TEC 2000

Thermoelectric

Temperature Controller

Instruction Manual

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Note to First Time Users

1. Understanding PID Feedback Control

The TEC2000 uses full Proportional, Integral, and Derivative (PID) feedback control for complete flexibility in optimizing the temperature controller to various thermal loads. Temperature control systems have response times that are dependent on many factors including the thermal properties of the materials used as well as the physical layout of the system. All of which can effect the thermal response time. If the response time is too slow, the system behavior will be sluggish and tend to be unstable or at the very least, experience significant overshoots in the settling of the temperature.

To compensate for this, the TEC2000 has three independent gain controls (PID) which allow the controller to be optimized to many different thermal loads.

Proportional Control - provides a relatively fast response to a change in temperature set points or thermal loads. One drawback is that a residual DC error always exists in proportional feedback systems, which results in an offset error between the desired operating temperature and the actual temperature of the controlled load.

Integral Control - removes the DC error introduced by proportional control by integrating the DC error and making corrections to the TEC output

Derivative Control - responds to a rate of change in the thermal load or temperature set point and thereby speeds up the response of the system to a changing load or setpoint.

By properly setting all three-control gains, the TEC2000 can provide optimal control for many different setups.

2. Response time of Thermistor vs. IC Sensor

Temperature sensors such as the AD590 and LM335 have slower response times than most typical thermistors. Therefore, when it is critical to minimize settling time use a thermistor if possible.

3. Increasing the TEC2000 loop stability for large thermal loads

In some cases, the response time of the system may be too sluggish for even the TEC2000 to control without significant overshoots in the temperature settling time. There are two ways to improve the stability for large thermal loads:

1. Disable the integral gain control by installing a jumper across JP1 (see Section 3.3.2). This may cause a offset between the set point temperature and the actual temperature but will yield the best dynamic performance.

2. Increase the time constant of the integral control circuit by adding addition capacitance across pins 8 and 9 of IC2 on the main circuit board (IC2 is part no. OP400 located near JP1). The capacitor must be a bipolar type and soldered directly to the IC pins. Its value is best determined empirically starting with values around 1μF and higher.

   Caution: This should only be done by qualified personnel.

1. General information

This manual contains the operating instructions for the Thorlabs TEC 2000 temperature controller. In the first chapter you will find a general description of the TEC2000, the technical specifications, a list of the available accessories, safety instructions and warranty information. Chapter 2 contains detailed operating instructions for the TEC 2000. Chapter 3 offers service information about the TEC 2000.

We aim to develop and deliver optimally suited control and measurement equipment for your application. To reach this goal, we need your suggestions on how our products can be further improved. Please let us know your proposals and criticisms. Our distributors and we are at your disposal at any time.

Thorlabs, Inc.

1.1 General description

The Thorlabs TEC2000. is an extremely precise temperature controller for laser diodes and detectors. Using the TEC2000 with the Thorlabs LDC500 Laser Current Source and Thorlabs temperature controlled laser heads, the laser wavelength and power can be precisely controlled.

The TEC2000 is well suited for:

- **wavelength stabilization of laser diodes**
- **noise reduction of detectors**
- **tuning the wavelength by regulating the temperature**
- **modulation of wavelength by modulating the temperature**

The well arranged front panel makes the unit easy to use. The operating parameters are indicated by an illuminated $4^{1}/_{2}$-digit LCD display. Measurement values are selected via press buttons.

The proportional gain (P), the integral gains (I), and the differential gain (D) of the PID temperature control loop can be set independently with a high degree of repeatability.

Different temperature sensors can be used with the TEC2000 (thermistor, AD590, AD592, LM335). With a thermistor, the temperature display is shown as a resistance value in kΩ. If the TEC 2000 is operating with a temperature IC (AD590/592 or LM335), the temperature is shown in °C.

To protect the connected TEC element against damage, the unit provides the following protection circuits:

- **Adjustable TEC current limit**
- **Separate enable switch for the TEC current**
- **Monitoring LED for TEC ON mode**
- **Automatic switch off of the TEC current if a temperature sensor error occurs**
- **Automatic switch off if the controller overheats**

Features:

- An independent current limit for the TEC element can be set with a 20-turn potentiometer to operate the TEC element.
- When switched on, the unit automatically is in TEC DISABLED mode, with the TEC current disabled.
- The output for the TEC current can be switched on or off via an enable button on the front panel.
- A DB9 male connector on the rear of the unit connects the temperature sensor and the TEC element.

- At the output jack, a control signal is available to drive an external LED to indicate TEC ON mode when the TEC current loop is activated.

- The set value of the temperature can be changed via an adjustment knob on the front panel or via an analog input on the rear panel.

- An analog voltage proportional to the actual value of the temperature is available on the rear panel for monitoring purposes.

- The unit has been designed for safe operation with environmental temperatures of more than 40 °C, provided that a free circulation of air through the ventilation louvers on the rear and on both side panels is guaranteed.

- In case of overheating caused by too high environmental temperatures or closed ventilation louvers, the unit automatically switches off the output to avoid damages.

- If the TEC circuit is interrupted or a break occurs in the interface cable the TEC current output is disabled and the “OPEN CKT” status LED will illuminate.

- The LED "OTP" (over-temperature-protection) indicates the controller is in an over-temperature mode and the output is disabled.

- After cooling down about 10 °C, the LED "OTP" turns off and the output current can be switched on again by pressing the "ENABLE" button.

- If an error occurs (OTP or OPEN), the corresponding LED lights up and a beeper sounds a short warning signal.

- The installed line filter and the transformer shielding provide for low ripple at the outputs.

- Thorlabs has laser mounts with TEC and temperature sensors built in for 5.6mm, 9mm, and TO-3 style laser packages.

1.2 Technical specifications

TEC output	
TEC current range	-2 A…+2 A
Compliance voltage	>6 V
Maximum output power	12 W
Resolution TEC current	1mA
Noise and ripple	<1 mA
Temperature sensors	
Thermistor (20kΩ/200 kΩ range)	
Control range	10Ω..20kΩ/200 kΩ
Resolution	1Ω/10 Ω
Setting accuracy	±0.2%
Temperature stability	≤2 Ω/20 Ω
IC-sensors (AD590/592, LM335)	
Control range	-40 °C…+150 °C
Resolution	0.01 °C
Setting accuracy	±0.1 °C
Temperature stability	≤1 mK
TEC current limit	
Setting range	0…≥2 A
Resolution	1mA
Setting accuracy	±0.02 A
Temperature control input	
Input resistance	10 kΩ
Control voltage	0…10 V
Input coefficient (AD590/592, LM335)	20 °C/V
Input coefficient (20kΩ/200 kΩ range)	2 kΩ/V, 20 kΩ/V
Control output	
Load resistance	≥1 kΩ
Output coefficient (AD590/592/ LM335)	50 mV/°C
Output coefficient (20 kΩ/200 kΩ range)	0.5V/kΩ,50mV/kΩ
Connectors	
Sensor, TEC, TEC ON signal	DB9 Male
Control input	BNC
Control output	BNC
Chassis ground	4mm banana
General data	
Power voltage ±10%	100/115/230V
Power frequency	50…60 Hz
Operating temperature	0…+40 °C
Storage temperature	-40 °C…+70 °C
Warm-up time for rated accuracy	10 min
Weight	6.6 lb.
Dimensions (W x H x D)	5.8 x 2.8 x 12.5”

1.3 Options and accessories

A TEC2000 Interface Cable, a grounding contact type line cord and this manual are delivered with the TEC 2000. The chart below shows the ordering code of the unit and the accessories available for delivery for the time being.

Ordering-code	**Short description**
TEC 2000	Thermoelectric Temperature Controller, TEC current 0 ... ± 2 A, supports thermistors and temperature-ICs (AD590/592 and LM335) as temperature sensor, illuminated 4½-digit LCD-display
	Accessories:
	Laser Diode heads for laser diodes:
TCLDM9	TEC Cooled Laser Diode mounts for 5.6mm and 9mm laser packages with RF modulation input. Built in optics mounting thread and support for Thorlabs cage assembly line accessories to created unlimited optical systems.
TCLDM3	Same as TCLDM9 but for use with TO-3 laser packages.
	Shielded cables:
TEC2000-CAB	cable to connect the Temperature Controller to a Laser Diode Head

1.4 Safety instructions

It is important for you to read this chapter before initial operation to ensure safe operation and to prevent damage to the TEC element and other equipment.

Only use the original line cord with grounding-contact type plug to connect the unit to power. The unit is grounded via the AC ground conductor. To avoid electric shock hazard, the plug of the line cord must be connected to a correctly grounded power outlet. Grounding of the unit by the ground conductor of the line cord is necessary for safe operation. An interrupt of the ground conductor may cause extreme danger and injuries to persons by electric shock.

To ensure safe operation of the unit, always keep the ventilating louvers on both sides and on the rear of the unit free from obstruction.

The unit must not be operated in the presence of flammable gases or fumes.

The unit must not be opened during operation. Qualified service personnel must do internal adjustment and replacement of parts only. Parts must not be replaced during operation. Under certain conditions, dangerous voltages may exist inside the unit even when the unit is disconnected from power.

Attention:

All statements regarding safety of operation and technical data in this manual are only valid if the operation is carried through correctly.

All connections to the load have to be made with shielded cables (unless otherwise noted)

***Thorlabs* must consent in writing to any changes done to any components or to using components not provided by *Thorlabs*.**

Mobile telephones and walkie-talkies must not be used within three meters of this unit since the field intensities produced by this radio equipment will exceed the maximum allowed level as per EN 50 082-1.

1.5 Warranty

Thorlabs warranties material and production of the TEC 2000 for 12 months from the date of shipment. During this period, *Thorlabs* will either repair or replace parts which prove to be defective. For warranty repair or service, the unit must be returned to *Thorlabs.*

Thorlabs warrants that the hardware, which is determined for this unit by *Thorlabs*, operates correctly if it is used according to our descriptions.

Thorlabs does not warranty that the unit will work without errors and interruptions or that this manual is free of errors. *Thorlabs* is not liable for consequential damages.

Limitation of warranty:

This warranty shall not apply to errors resulting from inadequate treatment, buyer supplied software and interfacing, modification, misuse, operation outside the environmental specifications or unauthorized maintenance.

No other warranty is expressed or implied. *Thorlabs* specifically disclaims the implied warranty of merchantability and suitability for particular purposes.

Thorlabs reserves the right to change this manual and the technical specifications of the unit described herein at any time.

This precision instrument may only be shipped if it is packed correctly inside the original packing (including the foam parts). If necessary, please ask your supplier for spare packing.

2. Operation

2.1 Starting up

Prior to operating the TEC 2000, check if the power voltage specified on the letterplate agrees with your local supply and that the appropriate fuse is inserted. Connect the unit to power with the provided line cord. Turn the unit on using the “ON” button on the front panel.

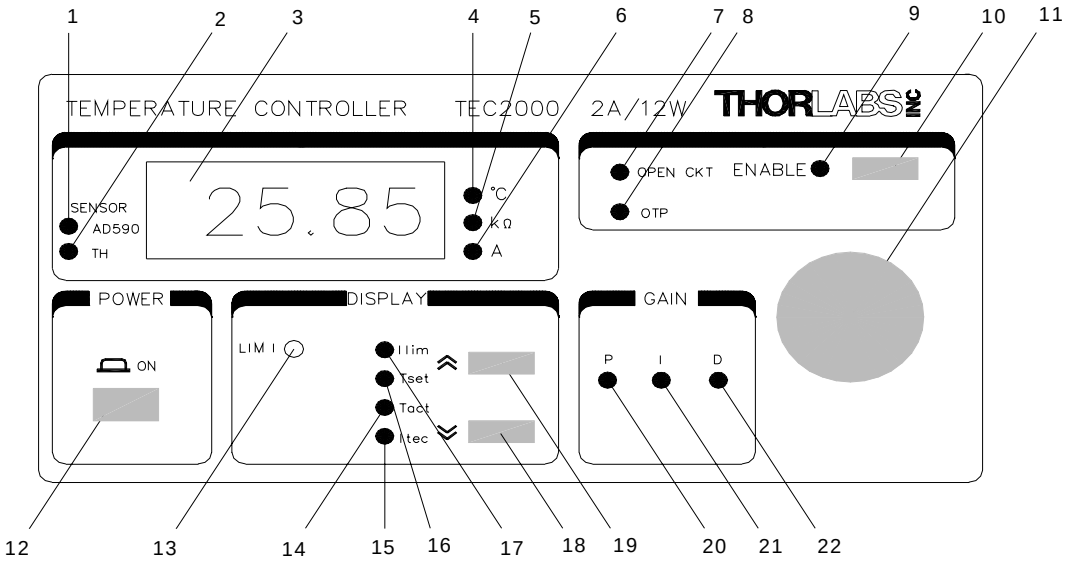
After turning on the unit, the LCD display (3) should become active and the LED indicating the selected measurement value (14 to 17) should also light up. If no display appears, check power connection and main fuse.

With buttons (18) and (19) the desired display value can be selected at any time.

The setting and measurement range with thermistors is between 0 and 19.99 kΩ or 0 and 199.9 kΩ. When the AD590/AD592 is used as a temperature sensor, the measurement range is between -199.99 °C and + 199.99 °C, the setting range between about -60 °C and about + 130 °C. The actual control range depends on the connected thermal load, the environmental temperature and so on.

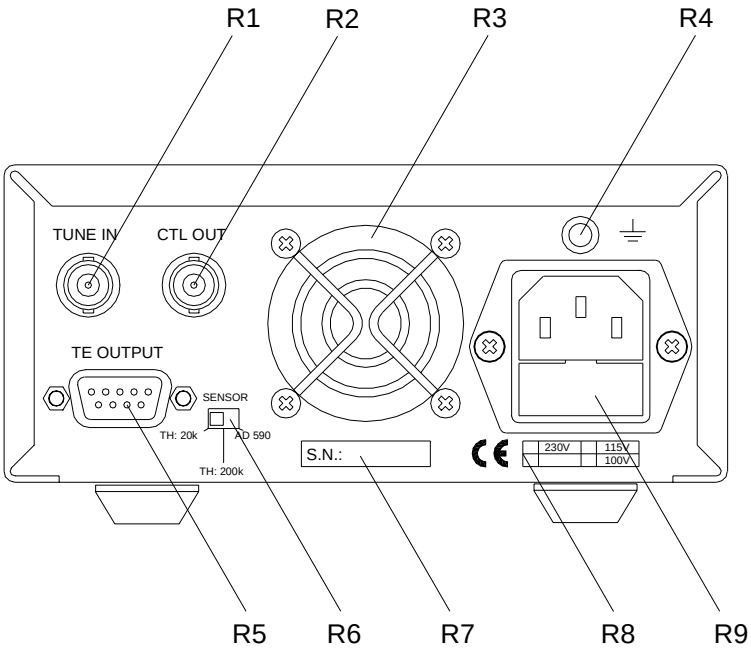
The TEC 2000 is immediately ready to use after turning on. The rated accuracy is reached, however, after a warming-up time of approximately 10 minutes.

2.2 Operating elements of the TEC 2000



1 Indicates that the selected temperature sensor is an AD 590
2 Indicates that the selected temperature sensor is a thermistor
3 4½-digit LCD display
4 Temperature display in °C
5 Resistance display in kΩ
6 Current display in A
7 LED display "maximum TEC current "ILIM" cannot be delivered, i.e. temperature sensor or TEC element missing or incorrectly connected"
8 LED display "over-temperature-protection"
9 LED display "TEC output switched on"
10 On/off switch for temperature control loop
11 Set temperature "TSET"
12 Power switch
13 Sets current limit "ILIM" for the TEC element
14 Displays the actual temperature "TACT´"
15 Displays the TEC current "ITEC"
16 Displays the set temperature "TSET"
17 Displays the current limit "ILIM"
18 Selects the measurement value for the display (toggle switch)
19 Selects the measurement value for the display (toggle switch)
20 Sets the proportional gain of the control loop (P)
21 Sets the integral gain (I) of the control loop
22 Sets the derivative gain (D) of the control loop

Fig. 2.1 Display and operating elements on front panel



R1 Analog control input "TUNE IN"
R2 Analog control output "CTL OUT"
R3 Fan
R4 DB9 jack chassis ground
R5 DB9 plug for the TEC element (TEC) and the temperature sensor
R6 Selects the temperature sensor and the thermistor resistance range
R7 Serial number of the unit
R8 States the admissible power voltage
R9 IEC320 AC power receptacle and main fuse holder

Fig. 2.2 Operating elements on rear

2.3 Operation

2.3.1 Setting the TEC current limit "ILIM"

The TEC 2000 delivers a maximum TEC current of 2 A. The TEC current "ILIM" can be set with the potentiometer "LIM I" and thus adapted to optimize the efficiency of the used TEC element.

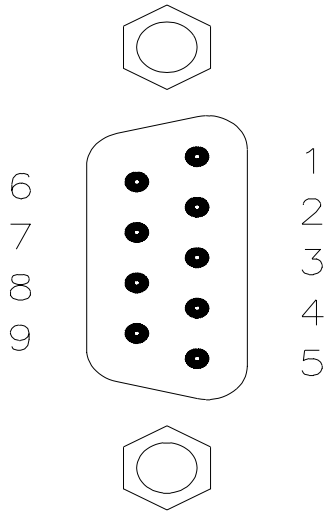
With buttons (18) or (19), switch to parameter "ILIM".

Use a screwdriver to set the desired TEC current limit "ILIM" with the 20-turn potentiometer "LIM I" (11) for the TEC element.

If switch (3) is in position "ILIM", the TEC current limit for the TEC element can be displayed at any time.

2.3.2 Connecting TEC element and temperature sensor

If laser diode heads by *Thorlabs* are used, the output "TE OUTPUT" (R5) of the TEC 2000 is connected to the output plug via the shielded cable TEC2000-CAB to the DB9 "TEC Driver" on the laser head.



Pin	Connection
	TEC element, status indication:
4	TEC (+)
5	TEC (-), status-LED (-)
1	Status-LED (+) (for TEC ON/OFF indication)
	Temperature sensor:
2	Thermistor (-)
3	Thermistor (+)
7	Transducer AD 590 (-), LM 335 (+)
9	Transducer AD 590 (+), LM 335 (+)
6	n.c.
8	AGND LM 335

Fig. 2.3 Pin assignment of plug "TE OUTPUT"

If other laser diode sockets are used, the TEC element and the temperature sensor should be connected with a shielded cable to the output plug "TE OUTPUT" (R5) on the rear panel according to the pin assignment in fig. 2.3.

Control LED for TEC ON mode

If an LED is connected between pin 1 and pin 5, as shown in fig 2.4, the LED lights up when the TEC current output is switched on (TEC ON mode).

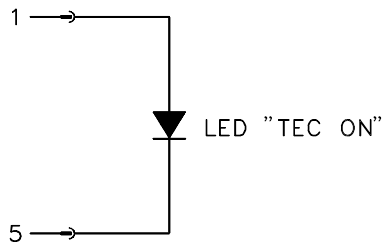


Fig. 2.4 TEC ON monitoring

Connecting the TEC element

Connect the thermoelectric cooler between pin 4 (TEC anode) and pin 5 (TEC cathode) of the DB9 (R5). The TEC element must be connected in a way that a cooling effect occurs if pin 4 is positive with respect to pin 5.

> **Attention:**
> **If the TEC module is connected with incorrect polarity, the TEC module may overheat and be destroyed.**

Check the TEC polarity as follows:

- Turn on the TEC 2000 (refer to chapter 2.1).
- Connect the temperature sensor to the plug "TE OUTPUT" (R5) (refer to connecting the temperature sensor).
- Select a suitable current limit "ILIM" for the TEC element (refer to chapter 2.3.1).
- Switch the LCD display to the measurement range "TSET" and set the desired set temperature with the front panel adjustment knob (11) (refer to Fig. 2.1).
- By pressing the “ENABLE” button (10), switch on the TEC 2000. The LED "ENABLE" (9) lights up.
- Switch the LCD display to the measurement range "TACT".

If the TEC module is connected with correct polarity, the difference between the set temperature "TSET" and the actual temperature "TACT" will decrease. If the control loop parameters are set properly (refer to chapter 2.3.4), the actual temperature will be in accordance with the set temperature.

If the TEC module is connected with incorrect polarity, the difference between set temperature and actual temperature will continuously increase. In this case, switch off the TEC current by pressing the “ENABLE” button (9) and change the TEC module wiring on the DB9 (R5).

Connecting the temperature sensor

The TEC 2000 can be used with a standard thermistor or with an IC temperature transducer such as an AD590/592, or LM335. The temperature sensor is selected with switch (R6) on the rear panel.

The LEDs (1) or (2) indicate the sensor selected by the switch (R6).

If no temperature sensor is connected or if the temperature sensor does not correspond to the sensor type selected with switch (R6), the LCD display (3) indicates overflow when "TACT" measurement value is indicated and the LED "OPEN CKT" (7) lights up in TEC OFF mode.
The temperature sensor is connected, depending on the used sensor type, via the DB9 "TE OUTPUT" (R5) on the rear panel.

In addition to the AD590/592 temperature sensor, the TEC2000 also works with an LM335 sensor. If an LM335 is used as temperature sensor, switch (R6) must be set to the same position as for operating with an AD590 sensor. Then the LED "AD590" (1) lights up. The LM335 sensor must be connected according to fig. 2.7.

THERMISTOR

The thermistor must be connected between pin 2 and pin 3 of the DB9 (R5). If the TEC2000 is operated with a thermistor as the temperature sensor, the thermistor resistance at set temperature "TSET" is to be set in kΩ.

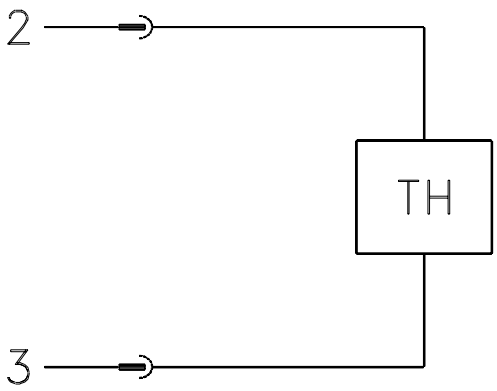


Fig. 2.5 Connecting a thermistor

When the actual temperature "TACT" is indicated, the thermistor resistance is shown on the LCD display (3).

The switch (R6) selects the resistance range of the thermistor. In position 20kΩ, the maximum thermistor range is 20 kΩ and the measurement current 100 µA. In position 200kΩ, the maximum thermistor resistance is 200 kΩ and the measurement current 10 µA.

The temperature dependence of an NTC thermistor is given by:

$$\mathbf{R(T) = R_N e^{B\left(\frac{1}{T}-\frac{1}{T_N}\right)}}$$

with:

RN nominal thermistor resistance at the temperature T**N**
TN nominal temperature (typ. 25° C)
B energy constant in K^{-1}

The nominal thermistor resistance RN value and the B value are given in the data sheet supplied by the thermistor manufacturer.

Evaluate the thermistor resistance for the desired set temperature.

Select with button (18) or (19) the display "TSET" to indicate the set value. Then Tset to the calculated resistance value with the adjustment knob (11).

If the thermistor characteristic R(T) is given in the data sheet, the desired resistance can be taken directly from it.

TEMPERATURE/CURRENT TRANSDUCER AD590

If the temperature/current transducer used is a AD590 or AD592, it is connected between pin 7 (AD 590-) and pin 9 (AD 590+) of the DB9 "TE OUTPUT" (R5) on the rear panel.

The accuracy of the displayed temperature depends on the tolerance of the transducer used. If required, the temperature display can be additionally calibrated for the transducer used.

For calibration of the temperature sensor, please refer to chapter 3.3.1.

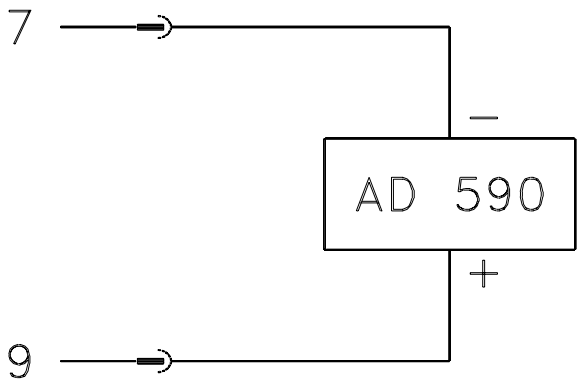


Fig. 2.6 Connecting a temperature/current transducer AD 590

TEMPERATURE/VOLTAGE TRANSDUCER LM 335

If the temperature/voltage transducer LM 335 is used as temperature sensor, it is connected to pin 9 (LM 335+), pin 7 (also LM 335+) and pin 8 (AGND) of the DB9 "TE OUTPUT" (R5) on the rear panel.

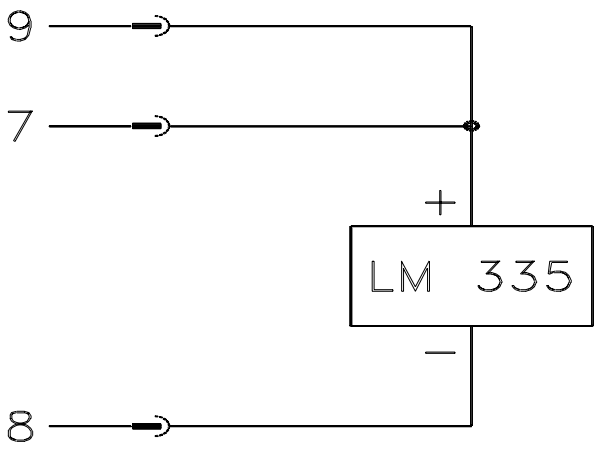


Fig. 2.7 Connecting a temperature/voltage transducer LM 335

2.3.3 Operating the Temperature Controller

With the TEC 2000, all TEC elements and most of the commercially available temperature sensors (thermistors, AD 590/LM 335) can be used.

The dynamic behavior of the temperature control loop depends on the TEC module, the sensor and the thermal load. Settling time and overshoot can be optimized for the thermal load by varying the control loop gain, the proportional gain (P), the integral gain (I), and the derivative gain (D) separately (refer to chapter 2.3.4).

Procedure to operate the TEC2000:

- Switch on the TEC 2000 (refer to chapter 2.1).
- Use cable TEC2000-CAB to connect the "TE OUTPUT" (R5) on the rear panel to the input "TEC Driver" on the Laser Diode Head (Thorlabs laser heads).

  If other laser diode sockets are used, the output plug "TE OUTPUT" (R5) is to be connected according to the pin assignment in fig. 2.3 and the description "connecting a temperature sensor" (refer to chapter 2.3.2).
- Select a suitable current limit "ILIM" for the TEC element (refer to chapter 2.3.1).
- Select the used sensor by setting switch (R6) for the temperature sensor to be used.

  Note:
  Only if a temperature sensor is connected to plug "TE OUTPUT" (R5) and the sensor type is selected correctly with switch (R6), can TEC ON mode be selected by pressing the “ON” button (R1).
- The LED "OPEN CKT" (7) lights up if the connected temperature sensor does not correspond to the sensor type selected with the switch (R6). In this case, check the connection of the temperature sensor.
- Using buttons (18) or (19) set mode position to "TSET" for displaying the selected set temperature.
- Set the desired temperature "TSET" with adjustment knob (11).
- If a thermistor is used as the temperature sensor, the resistance must be set in kΩ. If an AD 590 or an LM 335 is used as the temperature sensor, the temperature is set in °C.
- Switch on the TEC current output of the TEC 2000 by pressing the “ENABLE” button (10). With the output enabled, the LED "ENABLE" (9) lights up.

  Note:
  When the LED "OPEN CKT" (7) lights up, the TEC cannot be enabled. In this case, check the connection of the temperature sensor and the selected sensor type.
- If the LED "OPEN CKT" (7) lights up during normal operation, either the connection to the TEC element has been interrupted or the TEC element requires too high a voltage.

During operation, you can choose at any time the display showing "TSET", "TACT", "ILIM" or "ITEC" by selecting with buttons (18) or (19).

2.3.4 Adjusting the temperature control loop

By setting the control loop parameters of the PID control loop, the TEC 2000 can be optimally set to most thermal loads.

The proportional gain (P) for the temperature control can be adjusted with potentiometer "P" (20). Turning “P” clock-wise (CW) reduces the settling time, turning “P” counter-clockwise (CCW) increases the stability of the temperature control loop and thus reduces the overshoot.

The integral gain (I) of the temperature control loop can be adjusted with potentiometer "I" (21).

The derivative gain (D) of the temperature control loop can be adjusted with potentiometer "D" (22).

Procedure to adjust PID gain:

- Using buttons (18) or (19), switch into position "TACT" for displaying the actual temperature.
- Turn the three potentiometers "P" (20), "I" (21) and "D" (22) completely to CCW.

  Note:
  The settling behavior may be additionally observed at the "CTL OUT" (R2) output port on the panel by means of an oscilloscope.

  The Integral gain (I) can be completely disabled to make the setting of the proportional gain and the derivative gain easier. For this purpose, a jumper "JP1" needs to be temporarily installed on the controller PCB (refer to chapter 3.3.2).

- Set the desired temperature "TSET" to about room temperature and switch on the TEC current output with the “ON” button (10).
- Increase the set temperature about 1 °C or 2 °C with adjustment knob (11) or by setting a suitable signal to the analog control input "TUNE IN" (R1) on the rear panel, and watch the settling procedure of the actual temperature "TACT".
- Change the potentiometer "P" (20) by slightly turning it CW. Increase or decrease the set temperature again by about 1 °C or 2 °C and again watch the settling procedure of the actual temperature "TACT".
- Change the potentiometer "P" (20) as long as you can watch a low settling behavior with minimized temperature overshoots of the actual temperature "TACT". Then turn the potentiometer "D" (22) slightly to CW and again watch the settling procedure of the actual temperature "TACT".
- Change the potentiometer "D" (22) until a settling behavior of the lowest possible overshoots of the actual temperature "TACT" can be observed.
- If the Integral gain of the temperature control loop was switched off by installing the jumper "JP1", it must be reactivated by removing the jumper (refer to chapter 3.3.2).
- Turn the potentiometer "I" (21) slightly to CW and again observe the settling procedure of the actual temperature "TACT".
- Change the potentiometer "I" (21) until the optimal compromise between settling time and number of temperature overshoots at this thermal load has been found.

The values determined for the PID gains of the control loop are roughly indicated by arrows in the adjustment knobs of the operating elements (20, 21, 22).

> **Note:**
> If the thermal load has changed, you can easily reset the setting of the control loop parameters "P" (20), "I" (21) and "D" (22) you found suitable, if you wrote down the position of the adjustment knobs (20, 21, and 22) with optimal adaptation of the control loop previously.

2.3.5 Analog tuning of the temperature

The set temperature "TSET" can be tuned by an analog voltage via an independent, grounded input "TUNE IN" (R1) on the rear panel. The temperature set value is proportional to the sum of the signal at the input "TUNE IN" (R1) and the value set with the adjustment knob (11).

The tuning coefficient for the analog control input "TUNE IN" (R1) is:

range	voltage	operation mode
0 ... 20 kΩ	0 ... 10 V	thermistor, switch (R6) in position 20 kΩ
0 ... 200 kΩ	0 ... 10 V	thermistor, switch (R6) in position 200 kΩ
-50 °C ... +100 °C	- 2.5 V ... + 5 V	AD 590, LM 335

Procedure to Analog tune the temperature:

- Switch on the TEC 2000 (refer to chapter 2.1) and connect the temperature sensor and the TEC element to plug "TE OUTPUT" (R5) (refer to chapter 2.3.2).
- Select an adequate TEC current limit "ILIM" (refer to chapter 2.3.1). Select the sensor type with switch (R6) and set the desired set temperature "TSET" with the adjustment knob (11).
- Switch on the TEC current output of the TEC 2000 by pressing “ENABLE” (10). TEC enable mode is indicated by LED "ENABLE" next to the “ENABLE” button (10). The current now flows through the TEC element.
- Apply an analog voltage to jack "TUNE IN" (R1) on the rear panel.

> **Note:**
> Only slow variations of the temperature set value (<< 1 Hz) are possible via the analog control input "TUNE IN" (R1).

At the analog temperature control output "CTL OUT" (R2), the actual temperature "TACT" can be monitored.

2.3.6 Analog temperature control output

An analog output "CTL OUT" (R2) is provided on the rear panel. Here, a voltage proportional to the actual temperature "TACT" is applied for monitoring purposes, e.g. to monitor the settling behavior of the temperature control loop.

voltage	range	operation mode
0 ... 10 V	0 ... 20 kΩ	thermistor, switch (R6) in position 20 kΩ
0 ... 10 V	0 ... 200 kΩ	thermistor, switch (R6) in position 200 kΩ
-10 V ... +10 V	-200 °C ... +200 °C	AD 590, LM 335

External devices to monitor the operation may be connected to this output, e.g. to see if certain temperature limits of the device under test are exceeded.

The output "CTL OUT" (R2) is grounded. Thus an oscilloscope can be connected directly. Devices connected to these outputs should have an internal resistance of ≥ 1 kΩ.

2.3.7 Over-temperature-protection of the TEC 2000

The TEC 2000 has an automatic over-temperature-protection. When overheated by operating errors or high ambient temperatures, the current output is switched off automatically. LED "OTP" (8) (over-temperature-protection) lights up and the beeper sounds a short warning signal. The current through the TEC element is switched off (TEC OFF mode). Pressing “ENABLE” button (10) has no effect in this case.

When the temperature within the unit has decreased about 10 °C, LED "OTP" (8) turns off and the TEC current output can be switched on again with "ENABLE" button (10).

3. Service

3.1 Power voltage

The TEC 2000 operates at power voltages from 103 V ... 127 V or at power voltages 207 V ... 253 V. Prior to starting operation, check if the power voltage specified on the letterplate (R8) on the rear panel agrees with your local supply.

3.2 Replacing the main fuse

If the main fuse has blown due to power distortion, incorrect power voltage or other causes, it can be easily replaced from the rear without opening the unit.

Attention:
To avoid fire risk, only the fuse designated for the given power voltage must be used.

Execution:
Turn off the TEC 2000 and disconnect the line cord. Open the cover of the fuse holder (R9) on the rear panel with a screwdriver.

Remove the fuse drawer and replace the defective fuse.

Insert the fuse drawer and close the cover of the fuse holder.

3.3 Maintenance and repair

The TEC 2000 does not need regular maintenance by the user. The cover and the LCD display can be cleaned with a soft, moist cloth and mild detergent.

To keep the rated specifications (refer to chapter 1.2) for an extended time, it is recommended that the device be calibrated every two years by *Thorlabs*.

The TEC 2000 does not contain any modules that can be repaired by the user. If any malfunction occurs, the whole unit must be sent back to *Thorlabs*.

3.3.1 Calibrating the temperature sensor

Attention:
For calibrating the temperature sensor, internal adjustment during operation is required. It must only be done by qualified service personnel.

When using an AD 590 or an LM 335 IC sensor, the accuracy of the actual temperature depends on the tolerance of the temperature sensor used. For higher accuracy, the temperature display can additionally be calibrated to the temperature sensor.

Procedure to calibrate the temperature sensor:

- Switch off the TEC 2000 and disconnect the line cord. Remove the four screws in the plastic pieces on the rear panel and remove the cover plate.

- At the main PCB of the TEC 2000 there are the potentiometers "P1" and "P2". With potentiometer "P2", the zero of the temperature scale can be set. With potentiometer "P1", the scaling factor of the temperature scale can be set.

  Attention:
  Dangerous high voltages may be applied to electronic parts within the device. *Thorlabs* has all parts which carry power voltage covered to avoid contact. However, *Thorlabs* does not guarantee that this protection is sufficient in all circumstances. Therefore, be careful to not come into contact with any part within the unit.

- Connect the TEC 2000 to power by the line cord and switch on the opened unit.

- Use iced water to cool the temperature sensor to 0° C and calibrate the display of the actual temperature "TACT" with potentiometer "P2" to 0 °C.

- Use boiling water to heat the temperature sensor to about 100 °C, measure the water temperature and adjust the display of the actual temperature "TACT" with potentiometer "P1" to the measured water temperature.

Afterwards, close the unit with the cover and fasten the cover again with the screws on the bottom of the unit.

3.3.2 Switching off the Integral gain (I) of the temperature control loop

To simplify the setting of the P and D gains of the control loop, the Integral gain (I) can be switched off by setting a jumper on the main PCB of the TEC 2000. Especially in the case of high thermal loads, the setting of the P- and D-gain is simplified.

Attention:
To switch off the Integral gain (I), open the unit. Before removing the cover, the unit must be switched off at the power switch and the power plug must be removed from the power socket (R9).

Procedure to disable the Integral Gain (I):

- Switch off the unit, remove power plug from the main (R9), and loosen the screws of the cover at the bottom of the unit. Remove the cover.

  Attention:
  All parts carrying power voltage are covered against contact. However, *Thorlabs* does not guarantee this protection to be sufficient under all circumstances. Therefore, only use isolated tools and do not touch any parts within the unit.

- Set jumper "JP1" onto the provided pin board at the PCB of the TEC 2000.

- Replace the cover and fasten with the screws on the bottom of the unit.

- Connect the unit via the cable with the main supply and switch on the unit.

Setting the PID control loop:

Turn the three potentiometers "P" (20), "I" (21) and "D" (22) completely to CCW.

Set the potentiometers "P" (20) and "D" (22) (refer to chapter 2.3.4).

> **Note:**
> With the Integral gain (I) switched off, the temperature control loop does not settle to the set temperature "TSET", but reaches a temperature between the set temperature and the ambient temperature after the settling procedure.

- Having set the potentiometer "P" (20) and "D" (22) switch off, remove the power plug and open the unit. Switch on the Integral gain (I) of the temperature control loop by removing the jumper "JP1" on the PCB again.

- Replace the cover and fasten to the bottom of the unit. Connect the line cord and switch on the unit.

Afterwards, set the Integral gain (I) of the temperature control loop (refer to chapter 2.3.4).