section 7.2.10 for further information. This setting is only available if RTD sensor is selected.

The **Set T Null** function is used to zero the offset value between the set point and read back values. To use this function, have the unit operating with the temperature stabilized. It is important that the temperature is fully stabilized, not moving more than 1 or 2 counts on the display before this function is used. Once the temperature is fully stabilized, the **Set T Null** function will zero the offset between the set point and the read back temperature values. The set point is used as the calibration reference (the set point is calibrated using the **Cal Sensor** function above).

2.4.3.4 Save/Recall Menu

```
     Save/Recall    ▲
→Bin=               0
‣Save ← Exec →Recall
```

Figure 7 - Save/Recall Menu

The Save and Recall functions are used to store and retrieve 3040 setup configurations for future use. For example, a specific test setup may be saved for later use, and then another setup may be used presently. Then, when the user desires to perform the specific test, its setup is simply recalled.

Non-volatile memory is used for saving the instrument parameters. When a save operation is performed, all of the parameters which are currently in effect on the 3040 are stored. The user selects a “bin” number (1 - 10) for saving the parameters. Then, when that “bin” number is recalled, the 3040 is restarted and the parameters are reconfigured to the previously stored values.

A special “bin 0” is reserved for the reset state. Recalling bin 0 will reset the system to factory defaults.

2.5 Rear Panel Familiarization

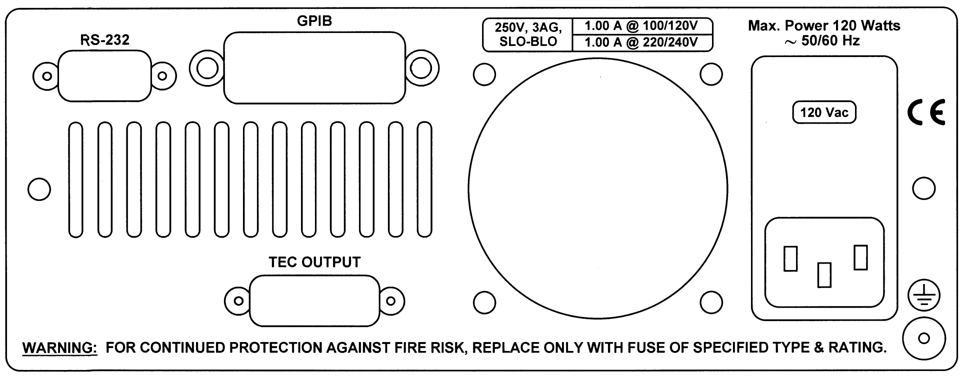

Figure 8 - Rear Panel

2.5.1 RS-232 Connector

The 3040 has an RS-232 connector located on the back panel. See section *Computer Interfacing Manual* for a more complete description of the RS-232 interface.

2.5.2 GPIB Connector

The GPIB connector, located on the back panel, allows full remote control as described in the Computer Interfacing Manual. It accepts a standard IEEE-488 cable for remote control, and uses Metric lock screws. See the *Computer Interfacing Manual* for a more complete description of the GPIB interface.

2.5.3 TEC Output Connector

The TEC Output connector provides the TEC connection. See section 3.3 for a detailed description of the TEC output connector.

2.5.4 Input Power Connector

Accepts a standard line cord for AC input. Also selects one of four AC input settings: 100V, 120V, 220V, and 240V. The cord must be removed to change the setting. A small screwdriver will open the top of the module and expose the rotary switch. Select the range that is closest to your expected nominal RMS line voltage. The voltage selection is set for 120 VAC prior to shipping.

CAUTION

Do not exceed 250 VAC on the line input.

Do not operate with a line voltage that is not within ±10% of the line setting. Too low of an input voltage may cause excessive ripple on the DC supplies. Too high of an input voltage will cause excessive heating.

2.5.5 GND Post

Provides access to chassis ground, which is also an earth ground as long as a standard 3-wire line cord is used. This is a protective conductor terminal to be used to achieve chassis grounding requirements when the main connectors don't provide an earth ground terminal. Use a minimum of 18 gauge wire to connect to this terminal.

2.6 Warm Up and Environmental Consideration

Operate the 3040 at an ambient temperature in the range of 0 to +40°C. Storage temperatures should be in the range of -20 to +60°C. To achieve rated accuracy, let the 3040 warm up for 1 hour. For greatest accuracy, recalibrate when ambient temperature changes more than a few degrees.

CAUTION

Operating above +40°C can cause excessive heating and possible component failures.

3. Temperature Controller Operation

3.1 Temperature Controller (TEC)

The Temperature Controller is a precision thermoelectric cooler controller. Features of TEC include:

- Close-case calibration
- Operational with most thermistors, IC and RTD temperature sensors
- Flexible setup with 3040 Save/Recall front panel functions
- High temperature stability
- Current Limit

3.2 TEC Safety Features

3.2.1 Conditions Which Will Automatically Shut Off the TEC Output

- High Temperature Limit
- Low Temperature Limit
- R Limit
- TEC Open
- Sensor Open
- Sensor Select changed
- Sensor Shorted
- Mode Change

Clearing the appropriate bits in the TEC OUTOFF register can disable each of these conditions. See the *Computer Interfacing Manual* for additional information.

3.2.2 Lockout Dial Button

The **Lockout Dial** button on the front panel located below the control dial disables the dial. This prevents any inadvertent changes in the output by accidental movement of the control dial.

3.2.3 TEC Interlock

The TEC interlock, located on the TEC connector, will shutdown TEC operation when the interlock lines are shorted together.

3.3 The TEC Connector

On the TEC, a 15-pin D-connector is used for input and output connections, as shown by the pin-out diagram below.

Pin	Description
1,2	TE+
3,4	TE-
5,6	Ground
7	Sensor+
8	Sensor-
13	Interlock Send
15	Interlock Return

Table 1 - TEC Connector Pintouts

3.3.1 TEC Grounding Consideration

The TEC output is isolated from chassis ground, allowing either output terminal to be grounded at the user's option.

3.4 TEC Operation

3.4.1 TEC Main Screen

The TEC main screen is shown and described below.

```
→Ts=  25.00 °C  OutT
  T=  23.95  I= 0.00
```

Figure 9 - TEC Main Screen

Is=, **Ts=, Rs=, is=, vs=** - Indicates the set point value of current, temperature, resistance, AD590 sensor current, or LM335 sensor voltage, respectively. In the screen shown above, the **Ts** is shown. **Is, Rs, is,** and **vs** would be seen when operating in those modes.

I=, **T=, R=, i=, v=** - Indicates the measured value of current, temperature, resistance, AD590 sensor current, or LM335 sensor voltage, respectively. An **err** indicates a sensor error, usually caused by the sensor not hooked up or the wrong sensor selected. In the screen shown above, the **T** is shown. **I**, **R, i**, and **v** would be seen when operating in those modes.

The status field is located in the upper right corner of the display (**OutT** in this example). When more than one status is active, they will cycle in the status field.

3.4.2 TEC Setup Menu

The TEC Setup menu is shown in Figure 10. Each section is described below in detail.

```
      TEC Setup     ▲
→Sens=           RTD
▸Mode=       Const T
▸Gain=       30 Fast
▸Lim Ite=     2.00 A
▸Tol Time=   5.000 S
▸Tol Temp=   0.20 °C
▸Lim Tl=    10.00 °C
▸Lim Th=    50.00 °C
▸C1=  3.9080 x 10-3
▸C2= -5.8019 x 10-7
▸C3=-4.2735 x 10-12
▸Ro=       100.000 Ω
```

Figure 10 - TEC Setup Menu

3.4.2.1 The ▲ and ▼ Soft Keys

Pushing the ▲ (previous) cursor soft key returns to the previous screen, while pressing the ▼ (next) cursor soft key advances to the next screen.

3.4.2.2 Sensor (Sens)

Selects the temperature sensor type used in your TEC mount. If the **None** is selected, only the ITE mode is allowed. This type is intended for applications running without a temperature sensor. See the following sections for discussions of the various sensor

types. The TEC supports the thermistor sensors (10µA and 100µA range), AD590, LM335, and RTD sensors.

3.4.2.3 Mode

3.4.2.3.1 Constant Temperature Mode (Const T)

This mode holds the TEC at a constant temperature based on feedback from the sensor in the TEC mount, using "**Ts=**" and "**T=**" variables. In this mode, the 3040 uses a control loop comparing the sensor input to the temperature set point, driving the ITE current positive or negative to reach and maintain that set point. The sensor's input is converted to temperature for display of actual TEC temperature. The ITE current is also displayed in this mode.

3.4.2.3.2 Constant Resistance/Reference Mode (Const R)

This mode operates identically to the Const T mode, but the sensor input is not converted to temperature, and is displayed in unconverted form. Likewise, the set point is used directly, not converted from temperature. Thermistor and RTD sensors use resistance ("**Rs=**" and "**R=**" variables), LM335 sensors use millivolts ("**vs=**" and "**v=**" variables), and AD590 sensors use microamps ("**is=**" and "**i=**" variables). Const R is primarily intended for users who know a sensor set point in "sensor" units, not in °C. ITE current is also displayed in these modes.

3.4.2.3.3 Constant Current Mode (Const ITE)

Unlike the modes above, the Const ITE mode allows the operator to explicitly set the amount and direction of current flow through the TEC, using "**Is=**" and "**Ite=**" variables. If a sensor has been selected, the TEC temperature will be displayed. Although temperature is not a factor in the amount or direction of current flow, the high and low temperature limits are observed, and will shutdown the output if exceeded in Const ITE mode, if a sensor is selected. For no temperature limits, set the sensor type to "None." Use caution when limits are not active, as the temperature may exceed your TEC's thermal limits.

3.4.2.3.4 Effects of Calibration on TEC modes

On startup, the TEC performs an auto-calibration to eliminate most of the error in ADC and DAC values. After this auto-calibration, each sensor type supported by the TEC has an offset calibration, while the ITE set point and read back has a two point calibration. These calibration constants are then used to calibrate a set point or read back value. This includes "cross-mode" values, such as displaying actual current while in constant temperature mode. While the current *set point* calibration has no effect in Const T mode, the *read back* calibration is used to more accurately display the actual current.

3.4.2.4 Gain

The Gain function controls two parameters of the hybrid PI control loop; proportional gain and integration time.

When the actual temperature and the set point are different, an error voltage is generated. This error voltage is directly related to the difference in the actual and set point temperatures. The error voltage is then amplified by the proportional gain. This amplified error voltage controls the amount of current driven through the TEC. The higher the gain, the more current will be driven for any given temperature difference, with the maximum current being determined by the current limit.

The error voltage also drives an integrator. The integrator's output also controls the amount of current being driven through the TEC. The integrator is an amplifier whose gain is proportional to time. The longer a given error voltage is present, the more current will be driven through the TEC, with the maximum current being determined by the current limit. The speed at which the integrator's output increases is the integration time, which can be "Slow" or "Fast".

The allowed Gain values are: 0.2 Slow, 0.6 Slow, 1 Slow, 1 Fast, 2 Slow, 3 Fast, 5 Fast, 6 Slow, 10 Slow, 10 Fast, 20 Slow, 30 Fast, 50 Fast, 60 Slow, 100 Fast or 300 Fast. The number actually defines the proportional loop gain. The slow/fast suffix indicates the speed at which the integrator's output increases. The slow setting allows for larger masses or greater distance between the sensor and the thermo-electric cooler by slowing the speed of the integrator.

Both the proportional gain and the integration time must be matched to the thermal characteristics of the TE cooler and sensor. If the settings are incorrect, the temperature set point will take an excessive amount of time to settle, or it will oscillate around the set point and never settle.

The Gain setting depends on the type of TE cooler that you are using, but we can suggest guidelines for selecting the proper gain. Set the gain to 1 fast and increase it until the actual temperature oscillates around the set temperature. Then reduce the gain to the next lower value.

To read the Gain setting, go to the setup. The display will show the value of the Gain setting. In Constant I_{TE} mode the Gain setting has no effect.

3.4.2.5 Limits

3.4.2.5.1 TE Current Limit (Lim ITE)

This sets the maximum drive current the TEC will allow. This maximum applies to all modes (constant ITE/R/T).

3.4.2.5.2 Temperature Limits (Lim Th and Lim Tl)

The TEC supports both a low and high temperature limit, and can be programmed to turn the TEC output off in the event those limits are exceeded (default state). The temperature limits are monitored regardless of the mode of the TEC. This has the added safety feature of shutting down the TEC in Const ITE or Const R mode when the temperature limit is exceeded (if the OUTOFF bits are enabled for this condition).

> **CAUTION**
> These limits do not apply if the sensor type is set to "None."

3.4.2.5.3 Resistance/Reference Limits (Lim Rh and Lim Rl)

Like the temperature limits, the TEC also supports both a low and high resistance/reference limit, and can be programmed to turn the TEC output off in the event those limits are exceeded, although by default this is disabled. These limits are monitored only while in Const R mode.

3.4.2.6 Tolerances (Tol Time and Tol Temp)

The **Tol Time** and **Tol Temp** elements are used for determining when the TEC is "in tolerance," where the actual temperature has stayed within **Tol Temp** of the set point for at least **Tol Time** seconds. The **Tol Time** value is expressed in seconds, and can range from 0.1 seconds to 60 seconds. The **Tol Temp** value is displayed in °C (the most common usage), and can range from 0.01 to 5.00. If at any time it goes outside the tolerance range, the time restarts at zero.

As an example, if the **Tol Time** is set to 5 seconds, the **Tol Temp** is set to 0.2°C, and the temperature set point was 25.0°C, the TEC would have to stay within 24.8°C and 25.2°C to be within tolerance. Out of tolerance is indicated by the **OutT** status in the status field.

The out of tolerance condition is most often used to shutdown laser outputs when a TEC is not operating within tolerance.

If the system was being operated over IEEE-488 or RS-232, once the TEC was within tolerance, its OUTOFF register could be set to turn the TEC off when out of tolerance. You would have to disable the Out of Tolerance bit in the TEC's OUTOFF register before you could turn the TEC back on.

3.4.2.7 C1, C2, C3, Ro

See the section of each of the sensors for a description of how C1, C2, C3, and Ro are used.

3.4.3 Thermistor and Thermistor Current Selection

3.4.3.1 Introduction

Choosing the right sensing current depends on the range of temperature you want to measure and the resolution you require at the highest measured temperature. To correctly set the thermistor current you must understand how the thermistor and the 3040 interact.

3.4.3.2 Thermistor Range

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

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

In the 3040 the practical upper temperature limit is the temperature at which the thermistor becomes insensitive to temperature changes. The maximum ADC input voltage of the 3040 limits the lower end of the temperature range. Thermistor resistance and voltage are related through Ohm's Law (V = I x R). The 3040 supplies current to the thermistor, either 10 µA or 100 µA , and as the resistance changes a changing voltage signal is available to the thermistor inputs of the 3040. The 3040 will over-range when the input voltage exceeds about 5 Volts. Figure 11 graphically shows the lower temperature and upper voltage limits for a typical 10 k Ohm thermistor. The practical temperature ranges for a typical 10 K thermistor (a 10 K thermistor has a resistance of 10 k Ohms at 25°C) are given in the table below.

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

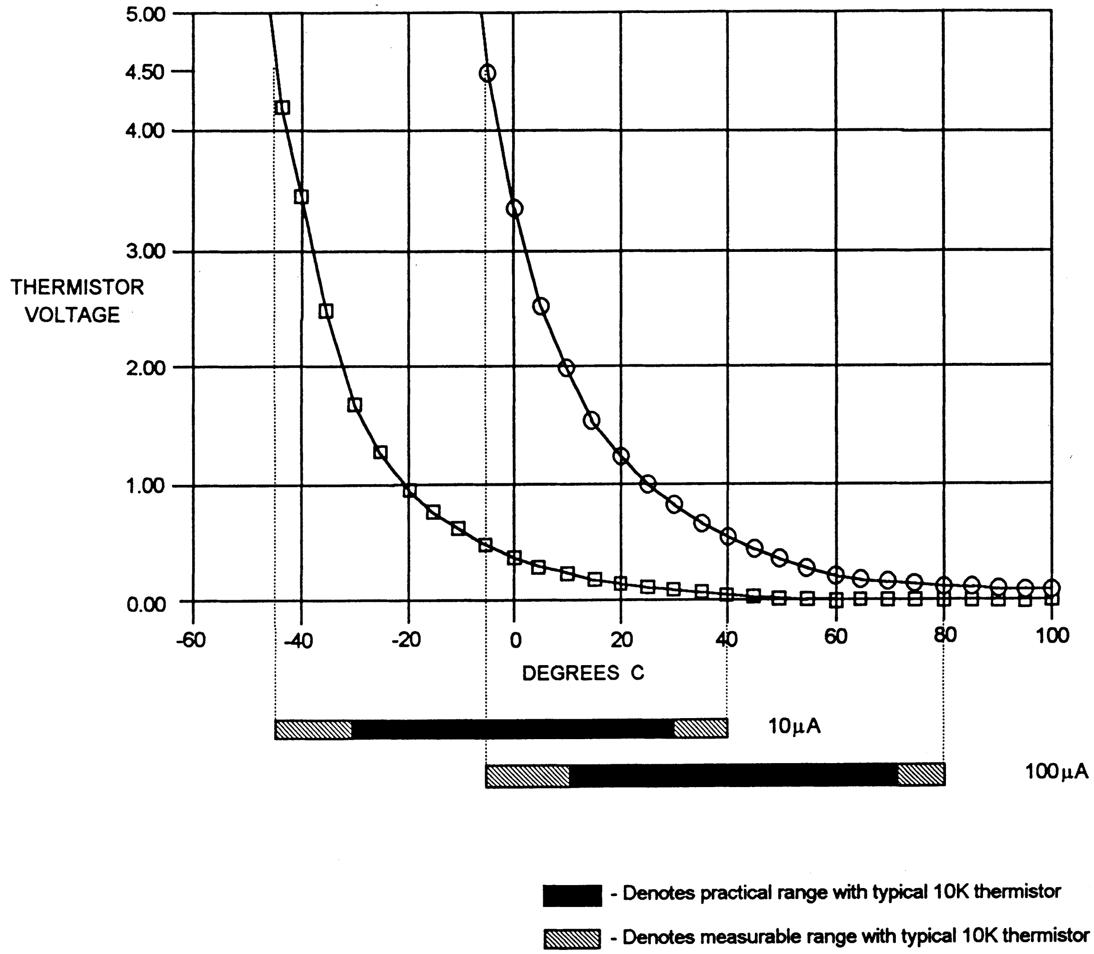

Figure 11 - Thermistor Temperature Range

3.4.3.3 Temperature Resolution

You must also consider measurement resolution since the resolution decreases as the thermistor temperature increases. The 3040 uses an A/D converter that has a maximum resolution of about 0.763Ω in 10uA range. The microprocessor converts this digital number to resistance, stores this resistance, then converts it to a temperature using the Steinhart-Hart equation, and stores this temperature. A temperature change of one degree centigrade will be represented by a greater resistance increase (and therefore more ADC counts) at lower temperatures because of the non-linear resistance of the thermistor. Resolution figures for a typical 10 kΩ thermistor are given below.

Temperature	Voltage at 10 µA	Resolution
-20 °C	56.0 mV/°C	0.018 °C/mV
25 °C	4.4 mV/°C	0.230 °C/mV
50 °C	1.4 mV/°C	0.700 °C/mV

For this thermistor, a temperature change from -20°C to -19°C will be represented by 737 ADC counts (if supplied with 10µA). The same thermistor will only change about 18 ADC counts from 49°C to 50°C.

3.4.3.4 Selecting Thermistor Current

To select the current setting for a typical 10 KΩ thermistor, determine the lowest temperature you will need to sample and select the current according to the range limits given above. If the temperature you want to sample is below -10°C you should use the 10µA setting.

With the current set to 10µA the best resolution you will see will be a 1.0°C temperature change. If, for example, the lower limit is 0°C you can choose either setting, but there is a tradeoff in terms of resolution. If you need better than 0.1°C measurement resolution you will have to change to 100µA.

If you need high resolution over a narrow range, for a very accurate measurement, you can set the current setting for the maximum resolution. For example, at a high temperature of 15°C, you require a measurement resolution of at least 0.05°C. This resolution is within the range of either setting, but at the 10µA setting the resolution is only 0.2°C while at the 100 µA setting the resolution is better than .05 °C.

Generally, it is best to use the 100µA setting for all measurements of -10°C or greater with a 10 K thermistor.

3.4.3.5 Selecting Thermistors

The type of thermistor you choose will depend primarily on the operating temperature range. These guidelines for selecting the range and resolution will apply to any thermistor. 10 K thermistors are generally a good choice for most laser diode applications where high stability is required near room temperatures. Similarly, 10 K thermistors are often a good choice for cooling applications where you want to operate at temperatures from -40°C to room temperature.

If you require a different temperature range or the accuracy you need can't be achieved with either current setting, select another thermistor. Thermistor temperature curves, supplied by the manufacturer, show the resistance versus temperature range for many other thermistors. Contact a Newport application engineer with your specific application.

3.4.3.6 The Steinhart-Hart Equation

The Steinhart-Hart equation is used to derive temperature from the non-linear resistance of an NTC (Negative Temperature Coefficient) thermistor.

The following section contains an explanation of the Steinhart-Hart equation and the values of these constants for some common thermistors.

Two terminal thermistors have a non-linear relationship between temperature and resistance. The resistance versus temperature characteristics for a family of similar thermistors is shown in Figure 12. It has been found empirically that the resistance versus temperature relationship for most common negative temperature coefficient (NTC) thermistors can be accurately modeled by a polynomial expansion relating the logarithm of resistance to inverse temperature. The Steinhart-Hart equation is one such expression and is given as follows:

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

Where T is in KELVIN. To convert T to °C, subtract 273.15.

Once the three constants C1, C2, and C3 are accurately determined, only small errors in the calculation of temperature over wide temperature ranges exist. Table 2 shows the results of using the equation to fit the resistance versus temperature characteristic of a common 10 kΩ thermistor. The equation will produce temperature calculation errors of less than 0.01°C over the range -20 °C to 50 °C.

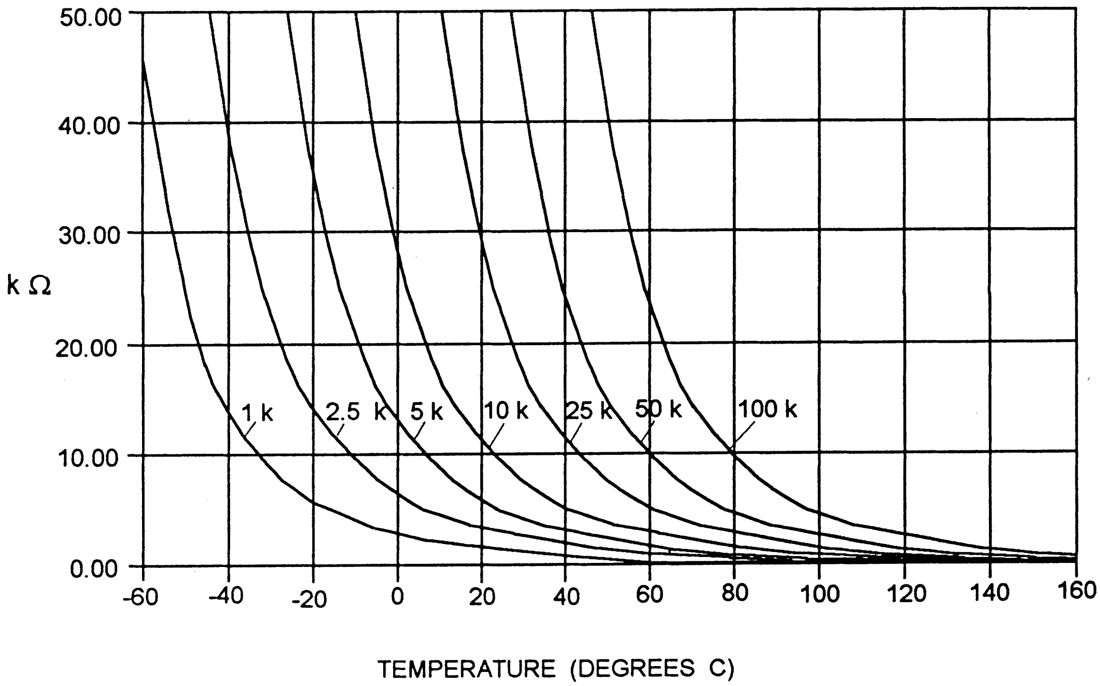

Figure 12 - Thermistor Resistance versus Temperature

R[1]	---------Error T (°C)---------- T Actual	Third Order Fit. Eq. 1[2]
96974	-20.00	-0.00
55298	-10.00	0.00
32651	0.00	-0.00
19904	10.00	-0.00
12494	20.00	-0.00
10000	25.00	0.00
8056	30.00	0.00
5325	40.00	0.00
3601	50.00	-0.00

Table 2 - Comparison of Curve Fitting Equations

The constants C1, C2, and C3 are expressed in the form n.nnnn, simplifying entry into the 3040.

[1] Resistance of a BetaTHERM 10K3 thermistor.

[2] Constants $C1 = 1.1292 * 10^{-3}$, $C2 = 2.3411 * 10^{-4}$, $C3 = 0.8775 * 10^{-7}$

3.4.3.7 Table of Constants

We have listed some common thermistors and included the appropriate calibration constants for the temperature range -20 °C to 50 °C in Table 3. The Model 3040, by default, uses the BetaTHERM 10K3 thermistor values.

Manufacturer	*C1 * 10⁻³*	*C2 * 10⁻⁴*	*C2 * 10⁻⁷*
BetaTHERM 10K3	**1.129241**	**2.341077**	**0.877547**
BetaTHERM 0.1K1	1.942952	2.989769	3.504383
BetaTHERM 0.3K1	1.627660	2.933316	2.870016
BetaTHERM 1K2	1.373419	2.771785	1.999768
BetaTHERM 1K7	1.446659	2.682454	1.649916
BetaTHERM 2K3	1.498872	2.379047	1.066953
BetaTHERM 2.2K3	1.471388	2.376138	1.051058
BetaTHERM 3K3	1.405027	2.369386	1.012660
BetaTHERM 5K3	1.287450	2.357394	0.950520
BetaTHERM 10K3	1.129241	2.341077	0.877547
BetaTHERM 10K4	1.028444	2.392435	1.562216
BetaTHERM 30K5	0.933175	2.213978	1.263817
BetaTHERM 30K6	1.068981	2.120700	0.901954
BetaTHERM 50K6	0.965715	2.106840	0.858548
BetaTHERM 100K6	0.827111	2.088020	0.805620

Table 3 - Thermistor Constants

3.4.4 AD590 and LM335

3.4.4.1 General

The 3040 uses two constants (C1 and C2) for calibrating the two linear thermal sensing devices, the AD590 and the LM335. C1 is used as the zero offset value, and C2 is used as the slope or gain adjustment. Therefore, C1 has a nominal value of 0, and C2 has a nominal value of 1 when using the AD590 or LM335. In order to calibrate a linear sensor device, the sensor must be operated at an accurately known, stable temperature. For example, the sensor may be calibrated at 0 °C if the sensor is placed in ice water until its temperature is stable. A highly accurate temperature probe, thermometer, environmental chamber, etc., may also be to determine the known temperature for calibration.

3.4.4.2 AD590 Sensor

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

$$i = 1\ \mu A / K$$

where i is the nominal current produced by the AD590, and K is in Kelvin.

The 3040 uses i to determine the nominal temperature, T_n, by the formula:

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

where T_n is in °C.

The displayed temperature, $T_d = C1 + (C2 * T_n)$, is then computed, where C1 and C2 are the constants stored in the 3040 for the AD590. The AD590 grades of tolerance vary, but typically without adjusting C1 and C2, the temperature accuracy is ±1°C over its rated operating range. However, the AD590 is not perfectly linear, and even with C1 accurately known there is a non-linear absolute temperature error associated with the device. This non-linearity is shown in Figure 13, reprinted from Analog Devices specifications, where the error associated with C1 is assumed to be zero.

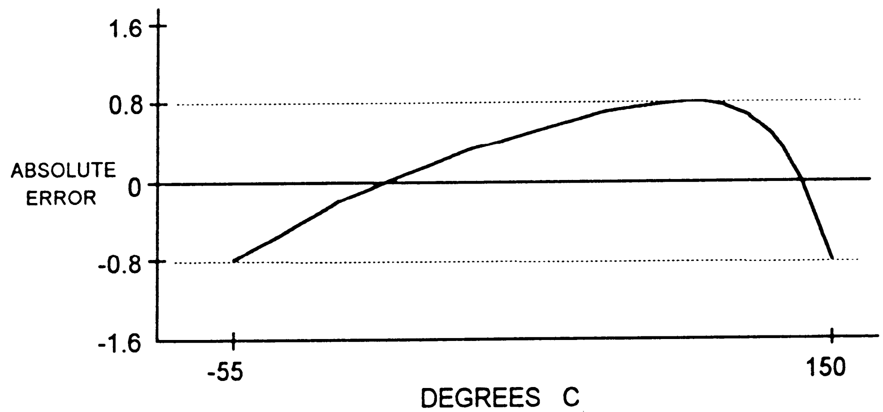

Figure 13 - AD590 Nonlinearity

If a maximum absolute error of 0.8°C is tolerable, the one point calibration of C1 should be used. If a greater accuracy is desired, the two point method of determining C1 and C2 should be used. Note however, the absolute error curve is non-linear, therefore the constant C2 will vary for different measurement points.

3.4.4.3 LM335 Sensor

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

$$v = 10mV / K$$

where v is the voltage produced by the LM335 and K is Kelvin.

The 3040 uses v to determine the nominal temperature, T_n, by the formula:

$$T_n = (v / (10mV / K)) - 273.15$$

where T_n is in °C.

The temperature, T_d, which is displayed by the 3040 is calculated as follows:

$$T_d = C1 + (C2 * T_n)$$

where C1 and C2 are the constants stored in the 3040 for the LM335.

When the LM335 is calibrated to 25°C, C1 = 0 and C2 = 1, and the temperature accuracy is typically ±0.5°C over the rated operating range. However, the LM335 is not perfectly linear, and even with C1 accurately known there is a non-linear absolute temperature error associated with the device. This non-linearity caused error is typically ±0.3°C, with the error associated with C1 assumed to be zero.

If a maximum absolute error of ±0.3°C can be tolerated, the one point calibration of C1 should be used. If a greater accuracy is desired, the two point method of determining C1 and C2 should be used. Note however, the absolute error associated with the constant C2 may vary over different temperature ranges.

3.4.4.4 Determining C1 and C2 for the AD590 and LM335

The nominal values of C1 and C2 are 0 and 1, respectively, for both types of devices. These values should be used initially for determining C1 and C2 in the methods described below.

The One Point method is easiest, but it ignores the non-linearity of the device. It is most useful when a high degree of temperature accuracy is not required.

The Two Point method can achieve a high degree of accuracy over a narrower operating temperature range, but requires two accurate temperature measurements.

3.4.4.4.1 One Point Calibration Method

The calibration described in this section is independent of the calibration procedure described in sections 7.2.4 and 7.2.6. Those sections deal with the internal calibration of the TEC, while the following calibration procedure is for calibrating the external AD590 or LM335 sensor. For the most accurate possible results, both calibration procedures should be performed.

The accuracy of this procedure depends on the accuracy of the externally measured temperature. It is used to determine the zero offset of the device, and it assumes that the gain (slope) is known.

1. Allow the 3040 to warm up for at least one hour. Select the desired sensor type in the setup menu.

2. Set the C1 parameter to zero. Set the C2 parameter to 1.

3. Place the sensor at an accurately known and stable temperature, T_a . Connect the sensor to the 3040 for normal Constant temperature operation. Allow the 3040 to stabilize at the known temperature, T_a and read the displayed temperature, T_d.

4. Determine the new value of C1 from the formula:

$$C1 = T_a - T_d$$

and enter the new C1 value.

3.4.4.4.2 Two Point Calibration Method

The calibration described in this section is independent of the calibration procedure described in sections 7.2.4 and 7.2.6. Those sections deal with the internal calibration of the TEC, while the following calibration procedure is for calibrating the external AD590 or LM335 sensor. For the most accurate possible results, both calibration procedures should be performed.

The accuracy of this procedure depends on the accuracy of the externally measured temperature. It is used to determine the zero offset of the device and the gain (slope).

1. Allow the 3040 to warm up for at least one hour. Select the desired sensor type in the setup menu.

2. Set the C1 parameter to zero. Set the C2 parameter to 1.

3. Place the sensor at an accurately known and stable temperature, T_{a1}. Connect the sensor to the 3040 for normal Constant temperature operation. Allow the 3040 to stabilize at the known temperature, T_{a1} and read the displayed temperature, T_{d1}. Record these values.

4. Repeat Step 3 for another known temperature, T_{a2}, and the corresponding displayed temperature, T_{d2}. The two known temperatures should at the bounds of the intended operating range. For best results, make the range between T_{a1} and T_{a2} as narrow as possible.

5. Determine the new value of C1 and C2 from the following calculations.

$$C2 = (T_{a1} - T_{a2}) / (T_{d1} - T_{d2}), \text{ and}$$

$$C1 = T_{a1} - (T_{d1} * C2)$$

6. Enter the new C1 and C2 values.

3.4.5 RTD Sensors

The following equation is used in temperature to resistance conversions:

$R_T = R_0$ [1 + C1 x T - C2 x T^2 - C3 x (T-100) x T^3) for T < 0°C
$R_T = R_0$ [1 + C1 x T - C2 x T^2) for T >= 0°C

where: R_T is the resistance in Ω at temperature T.
T is the temperature in °C.

3.4.5.1 RTD Constants

The constants entered for an RTD depend on the type of curve it has. Table 4 shows three standard types.

Curve	**TCR (Ω/Ω/°C)**	**C1**	**C2**	**C3**	**R0**
Laboratory	.003926	3.9848×10^{-3}	-0.58700×10^{-6}	4.0000×10^{-12}	100.00
US	.003910	3.9692×10^{-3}	-0.58495×10^{-6}	-4.2325×10^{-12}	100.00
European	.003850	3.9080×10^{-3}	-0.58019×10^{-6}	-4.2735×10^{-12}	100.00

Table 4 - RTD Constants

The Ro constant also applies for RTD sensors. It is nominally 100.00 Ω, but can be varied from 95.00 Ω to 105.00 Ω.

C H A P T E R 4

4. Principles of Operation

4.1 Introduction

A functional block diagram of the 3040 is shown in Figure 14. In each of the following sections there are functional block diagrams for the various circuit boards of the 3040.

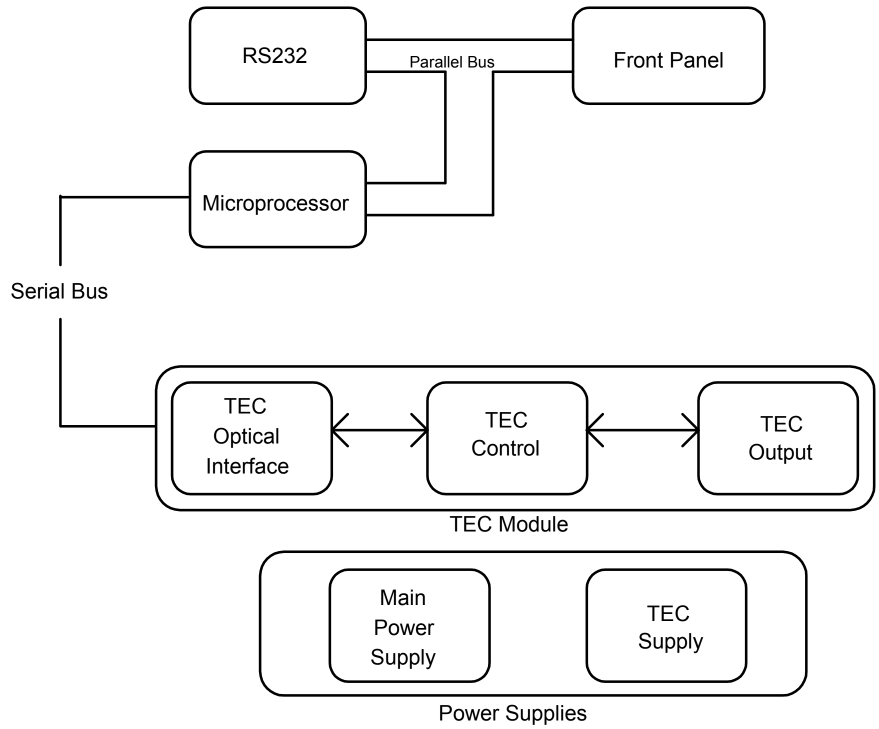

Figure 14 - 3040 Block Diagram

4.2 TEC Theory of Operation

Figure 15 shows the functionality of the TEC. The following sections detail the theory of operation for each of the blocks in Figure 15.

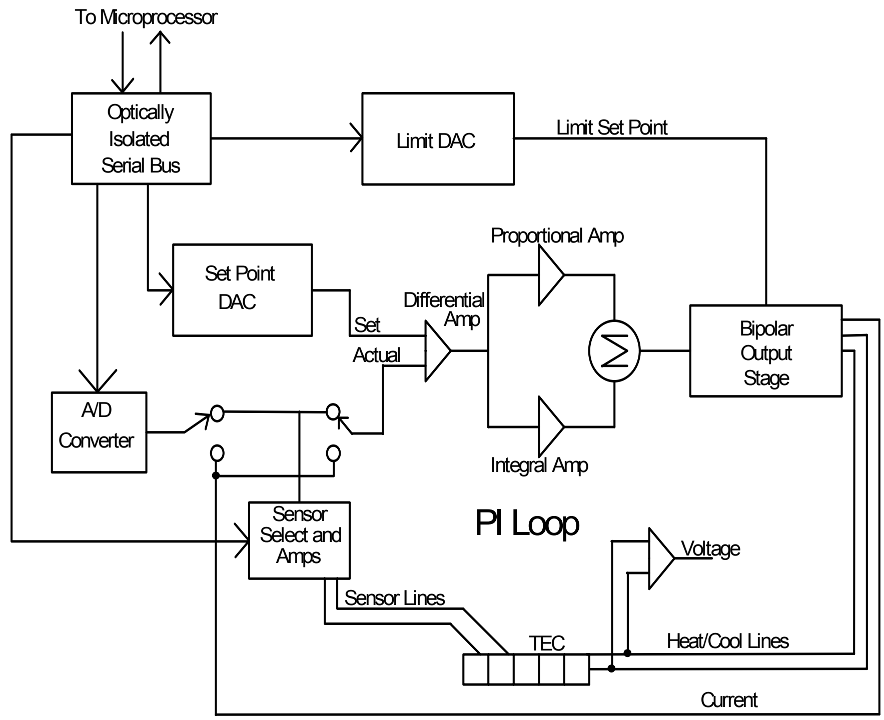

Figure 15 - TEC Board Diagram

4.2.1 TEC Interface

The TEC interface provides optically isolated serial communications between the TEC board and the microprocessor. Control signals are passed to the TEC board to set the TEC board status, current limit, and temperature set points. Instructions and data are sent over the serial interface to the optical barrier. Status and data are serially passed back to the microprocessor.

4.2.2 Limit DAC

The microprocessor loads the digitally stored current limit value into the current limit 12-bit DAC. The Limit DAC converts the digital limit signal from the microprocessor to a voltage which becomes the limit voltage for the Bipolar Output Stage. The current limit value is updated at power-up, at a "bin" recall, and whenever the LIM I_{TE} value is changed.

4.2.3 Set Point DAC

The microprocessor loads the digitally stored temperature or current set point value into the set point 16-bit DAC. The Set Point DAC converts a digital set point signal from the microprocessor to a voltage that becomes the set point input to the PI

control loop. The TEC set point value is updated during power-up, at a bin recall, and whenever a TEC set point value is changed.

4.2.4 A/D Converter

The 16-bit A/D converter measures the sensor voltage, TE current and TE voltage. The sensor measurement is used by the microprocessor in the calculation of temperature or thermistor resistance. The current measurement is used for the I_{TE} value and the voltage measurement is used for V_{TE}.

4.2.5 Sensor Select

Sensor selection is accomplished in the Sensor Select block of the TEC board. Precision 100µA and 10µA current sources may be selected for thermistor control. RTD, LM335 and AD590 IC temperature sensors may also be selected. The AD590 has a +5 VDC bias voltage, the LM335 has a 1 mA bias current, and the RTD has a precision 1 mA current source.

The output of the Sensor Select block of the TEC board is a voltage which is proportional to the actual temperature. This voltage is fed to the A/D converter which provides a digital measurement to the microprocessor, and to the PI control loop to close the feedback loop when temperature is being controlled.

4.2.6 Difference Amplifier

A differential amp provides a difference signal to the PI control. This signal is the difference between set temperature and actual temperature voltage.

4.2.7 Proportional Amplifier and Integrator

The proportional amplifier is part of a digitally controlled gain stage consisting of the analog switches and their associated resistors. The analog switches vary the ratio of resistance in the feedback circuit to change the gain.

The signal from the difference amplifier is sent to an integrator which reduces the difference between the set point temperature and the actual temperature to zero, regardless of the gain setting. An analog switch discharges the integrating capacitor whenever integration is not required to prevent unnecessary difference signal integration.

4.2.8 Bipolar Output Stage

The Bipolar Output Stage consists of circuits which limit the TEC output, sense the TEC output polarity, sense voltage and current limit conditions, as well as supply the bipolar TEC output. The following sections discuss these functions of the Bipolar Output Stage.

4.2.8.1 Current Limiting

The output of the proportional amplifier and integrator together form the control signal. Output current limiting is effected by bounding the control signal so that it is always less than the limit current. The limit current is set with the front panel controls or through the GPIB. The bipolar current limit levels are established by the output of the current Limit DAC.

4.2.8.2 Current Limit Condition Sensing

Comparators sense the output to determine when output current limiting is occurring. When this condition occurs, the I Limit signal is sent to the microprocessor.

4.2.8.3 Voltage Controlled Current Source

The bounded output control signal is applied to an amplifier. This amplifier and the current sensing amplifier form the output voltage controlled current source. The output of this stage directly drives the externally connected TE cooler.

4.2.8.4 Voltage Limit Condition Sensing

Comparators sense the output to determine when the TEC output compliance voltage limiting is occurring. This condition occurs whenever the TEC output is open or connected to a high resistance. If this condition occurs, the V Limit error signal is passed to the microprocessor.

4.2.9 TEC Control Modes

The 3040 provides three control modes for operation, constant T (temperature), constant R (resistance, voltage, or current), and constant I_{TE} (current) modes. Each of these modes is discussed in the following sections.

4.2.9.1 T Mode

In constant T mode the TEC is driven to the set point temperature. This temperature is monitored by the sensor in the TEC. In the case of a thermistor sensor, the thermistor's resistance is used to determine TEC's temperature by using the Steinhart-Hart conversion equation. The resistance is determined by measuring the voltage across the thermistor (with a known current of 10µA or 100µA). The I_{TE} current is also measured and saved. The TEC's output current is sensed across a resistor and the voltage is converted to an I_{TE} current value. V_{TE} is also measured.

When an LM335 sensor is used, a two-point conversion equation is used to determine the temperature. Its voltage is measured as well as the I_{TE} current and V_{TE} voltage.

When an AD590 sensor is used, another two-point conversion equation is used to determine the temperature. Its reference current is sensed across a resister, and this voltage is measured. The I_{TE} current and V_{TE} voltage are also measured.

4.2.9.2 R Mode

In constant R mode, the TEC is driven to the set point resistance, voltage, or current. This resistance, voltage, or current is measured. The I_{TE} current and V_{TE} voltage are also measured.

4.2.9.3 I_{TE} Mode

In constant I_{TE} mode, the TEC is driven with a constant current, at the I_{TE} set point value. The I_{TE} current is sensed across a resistor and the voltage is converted to I_{TE} current.

4.3 Microprocessor Board

The Microprocessor Board contains the microprocessor, memory, the serial interface to the TEC, front panel interface, and circuitry which saves the state of the 3040 at power down. The block diagram of the Microprocessor Board is shown in Figure 16.

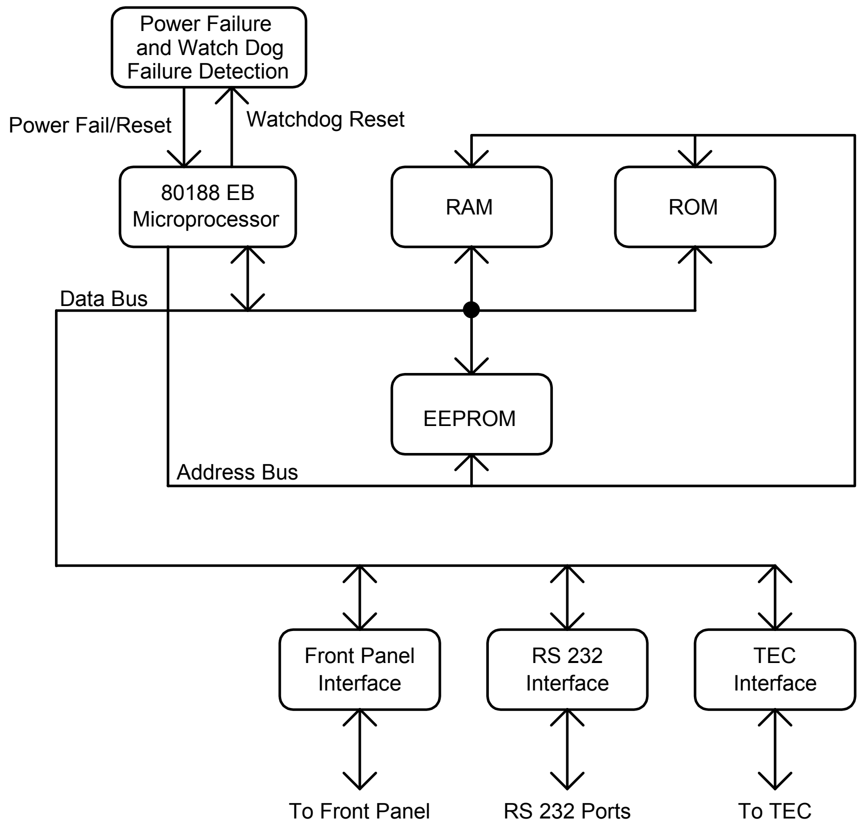

Figure 16 - Microprocessor Board Block Diagram

4.3.1 Microprocessor

The 3040 uses a CMOS 80188EB microprocessor to control its internal operations. The 3040 provides a fail-safe timer which generates a reset in the event of a malfunction. A 1 Hz watch-dog pulse is normally present. If for any reason this clock pulse fails to appear it will reset the 3040.

4.3.2 Memory

The 3040 uses three types of memory. RAM memory is retained only while power is applied to the unit. ROM memory contains the firmware. The third type of memory is electrically erasable programmable memory: EEPROM.

EEPROM stores calibration constants and other data that must be retained even when power is removed from the unit. The EEPROM does not require battery backup. Examples of data stored in this memory include the TEC and laser parameters and calibration constants.

4.3.3 Serial Interface

The 80188 communicates with the TEC via a serial interface bus. Parallel data from the microprocessor is converted to bi-directional serial data. Also provided is the RS-232 communication.

4.3.4 Front Panel Interface

Provides parallel communication with the front panel.

4.3.5 GPIB Interface

Provides parallel communication with the GPIB port.

4.3.6 RS-232 Serial Interface

Provides communication with the RS-232C serial port.

4.4 Power Supplies

AC power is supplied through the rear panel input power connector which provides in-line transient protection and RF filtering. The input power connector contains the fuses and the switch to select series or parallel connection of the transformer primaries for operation at 100 VAC, 120 VAC, 220 VAC, or 240 VAC.

4.4.1 Power Supply

The linear supply provides analog and digital circuit power as well as TEC drive current.

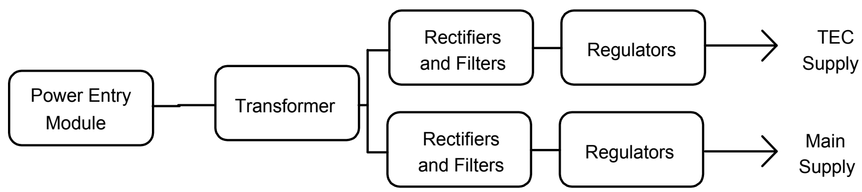

Figure 17 - Power Supply Block Diagram

4.4.2 Main Supply

This supply provides digital circuit power for all functions except the TEC. It also provides fan power.

5. Tips and Techniques

5.1 Introduction

This chapter is intended to further explain specific operational details of the Model 3040, as well as provide application examples.

5.2 TEC Limits

The TEC maintains several limits that control the operation of the unit. There are a total of five limits: I_{TE} current limit, high temperature limit, low temperature limit, high resistance/LM335 voltage/AD590 current limit (R/v/i), and low resistance/LM335 voltage/AD590 current limit.

Through the rest of this section, the resistance/LM335 voltage/AD590 current mode is collectively referred to as R mode, while the resistance/LM335 voltage/AD590 current limits are collectively referred to as the R limits.

I_{TE} Limit

The I_{TE} limit controls the maximum amount of current the TEC will drive while in any mode. The limit applies to both the positive and negative current drive. In temperature and R modes, it limits the amount of current that can be driven when controlling to the set point. In I_{TE} mode, it limits the set point to less than or equal to the limit. Unlike the temperature and R limits, the I_{TE} limit is controlled by hardware for immediate response.

Temperature Limits

The high and low temperature limits define the operating temperature range of the TEC, and are monitored while in any mode. The only case where temperature is not monitored is when a sensor type of “None” is selected. Temperature checking for high and low limits is done once per second, and when the system detects that a high or low temperature limit has been exceeded, it will shutdown the TEC output. Note, however, that clearing the appropriate bits in the TEC OUTOFF register through the GPIB or RS-232 interface can disable this automatic shutdown. The factory default is to shutdown the TEC on a temperature limit.

Resistance, LM335 Voltage, and AD590 Current Limits (R Limits)

In addition to temperature and current limits, the TEC also supports limits based on sensor values. R limits are monitored only when in the R mode, although as mentioned above, the T limits are monitored in any mode. R checking for high and low limits is done once per second. However, unlike a temperature limit, and when the system detects that a high or low R limit has been exceeded, by default it will *not* shutdown the TEC output. Note, however, that setting the appropriate bit in the TEC

OUTOFF register through the GPIB or RS-232 interface can enable this automatic shutdown. The factory default is to not shutdown the TEC on a R limit.

How a Sensor Change Affects R Values

Each time the sensor is changed, the old R limits and set point no longer apply to the new sensor. The 3040 calculates the new values for the upper and lower R limits and set point based on the temperature limits and set point. After the R values are initialized, changing the temperature limits or set point will not affect the corresponding R values until the next time the sensor type is changed.

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6. Maintenance

6.1 Introduction

There are no user serviceable parts inside the unit, do not attempt to remove the cover.

6.2 Fuse Replacement

The fuses are accessible on the back panel of the 3040. Before replacing a fuse, turn power off and disconnect the line cord. Use only the fuses indicated below.

Fuse Replacement	Line Voltage
1 Amp, 3 AG, Slo-Blo, 250V	100/120 VAC
1 Amp, 3 AG, Slo-Blo, 250V	220/240 VAC

6.3 Cleaning

Use mild soap solution on a damp but not wet cloth. Disconnect AC power before cleaning.

C H A P T E R 7

7. Calibration

7.1 Calibration Overview

All calibrations are done with the case closed. The instrument is calibrated by changing the internally stored digital calibration constants. All calibrations may be performed locally or remotely.

7.1.1 Environmental Conditions

Calibrate this instrument under laboratory conditions. We recommend calibration at 25°C ± 1.0°C. When necessary, however, the 3040 may be calibrated at its intended use temperature if this is within the specified operating temperature range of 0°C to 40°C.

7.1.2 Warm-Up

The 3040 should be allowed to warm up for at least 1 hour before calibration.

7.2 TEC Calibration

This chapter describes how to calibrate the TEC.

7.2.1 Recommended Equipment

Recommended test equipment for calibrating the TEC is listed in Table 5. Equipment other than that shown in the table may be used if the specifications meet or exceed those listed.

Description	Mfg./Model	Specification
DMM	HP34401A	DC Amps @ 1.0 A): ±1% Resistance (@ 10 ohms): 0.02%
Resistors	Metal Film	20 kΩ for 100µA calibration 200 kΩ for 10µA calibration 3 kΩ for LM335 sensor calibration 16 kΩ for AD590 sensor calibration 100 Ω for RTD sensor calibration
Resistor	High Power	1 Ω, 50 W, for current calibration
Connector	D-sub	15-pin male

Table 5 - Recommended Test Equipment

7.2.2 Local Operation Thermistor Calibration

a. Measure and record the exact resistance of your metal film resistor. Use nominal values of 20 kΩ for the 100µA setting, and 200 kΩ for the 10µA setting. With the TEC output off, connect the metal film resistor to the sensor input of the TEC.

b. Select the thermistor as sensor type by first pressing the **MENU** button, then the down arrow to enter the TEC Setup menu, until the **Sens** element is selected. Press the left or right right arrow to select either the 100µA or 10µA thermistor. Press the **MENU** button to return to the main screen.

c. Start the calibration procedure by first pressing the **MENU** button, then right arrow until the **System** menu is reached, press the down arrow until the **Calibrate Execute** function is selected, then press the right arrow to enter the **Calibration** menu. Next, press the down arrow until the **Cal Sensor** function is selected, then the right arrow key to execute the sensor calibration function.

d. Follow the on-screen instructions to complete the calibration. The calibration can be terminated without affecting the stored constants if the **MENU** key is pressed at any point prior to completing the calibration.

7.2.3 Remote Operation Thermistor Calibration

a. Measure and record the exact resistance of your metal film resistor. Use nominal values of 20 kΩ for the 100µA setting, and 200 kΩ for the 10µA setting. With the TEC output off, connect the metal film resistor to the sensor input of the TEC.

b. Send **TEC:SENS 1** 100µA thermistor, or **TEC:SENS 2** for the 10µA thermistor, followed by the **TEC:CAL:SEN** to enter sensor calibration mode.

   The 3040 will be ready to receive the resistance when, after a **TEC:CAL:SEN?** query is sent, a “1” is returned.

c. Input the actual resistance of the metal film resistor, in kΩ, (as an <nrf value>) via the **TEC:R <nrf value>** command.

   If, at any time prior to **TEC:R,** a command other than **TEC:R** or **TEC:R?** is sent to the 3040, the 3040 will cancel the calibration mode and then process the command(s).

Once the **TEC:R** value is sent, the **OPC?** query may be used to determine when the calibration is completed. The operation complete flag (bit 0 of the Standard Event Status Register) may be used to trigger an interrupt. This type of interrupt is enabled by setting bit 0 of the Service Request Enable register and using the ***OPC** command.

7.2.4 Local Operation AD590 Sensor Calibration

a. With the TEC output off, connect a precision 16 kΩ metal film resistor and a precision ammeter in series at the sensor input of the TEC.

b. Select the AD590 as sensor type by by first pressing the **MENU** button, then the down arrow to enter the TEC Setup menu, until the **Sens** element is selected. Press the left or right right arrow to select the AD590. Press the **MENU** button to return to the main screen.

c. Start the calibration procedure by first pressing the **MENU** button, then right arrow until the **System** menu is reached, press the down arrow until the **Calibrate Execute** function is selected, then press the right arrow to enter the **Calibration** menu. Next, press the down arrow until the **Cal Sensor** function is selected, then the right arrow key to execute the sensor calibration function.

d. Follow the on-screen instructions to complete the calibration. The calibration can be terminated without affecting the stored constants if the **MENU** key is pressed at any point prior to completing the calibration.

7.2.5 Remote Operation AD590 Sensor Calibration

a. With the TEC output off, connect a precision 16 kΩ metal film resistor and a precision ammeter in series at the sensor input of the TEC.

b. Enter the **TEC:SEN 4** and **TEC:CAL:SEN** to select the AD590 sensor and enter sensor calibration mode.

   The 3040 will be ready to receive the current value when, after a **TEC:CAL:SEN?** query is sent, the response from the 3040 is “1”.

c. Input the actual current measured, in µA, by the external ammeter (as an <nrf value>) via the **TEC:R <nrf value>** command.

   If, at any time prior to **TEC:R,** a command other than **TEC:R** or **TEC:R?** is sent to the 3040, the 3040 will cancel the calibration mode and then process the command(s).

Once the **TEC:R** value is sent, the **OPC?** query may be used to determine when the calibration is completed. The operation complete flag (bit 0 of the Standard Event Status Register) may be used to trigger an interrupt. This type of interrupt is enabled by setting bit 0 of the Service Request Enable register and using the ***OPC** command.

7.2.6 Local Operation LM335 Sensor Calibration

a. Use a 3 kΩ metal film resistor. With the TEC output off, connect the metal film resistor in parallel with a precision voltmeter to the sensor input of the TEC.

b. Select the LM335 as sensor type by by first pressing the **MENU** button, then the down arrow to enter the TEC Setup menu, until the **Sens** element is selected. Press the left or right right arrow to select the LM335. Press the **MENU** button to return to the main screen.

c. Start the calibration procedure by first pressing the **MENU** button, then right arrow until the **System** menu is reached, press the down arrow until the **Calibrate Execute** function is selected, then press the right arrow to enter the **Calibration** menu. Next, press the down arrow until the **Cal Sensor** function is selected, then the right arrow key to execute the sensor calibration function.

d. Follow the on-screen instructions to complete the calibration. The calibration can be terminated without affecting the stored constants if the **MENU** key is pressed at any point prior to completing the calibration.

7.2.7 Remote Operation LM335 Sensor Calibration

a. With the TEC output off, connect a 3 kΩ metal film resistor and a precision voltmeter in parallel at the sensor input of the TEC.

b. Enter the **TEC:SEN 3** and **TEC:CAL:SEN** to select the LM335 sensor and enter sensor calibration mode.

   The 3040 will be ready to receive the voltage value when, after a **TEC:CAL:SEN?** query is sent, the response from the 3040 is "1".

c. Input the actual voltage, in mV, measured by the external voltmeter (as an <nrf value>) via the **TEC:R <nrf value>** command.

   If, at any time prior to **TEC:R,** a command other than **TEC:R** or **TEC:R?** is sent to the 3040, the 3040 will cancel the calibration mode

and then process the command(s).

Once the **TEC:R** value is sent, the **OPC?** query may be used to determine when the calibration is completed. The operation complete flag (bit 0 of the Standard Event Status Register) may be used to trigger an interrupt. This type of interrupt is enabled by setting bit 0 of the Service Request Enable register and using the ***OPC** command.

7.2.8 Local Operation RTD Calibration

a. Measure and record the exact resistance of your 100 Ω metal film resistor. With the TEC output off, connect the metal film resistor to the sensor input of the TEC.

b. Select the RTD as sensor type by by first pressing the **MENU** button, then the down arrow to enter the TEC Setup menu, until the **Sens** element is selected. Press the left or right right arrow to select the RTD. Press the **MENU** button to return to the main screen.

c. Start the calibration procedure by first pressing the **MENU** button, then right arrow until the **System** menu is reached, press the down arrow until the **Calibrate Execute** function is selected, then press the right arrow to enter the **Calibration** menu. Next, press the down arrow until the **Cal Sensor** function is selected, then the right arrow key to execute the sensor calibration function.

d. Follow the on-screen instructions to complete the calibration. The calibration can be terminated without affecting the stored constants if the **MENU** key is pressed at any point prior to completing the calibration.

7.2.9 Remote Operation RTD Calibration

a. Measure and record the exact resistance of your 100 Ω metal film resistor. With the TEC output off, connect the metal film resistor to the sensor input of the TEC.

b. Send **TEC:SENS 5** to select the RTD sensor, followed by the **TEC:CAL:SEN** to enter sensor calibration mode.

   The 3040 will be ready to receive the resistance when, after a **TEC:CAL:SEN?** query is sent, a “1” is returned.

c. Input the actual resistance, in ohms, of the metal film resistor (as an <nrf value>) via the **TEC:R <nrf value>** command.

If, at any time prior to **TEC:R,** a command other than **TEC:R** or **TEC:R?** is sent to the 3040, the 3040 will cancel the calibration mode and then process the command(s).

Once the **TEC:R** value is sent, the **OPC?** query may be used to determine when the calibration is completed. The operation complete flag (bit 0 of the Standard Event Status Register) may be used to trigger an interrupt. This type of interrupt is enabled by setting bit 0 of the Service Request Enable register and using the ***OPC** command.

7.2.10 RTD Lead Resistance Calibration (Offset Null)

Because the RTD sensor reflects changes in temperature with small changes in resistance, even a small lead resistance (resistance caused by the wire running between the TEC and the RTD sensor) can cause significant temperature offset. The lead resistance may be taken out of the RTD reading as follows:

a. With the TEC output off, short the sensor wires as close to the RTD sensor as possible.

b. Start the calibration procedure by first pressing the **MENU** button, then right arrow until the **System** menu is reached, press the down arrow until the **Calibrate Execute** function is selected, then press the right arrow to enter the **Calibration** menu. Next, press the down arrow until the **Set RTD Null** function is selected, then the right arrow key to execute the RTD Null function.

c. Follow the on-screen instructions to complete the calibration. The calibration can be terminated without affecting the stored constants if the **MENU** key is pressed at any point prior to completing the calibration.

7.2.11 Local Operation ITE Current Calibration

The following procedure is for calibrating the ITE constant current source for both polarities of current.

a. With the output off, connect a 1 Ω, 50 W resistor with a calibrated ammeter in series across the TEC output terminals. If an ammeter with the appropriate current ratings is unavailable, connect a 1 Ω, 50 W resistor across the TEC output terminals and use a calibrated DMM to measure the voltage across the resistor. Calculate the current in the following steps by using Ohm's Law:

$I = V / R$

where V is the measured voltage across the resistor, and R is the measured load resistance.

b. Start the calibration procedure by first pressing the **MENU** button, then right arrow until the **System** menu is reached, press the down arrow until the **Calibrate Execute** function is selected, then press the right arrow to enter the **Calibration** menu. Next, press the down arrow until the **Cal Ite** function is selected, then the right arrow key to execute the Ite calibration function.

c. Follow the on-screen instructions to complete the calibration. The calibration can be terminated without affecting the stored constants if the **MENU** key is pressed at any point prior to completing the calibration.

7.2.12 Remote Operation ITE Current Calibration

a. With the output off, connect a 1 Ω, 50 W resistor with a calibrated ammeter in series across the TEC output terminals. If an ammeter with the appropriate current ratings is unavailable, connect a 1 Ω, 50 W resistor across the TEC output terminals and use a calibrated DMM to measure the voltage across the resistor. Calculate the current in the following steps by using Ohm's Law:

$$I = V / R$$

where V is the measured voltage across the resistor, and R is the measured load resistance.

b. Send **TEC:CAL:ITE** to enter ITE calibration mode.

The TEC will be placed in ITE mode, limit set to 50% of full scale plus 100 mA, and the ITE set point set to 50% of full scale.

The 3040 will be ready to receive the first measured current value when, after a **TEC:CAL:ITE?** query is sent, a “1” is returned.

c. Input the actual current (as an <nrf value>) via the **TEC:ITE <nrf value>** command. The 3040 will then drive the current to 25% of the initial set point.

The 3040 will be ready to receive the second measured current value when, after a **TEC:CAL:ITE?** query is sent, a “1” is returned.

d. Input the second actual current (as an <nrf value>) via the **TEC:ITE <nrf value>** command. The 3040 will then drive the current to the negative current value of the initial set point.

   The 3040 will be ready to receive the third measured current value when, after a **TEC:CAL:ITE?** query is sent, a "1" is returned.

e. Input the third actual current (as an <nrf value>) via the **TEC:ITE <nrf value>** command. The 3040 will then drive the current to 25% of the negative current value of the initial set point.

   The 3040 will be ready to receive the fourth measured current value when, after a **TEC:CAL:ITE?** query is sent, a "1" is returned.

f. Input the fourth actual current (as an <nrf value>) via the **TEC:ITE <nrf value>** command.

   If, at any time prior to the last **TEC:ITE,** a command other than **TEC:ITE** or **TEC:ITE?** is sent to the 3040, the 3040 will cancel the calibration mode and then process the command(s).

   Once the **TEC:ITE** value is sent, the **OPC?** query may be used to determine when the calibration is completed. The operation complete flag (bit 0 of the Standard Event Status Register) may be used to trigger an interrupt. This type of interrupt is enabled by setting bit 0 of the Service Request Enable register and using the ***OPC** command.

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8. Factory Service

8.1 Introduction

This section contains information regarding obtaining factory service for the Model 3040. The user should not attempt any maintenance or service of this instrument and/or accessories beyond the procedures given in chapters 6 and 7. Any problems which cannot be resolved using the guidelines listed in chapters 6 and 7 should be referred to Newport Corporation factory service personnel. Contact Newport Corporation or your Newport representative for assistance.

8.2 Obtaining Service

To obtain information concerning factory service, contact Newport Corporation or your Newport representative. Please have the following information available:

1. Instrument model number (On front panel)

2. Instrument serial number (On rear panel)

3. Description of the problem.

If the instrument is to be returned to Newport Corporation, you will be given a Return Materials Authorization (RMA) number, which you should reference in your shipping documents as well as clearly marked on the outside of the shipping container.

Please fill out the service form, located on the following page, and have the information ready when contacting Newport Corporation. Return the completed service form with the instrument.

Service Form

Newport Corporation
USA Office: 949/863-3144
FAX: 949/253-1800

Name ______________________________ RETURN AUTHORIZATION # _________

Company ____________________________ (Please obtain prior to return of item)

Address ____________________________

Country ____________________________ Date ______________________________

P.O. Number _________________________ Phone Number _____________________

Item(s) being returned:
Model # ____________________________ Serial # __________________________

Description ____

Reason for return of goods (please list any specific problems) ______________________

____

List all control settings and describe problem _________________________________

____

____

____ (Attach additional sheets as necessary)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Describe signal source.

(continued on next page)

Where is measurement being performed?
(factory, controlled laboratory, out-of-doors, etc.) ____

What power line voltage is used? ________________ Variation? ___________________________

Frequency? __________________________ Ambient Temperature? ________________________

Any additional information. (If special modifications have been made by the user, please describe below)

____

____

____

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9. Error Messages

9.1 Introduction

Error messages may appear on the display when error conditions occur in the respective functions of the 3040. For example, a current limit error in the TEC will be displayed.

In remote operation, the current error list can be read by issuing the "ERR?" query. When this is done, a string will be returned containing all of the error messages which are currently in the error message queue.

The errors codes are numerically divided into areas of operation as shown below.

Error Code Range	Area of Operation
E-001 to E-099	Internal Program Errors
E-100 to E-199	Parser Errors
E-200 to E-299	Execution Control Errors
E-300 to E-399	GPIB/RS232 Errors
E-400 to E-499	TEC Control Errors

Table 6 contains all of the error messages which may be generated by the 3040. Not all of these messages may be displayed. Some refer to GPIB activities only, for example.

Table 6 - Error Codes

Error Code	**Explanation**
E-001	Memory allocation failure.
E-002	Floating point error
E-104	Numeric type not defined.
E-106	Digit expected.
E-107	Digit not expected.
E-115	Identifier not valid.
E-116	Parser syntax error, character was not expected.
E-126	Too few or too many program data elements.
E-201	Value out of range.
E-214	Length exceeds maximum.
E-217	Attempted to recall a bin from a unsaved position.
E-218	Additional link could not be added to the link table because the link table is already full.
E-301	A response message was ready, but controller failed to

Error Code	Explanation
	read it.
E-302	3040 is talker, but controller didn't read entire message.
E-303	Input buffer overflow
E-304	Output buffer overflow
E-305	Parser buffer overflow
E-402	Sensor open disabled output.
E-403	TEC open disabled output.
E-404	TEC Current limit disabled output.
E-405	TEC Voltage limit disabled output.
E-406	TEC resistance/reference limit disabled output
E-407	TEC high temperature limit disabled output.
E-409	Sensor change disabled output.
E-410	TEC out of tolerance disabled output.
E-415	Sensor short disabled output.
E-416	Incorrect Configuration for Calibration Sequence to start.
E-417	TEC output must be on to begin calibration.
E-418	TEC C1, C2, or C3 constants are bad, all set to default values.
E-419	Mode change disabled output.
E-431	TEC link condition forced output on
E-432	TEC link condition forced output off
E-900	Calculation Error shutdown output
E-901	System over temperature shutdown all outputs
E-903	Loading of a saved bin shutdown TEC output

C H A P T E R 1 0

10. Specifications

10.1 Temperature Controller (TEC) Specifications

Specifications	**3040**
TEC Output	
Maximum Current	4 Amps
Compliance Voltage	> 8 Volts
Typical Power	32 Watts
TE Current Resolution (mA)	0.122
TE Current Accuracy (mA)	± (0.02 % set point + 4 mA)
Current Limit	
Range	0 to 4 Amps
Accuracy	± 20 mA
Ripple/Noise (rms)	< 1 mA
Short Term Stability (1 hour)	< 0.0005 °C
Long Term Stability (24 hour)	< 0.001 °C
Temperature Coefficient (°C/°C)	< 0.05
Display	
Range	
Temperature	-100.00°C to +240.00°C
Resistance (10 µA)	0.01 kΩ to 495.000 kΩ
Resistance (100 µA)	0.001 kΩ to 49.500 kΩ
Resistance (RTD)	20 Ω to 192 Ω
TE Current	± 4.00 Amps
TE Voltage	±0.0 to ±8.0 Volts
AD590 Current	248.15 µA to 378.15 µA
LM335 Voltage	2331 mV to 3731 mV
Resolution	
Temperature	0.01°C
Resistance (10 µA)	10 Ω
Resistance (100 µA)	1 Ω
Resistance (RTD)	0.01 Ω
TE Voltage	0.1 V
TE Current	1 mA
AD590 Current	0.01 µA
LM335 Voltage	0.1 mV

Accuracy[1]

Temperature	± 0.1 °C
Resistance (10 µA)	± (0.04% + 16 Ω)
Resistance (100 µA)	± (0.05% + 8 Ω)
Resistance (RTD)	± (0.03% + 50 mΩ)
TE Voltage	± (0.005% + 100 mV)
TE Current	± (0.09% + 2 mA)
AD590 Current	± (0.005% + 0.5 uA)
LM335 Voltage	± (0.09% + 1 m V)

Temperature Sensors	**Thermistor**	**AD590**	**LM335**	**RTD (100Ω)**
Temp Control Resolution	0.01 °C	0.01 °C	0.01 °C	0.01 °C
Temp Control Accuracy	± 0.05 °C	± 0.05 °C	± 0.05 °C	± 0.05 °C[2]
Sensor Bias Current or Voltage	10 µA/100 µA	+5 Volts	1 mA	1 mA

Temperature Calibration

Thermistor	$1/T = (C1 \times 10^{-3}) + (C2 \times 10^{-4})(\ln R) + (C3 \times 10^{-7})(\ln R)^3$
AD590	$T = C1 + C2 \times (I_{AD590}/1\mu A/K - 273.15)$
LM335	$T = C1 + C2 \times (V_{LM335}/10mV/K - 273.15)$
Pt RTD	$Rt = Ro [1 + C1T + C2T^2]$; $T \geq 0$ °C,
	$Rt = Ro [1 + C1T + C2T^2 + C3T^3(T - 100)]$; $T < 0$ °C
	Ro = resistance at 0 °C where, Ro=100Ω for a 100Ω Pt RTD.

10.2 General Specifications

Display	
Type	LCD character display, 2 lines by 20 characters
Back Lighting	Green LED
Controls	Brightness and Contrast (contrast optimizes viewing angle)
Channel Active	Green TEC LED indicates that TEC output is on.
Power Requirements	90-132, 198-250 volts, 1 Amp Max. (user selectable), 50 to 60 Hz
Size (H x W x D)	86 mm x 215 mm x 280 mm (3.5 " x 8.5" x 12")
Mainframe Weight	3.6 kg (8.0 lbs.)
Operating Temperature	0 to 40°C, < 70% relative humidity non-condensing
Storage Temperature	-20°C to 60°C, < 90% relative humidity non-condensing
Isolation	TEC electrically isolated with respect to earth ground.Output

Connectors:	
Temperature Controller (TEC)	15-pin female D-sub
Chassis Ground	4 mm Banana Jack
GPIB Connector	24 pin IEEE-488
RS232 Connector	9-pin male D-sub

In accordance with ongoing efforts to continuously improve our products, Newport Corporation reserves the right to modify product specifications without notice and without liability for such changes.

[1] ± (% of reading + fixed error)
[2] RTD Accuracy is with lead wire resistance calibrated out.