THORLABS

Temperature Controller

TED4015
Operation Manual

2017

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Contents

We aim to develop and produce the best solution for your application in the field of optical measurement technique. To help us to live up to your expectations and improve our products permanently we need your ideas and suggestions. Therefore, please let us know about possible criticism or ideas. We and our international partners are looking forward to hearing from you.

Thorlabs GmbH

Warning

Sections marked by this symbol explain dangers that might result in personal injury or death. Always read the associated information carefully, before performing the indicated procedure.

Attention

Paragraphs preceeded by this symbol explain hazards that could damage the instrument and the connected equipment or may cause loss of data.

Note

This manual also contains "NOTES" and "HINTS" written in this form.

Please read these advices carefully!

1 General Information

This part of the operation manual contains specific information on how to operate a TED4015 Temperature Controller. A general description is followed by explanations of how to operate the unit manually. The instrument provides a USB 2.0 Full Speed interface according to the USB 2.0 specification, the USBTMC specification and the USBTMC USB488 specification.

The TED4015 is a high power precision temperature controller for laser diodes and detectors.

Special highlights of the TED4015 Temperature Controllers are:

- Wide range of supported temperature sensors (Thermistors, PT100, PT1000, AD590, AD592, LM35, LM135, LM235, LM335)
- TEC elements can be operated in constant temperature as well as in constant current mode.
- Adjustable temperature window protection
- PID Auto-Tune algorithms for automatic PID control loop settings
- Manual tuning of PID control loop settings
- Selectable temperature unit (°C, °F and Kelvin)
- Temperature loop monitoring for laser protection
- A wide variety of protection features safeguard the TEC element from damage.
- USB interface for remote operation supporting the USBTMC protocol
- SCPI compliant command set
- VXIpnp Instrument Drivers for various programming environments including NI-LabVIEW™, NI-LabWindows™/CVI and MS-Visual Studio
- Power efficient by active power management

Related documents:

- LDC4000 Series Operation Manual available at www.thorlabs.com
- ITC4000 Series Operation Manual available at www.thorlabs.com
- Series 4000 Programmers Reference Manual at www.thorlabs.com

1.1 Safety

Attention

The safety of any system incorporating the equipment is the responsibility of the assembler of the system.

All statements regarding safety of operation and technical data in this instruction manual will only apply when the unit is operated correctly as it was designed for.

The TED4015 must not be operated in explosion endangered environments!

Do not obstruct the air ventilation slots in the housing!

Do not remove covers!

Do not open the cabinet.There are no parts serviceable by the operator inside!

This precision device is only serviceable if properly packed into the complete original packaging including the plastic foam sleeves. If necessary, ask for replacement packaging.

Refer servicing to qualified personnel!

Only with written consent from Thorlabs may changes to single components be made or components not supplied by Thorlabs be used.

Attention

Prior to applying power to the TED4015, make sure that the protective conductor of the 3 conductor mains power cord is correctly connected to the protective earth ground contact of the socket outlet! Improper grounding can cause electric shock resulting in damage to your health or even death!

Ensure that the line voltage setting of the fuse holder at the rear panel agrees with your local supply and that the corresponding fuses are inserted. If not, please change the line voltage setting (see section Line voltage settings) and the mains fuses (see section Replacing the Mains Fuses).

To avoid risk of fire, only the appropriate fuses for the corresponding line voltage must be used.

All modules must only be operated with duly shielded connection cables.

Attention

The following statement applies to the products covered in this manual, unless otherwise specified herein. The statement for other products will appear in the respective accompanying documentation.

Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules and meets all requirements of the Canadian Interference-Causing Equipment Standard ICES-003 for digital apparatus. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/T.V. technician for help.

Users that change or modify the product described in this manual in a way not expressly approved by Thorlabs (party responsible for compliance) could void the user's authority to operate the equipment.

Thorlabs GmbH is not responsible for any radio television interference caused by modifications of this equipment or the substitution or attachment of connecting cables and equipment other than those specified by Thorlabs. The correction of interference caused by such unauthorized modification, substitution or attachment will be the responsibility of the user.

The use of shielded I/O cables is required when connecting this equipment to any and all optional peripheral or host devices. Failure to do so may violate FCC and ICES rules.

Attention

Mobile telephones, cellular phones or other radio transmitters are not to be used within the range of three meters of this unit since the electromagnetic field intensity may then exceed the maximum allowed disturbance values according to IEC 61326-1.

This product has been tested and found to comply with the limits according to IEC 61326-1 for using connection cables shorter than 3 meters (9.8 feet).

Vous pouvez trouver les traductions françaises des paragraphes ayant trait à la sécurité d'utilisation de ce produit sur le lien suivant:

https://www.thorlabs.com/_sd.cfm?fileName=18861-D04.pdf&partNumber=TED4015

En outre, vous pouvez soit scanner le QR code, soit vous référer à la section "Documents" sur la page web du produit.

1.2 Protection of the TEC Element

To protect the connected TEC element (Peltier element) the TED4015 Temperature Controller includes the following protective circuits:

Limit of the TEC current in all operating modes
Protection against thermal destruction.

Sensor fault detection
Protection against use of incorrect temperature sensors / protection against line interruption of the temperature sensor.

Contact protection of the TEC element (open circuit)
Protection against cable damage, bad contact or too high TEC element resistance.

Control LED for TEC current ON
Protection against accidental turning off the TEC output.

Over-temperature protection

Protection against malfunction caused by internal overheating of the controller.

Defined states after switch-on

When switching on the TED4015 Temperature Controller with the mains switch the output is always switched off.

Mains filter

Protection against line bursts or transients.

Line failure monitoring

In case of line failure / line interruption the instrument will wake up anew as if it has been switched on. So the output remains switched off.

1.3 Ordering Codes and Accessories

Ordering code	Short description
TED4015	Thermoelectric Temperature Controller, TEC current range 0 ... ± 15 A
CAB4000	Shielded cable to connect the TED4015 Temperature Controller to a Thorlabs LM14S2, LDM21 or TCLDM9 Laser Diode Mount (male 17W2 mixed DSUB connector to female 9 pin DSUB connector). The rated TEC-Current is 5A.
CAB4001	Shielded cable to connect the TED4015 Temperature Controller to a Thorlabs High Power TEC or Laser Diode Mount (male 17W2 mixed DSUB connector to male 17W2 mixed DSUB connector). The rated TEC-Current is 20A.
CON4001	Connector Kit for TED4015 instruments, 20A: Mixed DSUB connector type 17W2 (male) with two 20A high current contacts (male)
CAL-TED4000	Recalibration of a TED4015 device

Please visit our homepage www.thorlabs.com for further information.

2 Getting Started

Inspect the shipping container for damage.

If the shipping container appears to be damaged, keep it until you have checked the contents and you have inspected the device mechanically and electrically.

Verify that you have received the following items:

- 1 TED4015
- 1 power cord, connector according to ordering country
- 1 USB cable (A-B) 2 m
- 1 TED4015 operation manual
- 1 Series 4000 instrumentation CD (containing manuals, drivers, tools and software)
- 1 CAB4000 shielded cable to connect the TEC controller to a Thorlabs LM14S2, LDM21 or TCLDM9 laser diode mount (male17W2 mixed DSUB connector to female 9 pin DSUB connector), rated TEC current 5A
- 1 Connector Kit CON4001 for TED4015, rated TEC current 20A:
    - 1 Mixed DSUB connector type 17W2 (male) with 2 high current contacts (male)
    - 1 Mixed DSUB connector type 17W2 (female) with 2 high current contacts (female)

2.1 Preparation

Connect the mains connector (R9) of the unit to the line via the provided mains cable (refer to Figure 2, chapter Operating elements at the rear panel). An external thermal setup can be connected to ground potential via the connector jack of the chassis ground (R7).

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2.2 Operating Elements

Front Panel
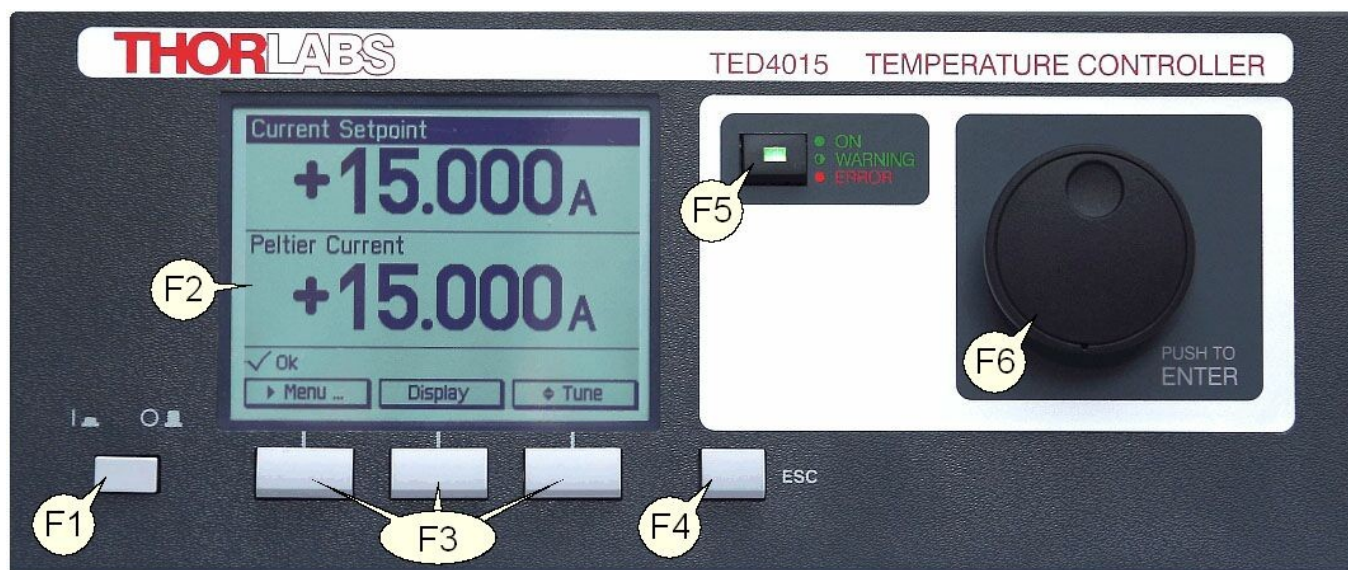
F1		Line switch (On/Off)
F2		LC display, 320x240 Pixel
F3		Softkeys for menu navigation
F4	ESC	Escape key
F5	ON	On/Off button for the TEC output with TEC ON LED (green) and ERROR LED (red)
F6		Adjustment knob to change set values, push to enter

Rear Panel
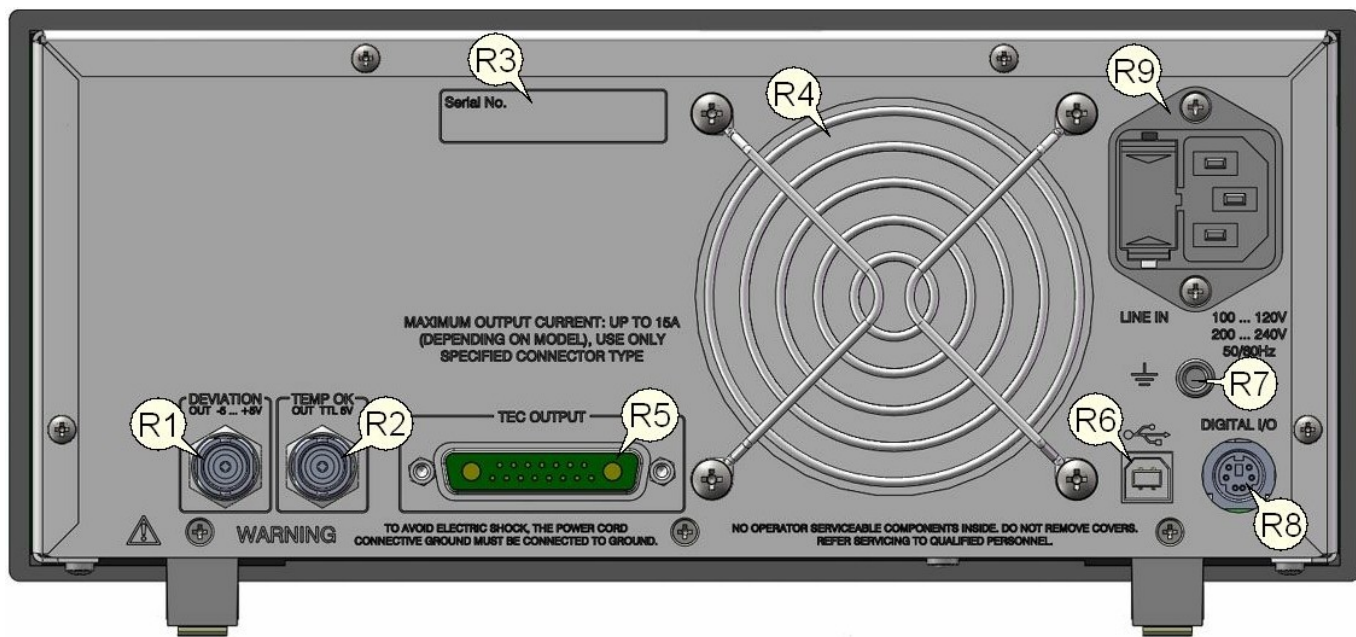
R1	DEVIATION OUT	Temperature Deviation Output, -5 ... +5 V
R2	TEMP OK OUT	Temperature OK Output, TTL (5 V if actual temperature is inside the temperature window)
R3		Serial number of the unit
R4		Cooling fan
R5	TEC OUTPUT	Mixed DSUB jack (17W2) for the TEC element and the temperature sensors
R6	⟜	USB connector
R7	⏚	4 mm banana jack for chassis ground
R8	DIGITAL I/O	MiniDin-6 jack for 4x digital I/O, I/O supply voltage (internal +12 V) and GND
R9	LINE IN	Mains connector and fuse holder

2.3   First Operation

Warning

Prior to switching on your TED4015, please read the safety instructions in chapter [Safety](#) carefully.

Turn on the unit by means of the line switch (F1 - see section [Operating elements at the front panel](#)).

After switching on the unit, the backlight of the display (F2) must get visible and the backlight behind the adjustment knob (F6) must light up.

If nothing is shown on the display, please check the line voltage (see chapter [Line Voltage Settings](#)) and the mains fuses (see chapter [Replacing the mains fuses](#)).

The TED4015 is immediately ready to use after turning on. The rated accuracy is reached, however, after a warming-up time of approx. 30 minutes.

After switching on the unit, the graphics display will show the device status, followed by the measurement screen.

By using the softkeys (F3) you can select the menu items, the set values and the measurement values to be displayed. You can change the set values by pressing the **Modify** button or the adjustment knob and then turning the adjustment knob (F6). Push this knob or the **Done** key to enter the adjusted value. If several menu items are displayed, you can select them also by turning and then pressing the adjustment knob.

If changing a parameter isn't permitted in the actual operating mode, or you arrive at the end of a parameter number range, entering is declined and a short beep is audible.

From any menu level, you can navigate to the next higher menu level using the **ESC** key (F4). The highest level is the measurement screen.

To leave the measurement screen and to enter the menu, press the **Menu** key or the **ESC** key.

2.4   System Preferences

In the System Preferences menu you can make different settings about your TED4015 system configuration, including Message Handling, Display Brightness, Display Contrast, Sound Signals on/off and Update Capability. To get into the System Preferences menu, turn the adjustment knob or press **Up / Down** until System Preferences is highlighted. Confirm by pressing **Enter** or the adjustment knob again.
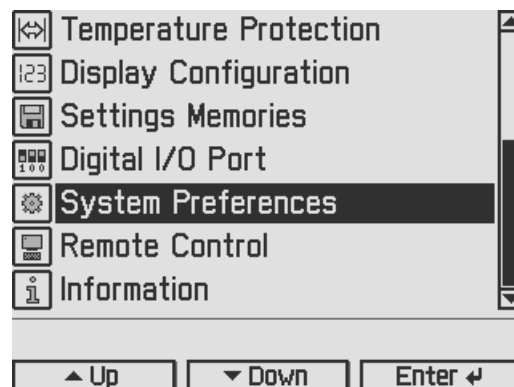
Turn the adjustment knob or press **Up / Down** and select your desired menu item by pressing the **Modify** key or the adjustment knob. Make your necessary changes and confirm with the **Enter** key or by pressing the adjustment knob again.
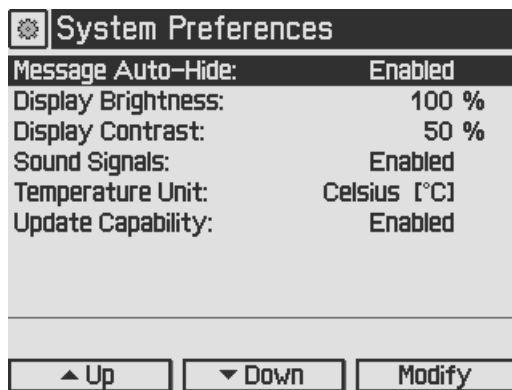
Message Auto-Hide:

Message and error conditions which force the Laser output to switch off may disappear after a short time. So it may be preferable to keep the error messages displayed. You can choose the following settings:

Enabled (auto-hide): Error pop-up messages disappear after 10 seconds, you can close them instantly by pressing the ESC button (F5).

Disabled: Messages are displayed until they will be confirmed by pressing the ESC button.

Display Brightness, Display Contrast:

Both display parameters can be changed from 0% to 100%. The brightness value also determines the illumination brightness of the adjustment knob.

Note

Please take care not to reduce the contrast value to a level making it impossible to read the display.

Sound Signals:

Here you can disable or enable the audibility of the error beeps and the menu navigation click response.

Temperature Unit:

The preferred temperature unit can be selected: °C (Celsius), °F (Fahrenheit), and K (Kelvin). The conversion between the units will be calculated automatically.

Line Frequency:

According to the mains properties, the line filter frequency can be set to 50 Hz or 60 Hz to suppress unwanted readout aliasing effects. The "Auto" function detects the line frequency automatically (default setting).

Update Capability:

Firmware updates can be performed by the user via the USB interface.

Three options are available:

Enabled: Firmware can be updated at any time.

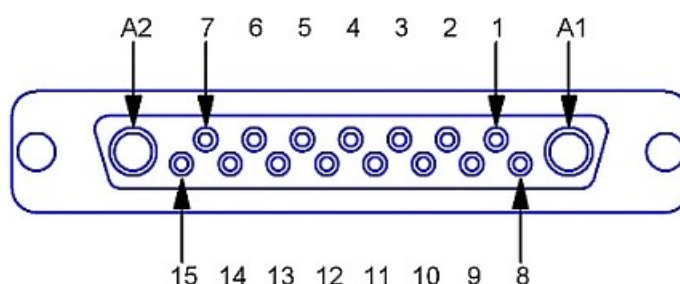**Enabled once:** Firmware can be updated once, afterwards this setting changes to disabled.

Disabled: Firmware update is inhibited (default setting).

For more information please refer to section Firmware Update.

3 Operating the TED4015

3.1 Connecting Components

3.1.1 Pin Assignment of the TEC Output Jack

Pin	Connection
TEC element (Peltier element) [1]	
A1	TEC element (+, when cooling)
A2	TEC element (-, when cooling) **Attention: Do not connect to Ground!**
2	Voltage measurement TEC element (+)
9	Voltage measurement TEC element (-)
Open circuit monitoring, status indicator, external fan	
1	Interlock, TEC ON LED (+)
7	12V Output (for external fan; max. current = 500mA)
15	Ground for 12V Output and Interlock, TEC ON LED (-)
Temperature sensor	
3	Thermistor (-), PT100/1000 (-), analog ground
4	Thermistor (+), PT100/1000 (+)
10	PT100/1000 (-), AD590/592 (-), LM35 out, LM135/235/335 (+)
11	PT100/1000 (+), AD590/592 (+), LM35/135/235/335 (+)
5,12	Analog ground, LM35/135/235/335 (-)
Other	
14	I/O 1-wire (currently not used)
6	Digital ground for I/O 1-wire
8, 13	Not connected

[1] TEC element output pins and voltage measurement input pins are "ground-free". *Do not connect* any of these pins to Ground, otherwise the electronic circuit will be damaged!

Attention

The maximum TEC output current for the TED4015 series is 15A. Use only the specified connector type: 17W2 mixed DSUB plug with high power contacts A1 and A2 rated for at least 15A current. For wiring of A1 and A2 use only wires rated for at least 15A current.

If Thorlabs laser diode mounts like TCLDM9, LDM21, or LM14S2 are used, the easiest way to connect them using a shielded cable CAB4000 (rated TEC current is 5A).

For use of other equipment, a shielded cable with two 17W2 mixed DSUB plugs, CAB4001, (20A current rating) is also available.

When using a custom-made cable, we recommend to use a shielded cable for the sensor inputs with twisted pairs. Use a separate shielded cable for the TEC current and TEC voltage measurement lines. The TEC current lines should be as short as and as close as possible to minimize inductance.

3.1.2 Connecting a TEC Element

Attention

The TEC element output of the TED4015 is a ground-free output. Do not connect the TEC element pins to any grounded pins (3, 5, 6, 12, 15) or to case ground, otherwise the electronic circuit will be damaged.

A TEC element connected with wrong polarity may lead to thermal runaway and damage of the connected components.

Connect the thermoelectric cooler (TEC or Peltier element) to the high current contacts A1 (TEC+) and A2 (TEC-) of the 17W2 DSUB jack (R16, see section Operating elements at the rear panel).

When the Temperature controller is in cooling mode, current flows from TEC+ to TEC-. This is defined as positive current, and with the TEC element connected correctly, its active surface (which is in contact with the tempered object) gets colder.

Check the TEC polarity as follows:

- Connect the TEC element and the temperature sensor to the 17W2 DSUB jack "TEC OUTPUT" (R16) (Refer to section Connecting the TEC element and Connecting a temperature sensor). The sensor and the TEC element must be in good thermal contact to the thermal load. The use of thermal conducting grease is recommended. Please refer to section Setup and function of a temperature controller.
- Turn on the TED4015.
- Select the appropriate sensor type by pressing **Menu.** Scroll to Temperature Sensor Setup by turning the adjustment knob. Switch into the the Temperature Settings by pressing the Enter button or the adjustment knob (F8) and select the appropriate sensor: **Menu** / Temperature Sensor Setup / Temperature Sensor. Confirm by pressing **Done** or the adjustment knob (F8) again.
- Adjust a suitable current limit for the TEC element by selecting **Menu** / Temperature Source Setup / Current Limit. Confirm by pressing **Done** or the adjustment knob (F8). (refer to section Setting the TEC source parameters).
- Switch the display back to the measurement screen and set the desired temperature by pressing and turning the adjustment knob (F8). Confirm the entered value by pressing the adjustment knob.
- Switch on the TED4015 TEC output current by pressing the key TEC ON (F6). The green LED in TEC ON key (F6) lights up (see section Operating elements at the front panel). If the green LED in TEC ON key is flashing, the current temperature is out of the temperature window.

If the TEC module is connected with correct polarity, the difference between the temperature set point and the actual temperature will decrease. Provided that the control loop parameters are set properly (refer to section PID control loop), the actual temperature should be in accordance with the temperature set point rather quickly.

If the TEC module is connected with reversed polarity, the difference between the temperature set point and the actual temperature will increase continuously. In this case, switch off the TEC current by pressing key "TEC ON" (F6) and correct the TEC module wiring.

3.1.3 Connecting a Temperature Sensor

The temperature controller in the TED4015 can be used with the following temperature sensors: NTC thermistor, AD590, AD592, LM35, LM335, LM235, LM135, PT100, and PT1000.

The setting and measurement range of thermistors is 100 Ω to 100 kΩ (Low range) and 1 kΩ to 1 MΩ (High range). The displayed temperature of the used thermistor and the temperature set point range are dependent on the sensor parameters.

If one of the other sensor types is used, the measurement range is -55°C to +150°C.

The actual control range and the accuracy of the displayed temperature depend on the operating range and the tolerance of the used sensor, and on the individual thermal setup.

The temperature sensor is connected to the 17W2 DSUB jack "TEC OUTPUT" (R16, Operating elements at the rear panel). The wiring depends on the used sensor type.

Attention

Do not connect any sensor pin to the TEC element pins A1 or A2, otherwise the connected components may be damaged!

3.1.3.1 NTC Thermistor

Connecting a thermistor
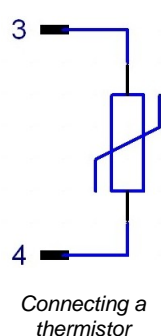
The thermistor is connected between pin 3 and pin 4 of the 17W2 mixed DSUB jack (R16, Operating elements at the rear panel). The polarity is unimportant if the thermistor is ungrounded. If one pin of the thermistor is grounded (for example in a laser module), this pin must be connected to pin 3.

With a thermistor as temperature sensor, the resistance can be converted into the temperature by using the Exponential or the Steinhart-Hart calculation method.

Using the exponential method, the relation between temperature and NTC thermistor resistance (and vice versa) is approximated by the formulas:

$$R(T) = R_0 * e^{\beta(\frac{1}{T} - \frac{1}{T_0})} \Leftrightarrow T(R) = \frac{\beta * T_0}{T_0 * \ln(\frac{R}{R_0}) + \beta}$$

with: R_0 - Thermistor nominal resistance at temperature T0

T_0 - Nominal temperature (usually 298.15 K = 25° C)

β - Thermistor constant (sensitivity index, B value)

T - temperature in K (Kelvin)

For R_0, T_0 and β please refer to the data sheet of the thermistor.

Using linearization series resistors, the thermistor measurement circuit of the instrument is optimized for best resolution with R_0 = 10 kΩ (Low Range) and R_0 = 100 kΩ (High Range). Thermistors with other R_0 values can be used at the expense of a degraded resolution, depending on the actual sensor resistance.

If the exponential method parameters given in the thermistor data sheet are stored in the TED4015 setup, the thermistor temperature can be shown on the display.

A further way of approximating the relation between temperature and thermistor resistance is the method according to Steinhart-Hart, described by the formula

$$1/T = A + B * \ln(R) + C * (\ln(R))^3$$

with the Steinhart-Hart parameters A, B and C; T - temperature in K. To select the calculation method and to enter the thermistor parameters, please refer to section Thermistor settings.

### 3.1.3.2 Current Temperature Sensors AD590 or AD592
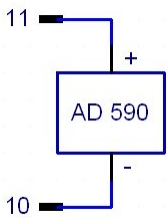
If a temperature/current transducer AD590 or AD592 is used as temperature sensor, it has to be connected to pin 10 (-) and pin 11 (+) of the 17W2 mixed DSUB jack "TEC OUTPUT" (R16, Operating elements at the rear panel) at the rear of the unit.

3.1.3.3 Voltage Temperature Sensor LM35
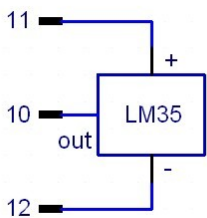
If the temperature/voltage transducer LM35 is used as temperature sensor, it must be connected to pin 10 (out), pin 11 (+) and pin 12 (-) of the 17W2 mixed DSUB jack "TEC OUTPUT" (R16, Operating elements at the rear panel) at the rear of the unit.

3.1.3.4 Voltage Temperature Sensors LM335, LM235 or LM135
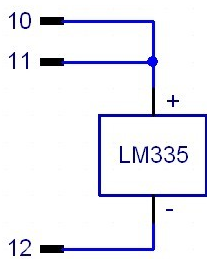
If the temperature/voltage transducer LM135, LM235 or LM335 is used as temperature sensor, it has to be connected to pin 10 (+), pin 11 (also +) and pin 12 (-) of the 17W2 mixed DSUB jack "TEC OUTPUT" (R16, Operating elements at the rear panel) at the rear of the unit.

3.1.3.5 Platinum RTD Temperature Sensors PT100 or PT1000
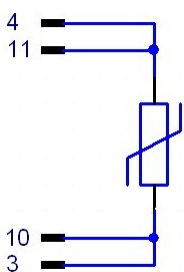
Pin 3 and 4 of the DSUB Connector are the current source, Pin 10 and 11 are the voltage measurement pins for the 4-wire measurement setup.

One connector of the sensor has to be connected to pin 4 and 11 and the other to pin 3 and 10 of the 17W2 mixed DSUB jack "TEC OUTPUT" (R16, Operating elements at the rear panel) at the rear of the unit.

For optimum performance, use a separate wire for each pin of the DSUB connector and connect the corresponding wires only at the PT100 or PT1000, as close as possible to the sensor (see Figure 13).

3.1.4 Setting up the TEC Voltage Measurement

A1

+

−

A2

TEC voltage four terminal measurement

2

9
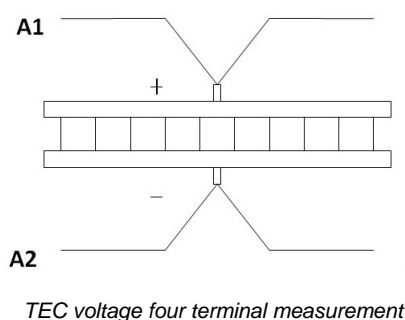
If the voltage of the TEC element shall be measured and displayed with enhanced accuracy, two additional cables must be connected directly from the two poles of the TEC element to pin 2 and 9 of the TEC OUTPUT jack (four terminal measurement, see figure to the left).

If pin 2 and pin 9 are left unconnected, the TEC voltage is measured internally at the contacts A1 and A2 of the TEC output jack (two terminal measurement). This leads to a measurement error due to the voltage drop along the lines to the TEC element, so a slightly increased voltage will be displayed.

3.1.5 Connecting Interlock and TEC ON Monitoring

Pin 1 and pin 15 of the "TEC OUTPUT" jack (R16) are test contacts to determine whether a TEC setup is connected or the connection has been interrupted. These pins must be connected externally by a wire (total resistance <430 Ω). When this "interlock" connection is opened, the TED4015 switches off the TEC output current automatically. If the TEC output was off, it cannot be switched on and an error message "TEC cable connection fault" appears.

If a LED with a 1 kΩ parallel resistor is connected between pin 1 and pin 15 as shown in Figure 15, the interlock connection is interpreted as closed, too. The LED lights up when the TEC current output is switched on (TEC ON mode).

1   R   LED "TEC ON"   15   1   R   15
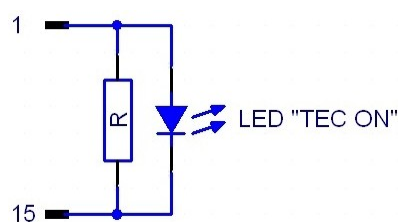
Note

The TED4015 Controllers don't support the "TEC lockout" feature of the Thorlabs laser diode mounts. These mounts usually have an on-board jumper to bypass the TEC lockout function. For details please refer to the operating manual of the laser diode mount.

3.1.6 TEC control outputs

Temperature OK output

This output (R15, see section Operating elements at the rear panel) provides a TTL signal (+5 V), which gets low (0 V) when the window protection is active. Please refer to section Temperature protection.

This jack can be used to monitor the temperature of a laser diode when using a *Thorlabs* LDC200C series laser driver. Simply connect the corresponding plug of the laser driver to this output of the TED4015. The laser will be switched off if the laser temperature moves out of the temperature window. Further details can be found in the operation manual of the respective laser driver.

Analog temperature deviation output

A temperature output "DEVIATION OUT" (R14, see section Operating elements at the rear panel) is provided at the rear of the unit. At this jack, a voltage proportional to the actual temperature deviation, scaled to the adjusted temperature window is applied for monitoring purposes, e.g. to watch the settling behavior of the temperature control loop by means of an oscilloscope. The voltage ranges from -5 V to +5 V. The voltage formula is:

$$U_{out} = 5V \times \frac{T_{set} - T_{act}}{T_{win}}$$

Example:

If the temperature set point is 25 °C and the temperature window is set to 2 °C, an actual temperature of

    23 °C leads to -5 V at the output
    25 °C   leads to 0 V at the output
    27 °C   leads to +5 V at the output
(please refer to section Temperature protection).

The temperature deviation output "DEVIATION OUT" is grounded. Thus standard measurement equipment can be connected directly. Devices connected to this output should have an input resistance $\geq$ 10 kΩ.

3.2 Power-up

Warning

Prior to switching on your TED4015, please read the safety instructions in chapter Safety carefully.

Turn on the unit by means of the line switch (F1, see section Operating elements at the front panel).
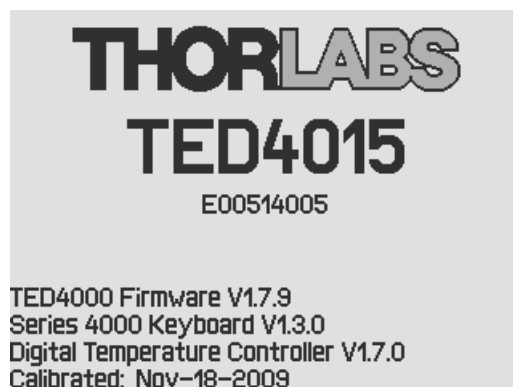
After switching on the unit, the graphics display will show the device status, followed by the measurement screen shown below. In the device status window device specific information like device name, serial number, the installed firmware versions, and the calibration date will be shown. If any system error has occurred (please refer to chapter Error Messages), the TED4015 unit will stay in the device status window. You can switch to the measurement screen window by pressing the ESC key.
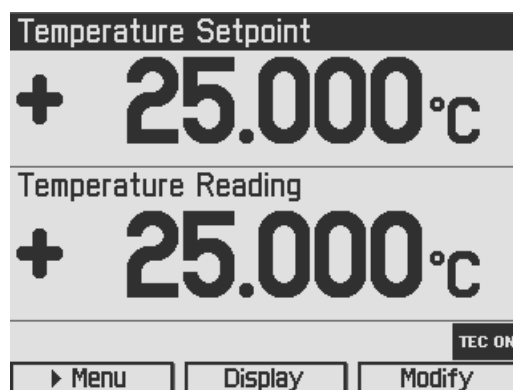
The display can be configured to show two, four or six values. Factory setting is the two value screen.

To change a setpoint displayed on screen, select it using the softkeys or turning the adjustment knob. Press the **Modify** button or the adjustment knob to get into the entry mode. Adjust the value by turning the adjustment knob. The entry position to be changed can be selected by the **Coarse** or **Fine** buttons. Confirm your entry by pressing the **Done** button or the adjustment knob again.

Please refer to chapter Display Configuration for more information about selecting setpoints and measurement readings.

Switch into the menu by pressing the **Menu** button or the ESC key. In the TED4015 menu you can change different TED4015 settings described in the following chapters.

For a complete menu item listing, please refer to chapter Menu structure overview.

3.3 TEC Source Setup

```
┌─────────────────────────────────────┐
│ [⌖T] TEC Source Setup                │
│ Operating Mode: Constant  Temperature │
│ Current Limit:              5.000 A   │
│ Constant Temperature Mode            │
│   Setpoint Low Limit:     +   0.000 °C │
│   Setpoint High Limit:    + 70.000 °C │
│   Temperature Setpoint:   + 25.000 °C │
│ Current Source Mode                  │
│   Current Setpoint:       +   0.000 A │
│                              ┌──────┐ │
│                              │TEC ON│ │
│ ┌────────┐ ┌────────┐ ┌─────────────┐│
│ │ ▲ Up   │ │ ▼ Down │ │   Modify    ││
│ └────────┘ └────────┘ └─────────────┘│
└─────────────────────────────────────┘
```

Setting the operating mode:

In the TEC Source Setup menu, the temperature controller operating mode of your TED4015 can be changed. It can be shifted between Current Source mode and Constant Temperature mode. In Current Source mode, an internal constant current loop is closed, and the TEC output current can be set in Ampere. In Constant Temperature mode a temperature control loop will be closed via an external feedback source (current, voltage or resistance temperature sensor). A TEC current depending on the feedback value will be driven. If the Exponential or Steinhart-Hart parameters of the connected thermistor sensor are known and entered, the TED4015 offers a temperature control in Celsius, Fahrenheit or Kelvin.

Setting the TEC current limits:

In the TEC Source Setup menu, the TEC current limit for the constant current and the constant temperature mode can be set. This feature protects the TEC element against excessive TEC current.

Setting the temperature set point limits:

In the TEC Source Setup menu, the temperature set point limits for the constant temperature mode can be set. This feature protects the TEC setup against accidental excessive temperatures. The limit values can be set from -55°C to +150°C.

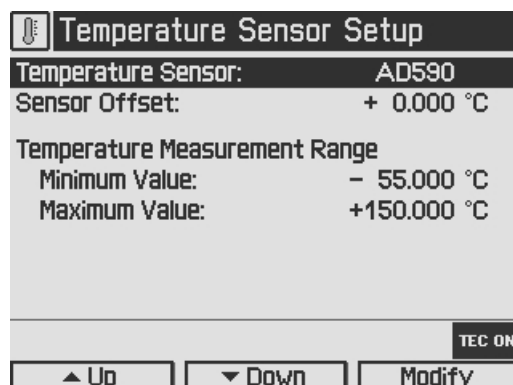**Setting the temperature set point:**

Enables the temperature setting in constant temperature mode. Entries will be ignored in constant current mode.
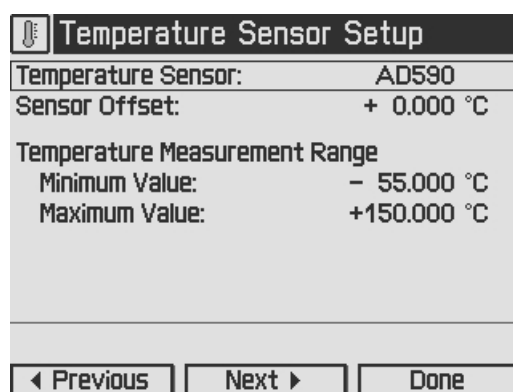
Setting the constant current mode set point:

Offers a current setting in constant current mode. Entries will be ignored in constant temperature mode.

3.4 Temperature Sensor Setup

From the Main menu, select the Temperature Sensor Setup menu and press **Enter** or the adjustment knob.

Select Temperature Sensor by pressing **Modify** or the adjustment knob.

The Temperature Sensor line is in entry mode, the border is flashing. By pressing **Previous** or **Next** or by turning the adjustment knob you can choose the appropriate temperature sensor:

AD590:   current sensor, means also AD592, 1 µA/K
Thermistor (low): NTC Thermistors, measurement range 100 Ω to 100 kΩ
Thermistor (high):   NTC Thermistors, measurement range 1 KΩ to 1 MΩ
PT100:   Platinum RTD sensor, 100 Ω at 0°C
PT1000:   Platinum RTD sensor, 1000 Ω at 0°C
LM35:   Voltage sensor, 10 mV/°C, 0 V at 0 °C
LM335:   Voltage sensor, 10 mV/K, 0V at 0 K, means also LM235 / LM135

Confirm your choice with **Done** or by pressing the adjustment knob again.

For IC sensors, the calculation coefficients are predetermined by your TED4015: 1µA/K for the current sensors AD59x, 10mV/°C for LM35 and 10mV/K for LMx35.

If no temperature sensor is connected or if the temperature sensor does not correspond to the selected sensor type, the red LED in the "TEC ON" key (F6, see Operating elements at the front panel) lights up and in the the status line the indicator "SENSOR" is shown. If the TEC output is switched on and the sensor lines are broken the TEC output will be switched off immediately. An short beep and an error message "Temperature sensor failure detected" appears at the bottom of the measurement display.

The set temperature for all sensors can be entered in Celsius, Kelvin or Fahrenheit. You can set your favored temperature unit in the System Preferences Menu (see section System preferences).

The TED4015 controllers offer an offset compensation for temperature sensors. The setting range is ±10 °C. Use a calibrated thermometer to verify the real sensor temperature. From this, subtract the temperature displayed by the TED4015 (take care of the proper signs). Enter the result as Sensor Offset in the Temperature Sensor Settings Menu. The displayed actual temperature will be shifted by this amount and will give you an improved absolute accuracy.

Temperature Sensor Setup

Temperature Sensor:	AD590
Sensor Offset:	+ 0.000 °C

Temperature Measurement Range
Minimum Value: − 55.000 °C
Maximum Value: +150.000 °C

TEC ON

◄ Coarse   Fine ►   Done

3.5 Thermistor Settings

In Thermistor Settings menu, the parameters for a thermistor temperature calculation may be set, if a thermistor is used as temperature sensor.

You can choose between two calculation methods, Exponential or Steinhart-Hart. The parameters for the respective method can be set in the two additional menu items as shown below:

For the Exponential Method, the required parameters are R0, T0 and . You can find these values in the data sheet of your thermistor. R0 is the resistance value at the nominal temperature T0, for most thermistors T0 is 25°C. The   value is a material-specific thermistor constant.

For the Steinhart-Hart calculation, you need the A, B and C parameters of your thermistor, indicated in some data sheets.

3.6 PID Control Loop

Manual tuning:

By setting the control loop parameters of the PID control loop manually, the temperature controller of the TED4015 can be adapted to the most different thermal loads.

Two different ways are possible to find the optimal parameters. A PID Auto-Tune function can help to find the optimal parameters easily (see section PID auto tune).

```
┌──┐ PID Control Loop
│PID│
│⊹⚙│
│ ⌇ │
├──┴──────────────────────────────────┤
│ Proportional:              4.500 A/K │
│ Derivative:                5.200 A/Ks│
│ Integral:                  0.800 As/K│
│ Oscillation Period:       10.000 s   │
│                                      │
│ PID Control Loop Testing             │
│   Setpoint:            +  25.000 °C  │
│   Temperature:         +  25.000 °C  │
│   Deviation:           +   0.000 °C  │
│                              ┌──────┐│
│                              │TEC ON││
├──────────┬──────────┬────────┴──────┤
│  ▲ Up    │  ▼ Down  │    Modify      │
└──────────┴──────────┴───────────────┘
```

A manual tuning of the P, I and D parameter can be done with the following steps:

Set the Temperature set point to your required temperature.

```
┌──┐ PID Control Loop
│PID│
│⊹⚙│
│ ⌇ │
├──┴──────────────────────────────────┤
│ Proportional:              4.500 A/K │
│ Derivative:                5.200 A/Ks│
│ Integral:                  0.800 As/K│
│ Oscillation Period:       10.000 s   │
│                                      │
│ PID Control Loop Testing             │
│ ┌─────────────────────────────────┐ │
│ │ Setpoint:            +  25.000 °C│ │
│ └─────────────────────────────────┘ │
│   Temperature:         +  25.000 °C  │
│   Deviation:           +   0.000 °C  │
│                              ┌──────┐│
│                              │TEC ON││
├──────────┬──────────┬────────┴──────┤
│ ◄ Coarse │ Fine ►   │     Done       │
└──────────┴──────────┴───────────────┘
```

Set the Proportional parameter to a very low value (e.g. 0.2) and the Derivative and Integral parameters to minimum (0) in the PID control loop settings menu. Set the Oscillation Period to Minimum (0.2 s).

```
┌──┐ PID Control Loop
│PID│
│⊹⚙│
│ ⌇ │
├──┴──────────────────────────────────┤
│ ┌─────────────────────────────────┐ │
│ │ Proportional:            0.200 A/K│ │
│ └─────────────────────────────────┘ │
│ Derivative:                0.000 A/Ks│
│ Integral:                  0.000 As/K│
│ Oscillation Period:        0.200 s   │
│                                      │
│ PID Control Loop Testing             │
│   Setpoint:            +  25.000 °C  │
│   Temperature:         +  25.323 °C  │
│   Deviation:           +   0.323 °C  │
│                              ┌──────┐│
│                              │TEC ON││
├──────────┬──────────┬────────┴──────┤
│ ◄ Coarse │ Fine ►   │     Done       │
└──────────┴──────────┴───────────────┘
```

Note

The settling behavior may be additionally observed at the DEVIATION OUT jack (R14, section Operating elements at the rear panel) by means of an oscillo-scope (please refer to section TEC control outputs).

Switch on the TEC output with the switch " TEC ON" (F6, see section Operating elements at the front panel). Watch the course of the actual measured temperature. If it oscillates continuously, or even builds up to increasing amplitude, switch the TEC output off immediately. Further decrease the Proportional parameter before switching the TEC output on again.

Proportional (P) parameter:

Repeatedly increase and decrease the Temperature set point about 1…2C around your desired target temperature with the adjustment knob (F8). Watch the settling behavior of the actual measured temperature.

```
┌─────────────────────────────────────────┐
│ ▐PID▌ PID Control Loop                   │
│ Proportional:          0.200 A/K         │
│ Derivative:            0.000 A/Ks        │
│ Integral:              0.000 As/K        │
│ Oscillation Period:    0.200 s           │
│                                          │
│ PID Control Loop Testing                 │
│  Setpoint:          +  27.000 °C         │
│  Temperature:       +  26.401 °C         │
│  Deviation:         −   0.599 °C         │
│                              ┌────────┐  │
│                              │ TEC ON │  │
│ ┌─ Coarse ─┐ ┌─ Fine ▶ ─┐ ┌─ Done ─┐    │
│ └──────────┘ └──────────┘ └────────┘    │
└─────────────────────────────────────────┘
```

Increase the P parameter gradually by turning the adjustment knob clockwise. Higher values will increase the settling speed. To high values will increase the amplitude and number of overshoots. This may lead to an unstable system (continuous oscillation or even increasing amplitude), which should be avoided. The P parameter is set correctly when the oscillation is recognizably damped, this means the actual temperature approaches the set point with each overshoot having about half the amplitude of the previous overshoot. Due to the disabled Integral constant, a temperature deviation may remain. Please evaluate the time span between the maximum temperature of the positive overshoot and the minimum temperature of the following negative overshoot (i.e., half a period); doubling this value will be approximately equal to the full period of a continuous, undamped oscillation. You will need this data to set the "oscillation period" value as described below.

Oscillation period:

The oscillation period value corresponds to the resonance frequency of the temperature control setup. The value entered here impacts the control cycle period of the digital PID control, which is determined as one-hundredth of the oscillation period. Enter the time span recorded in the previous section when you adjusted the P parameter and observed the settling behavior of the temperature.

```
┌─────────────────────────────────────┐
│ ▓▓ PID Control Loop                  │
├─────────────────────────────────────┤
│ Proportional:            4.500 A/K   │
│ Derivative:              0.000 A/Ks  │
│ Integral:                0.000 As/K  │
│ Oscillation Period:      0.200 s     │
│                                      │
│ PID Control Loop Testing             │
│   Setpoint:           + 27.000 °C    │
│   Temperature:        + 27.045 °C    │
│   Deviation:          +  0.045 °C    │
│                             ┌──────┐ │
│                             │TEC ON│ │
│ ┌─────────┐ ┌────────┐ ┌──────────┐ │
│ │ ◄ Coarse│ │ Fine ► │ │   Done   │ │
│ └─────────┘ └────────┘ └──────────┘ │
└─────────────────────────────────────┘
```

Derivative (D) parameter:

Change again repeatedly between temperature set points ±1...2°C around your desired target temperature while observing the settling behavior of the actual temperature.

```
┌─────────────────────────────────────┐
│ ▓▓ PID Control Loop                  │
├─────────────────────────────────────┤
│ Proportional:            4.500 A/K   │
│ Derivative:              0.500 A/Ks  │
│ Integral:                0.000 As/K  │
│ Oscillation Period:     10.000 s     │
│                                      │
│ PID Control Loop Testing             │
│   Setpoint:           + 27.000 °C    │
│   Temperature:        + 27.044 °C    │
│   Deviation:          +  0.044 °C    │
│                             ┌──────┐ │
│                             │TEC ON│ │
│ ┌─────────┐ ┌────────┐ ┌──────────┐ │
│ │ ◄ Coarse│ │ Fine ► │ │   Done   │ │
│ └─────────┘ └────────┘ └──────────┘ │
└─────────────────────────────────────┘
```

Increase the D parameter gradually by turning the adjustment knob (F8) clockwise.

Higher values will decrease the amplitude and number of overshoots. To high values will increase again overshoot effects or will even lead to an unstable system. The D parameter is set correctly when the actual temperature settles at a value close to the temperature set point after a minimum of overshoots. Due to the disabled Integral constant, a temperature deviation may remain.

Integral (I) parameter:

Change again repeatedly between set temperatures ±1...2°C around your desired target temperature.

```
┌─────────────────────────────────────┐
│ ▓▓ PID Control Loop                  │
├─────────────────────────────────────┤
│ Proportional:            4.500 A/K   │
│ Derivative:              5.200 A/Ks  │
│ Integral:                0.800 As/K  │
│ Oscillation Period:     10.000 s     │
│                                      │
│ PID Control Loop Testing             │
│   Setpoint:           + 27.000 °C    │
│   Temperature:        + 27.000 °C    │
│   Deviation:          +  0.000 °C    │
│                             ┌──────┐ │
│                             │TEC ON│ │
│ ┌─────────┐ ┌────────┐ ┌──────────┐ │
│ │ ◄ Coarse│ │ Fine ► │ │   Done   │ │
│ └─────────┘ └────────┘ └──────────┘ │
└─────────────────────────────────────┘
```

Increase the I parameter gradually by turning the adjustment knob (F8) clockwise.

Higher values will accelerate the settling to the set temperature. To high values will increase the amplitude and number of overshoots or will even make the system instable. The I parameter is set correctly when the actual temperature reaches the set temperature in a short time with a minimum of overshoots.

The following table summarizes the effects of increasing the P, D and I share:

Effects of increasing parameters				
Parameter	**Rise Time**	**Overshoot**	**Settling Time**	**Steady-state Error**
Proportional K_P	Decrease	Increase	Small Change	Decrease
Derivative K_D	Small Decrease	Decrease	Decrease	None
Integral K_I	Decrease	Increase	Increase	Eliminate

3.7 PID Auto Tune

A very simple method to adapt the PID parameters to the characteristics of your thermal setup is the use of the implemented PID Auto-Tune function. It is easy to use and gives good results after relatively short time (depending on the time response of your thermal setup).
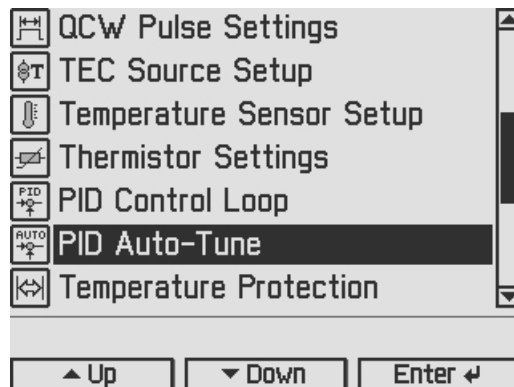
The implemented PID Auto-Tune algorithm is using the Ziegler-Nichols method. That means the I and D shares are set to zero and the algorithm is looking for the "critical gain" KC at which the output of the control loop starts to oscillate. The algorithm is optimized for finding good PID parameters as quick as possible.

The new parameters are displayed and you can set them active or discard them.

This gives a good transient oscillation to a new temperature set point, but it is more optimized to avoid influences of disturbances from outside, such as changes in ambient air temperature, changes in heat sink temperature, laser diode power (lost heat) and so on.

Strictly speaking, a set of PID parameters is valid only for the temperature set point active during PID Auto-Tuning. However, a new temperature set point not too far away will also lead to an adequate transient response. Therefore you will be able to control the temperature of your system effectively in a certain temperature range of many degrees (depending on your thermal setup).

If the system behavior for another temperature set point is not good enough, you can start the PID Auto-Tune function at the new temperature set point again. In this case, a quick 5 step Auto-Tune procedure is started under the following conditions:

- You already finished a PID Auto-Tuning successfully before
- You didn't change the PID parameters by hand in the meantime
- You didn't unplug the cable between the TED4015 and your thermal setup (e.g. changing the mount).

To save time, the new quick PID Auto-Tune process tries only to readjust the PID parameters calculated before. It starts without changing the KP value and the oscillation period value.

Normally you will get better PID parameters for the new temperature set point after a shorter time. If the KP tuning has to be greater than the allowed range the re-adjusting fails and the complete PID Auto-tuning over the whole KP range is started automatically, giving you a better tuned PID-Controller at the end.

Sometimes the PID Auto-Tune function may not finish successfully. In that case, the KC of your system may be outside the possible tuning range (smaller than 0.1 or greater than 100). Please try it out by manually tuning the PID-Controller.

If the PID Auto-Tune function finishes very fast but gives bad results, your system might be too noisy, and the noise (maybe 50 or 60 Hz) could be interpreted as oscillations of your system. Eliminate the noise and try the PID Auto-Tune function again.

If you don't like the system performance given by the PID Auto-Tune function, you can tune the parameters manually (see section PID control loop settings).

When you found the ideal PID parameters for your system, you can save them together with many other settings (e.g. temperature set point, current limit …) into one of the eight memory locations (see section Saving and restoring setups).
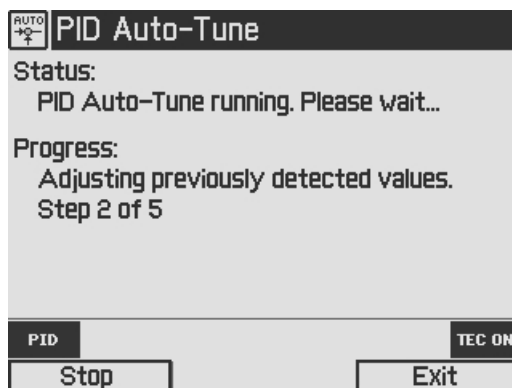
Press Start to run the PID Auto-Tune procedure. The following screenshots show a selection from the 8 steps of a full range tuning. The green LED in the TEC ON key is flashing while the procedure is running. Press Cancel or the ESC key to abort the procedure.
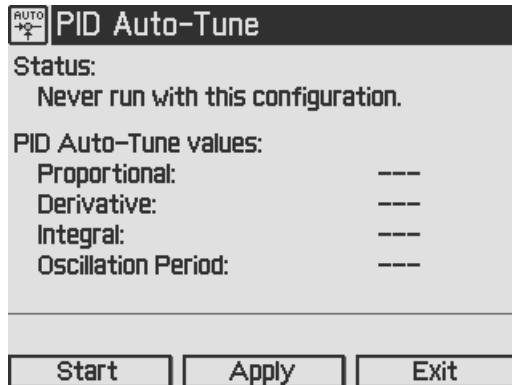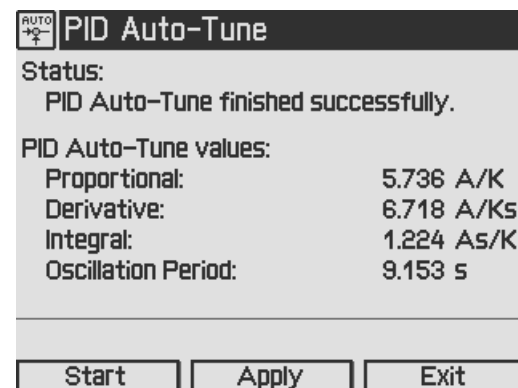

PID auto-tune never run
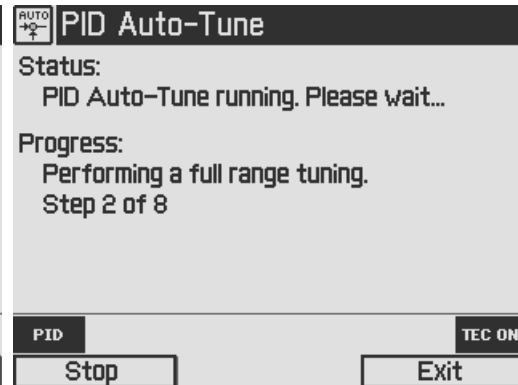
PID full range tuning

Adjusting previously detected values

PID auto-tune finished successfully

3.8 Temperature Protection

The TED4015 temperature controller provides an adjustable **Temperature Window** to monitor the correct function of the temperature control. The display shows a "plus / minus" value, so if you select i.e. 5 °C, the window will reach from 5 °C below the temperature setpoint to 5 °C above the temperature setpoint.
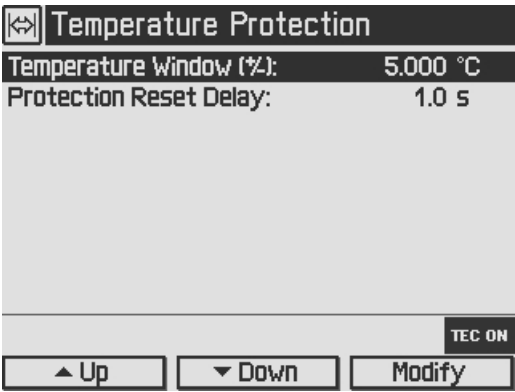
If the actual temperature moves out of the preset window, the green LED in the ON key (F5, see Figure 1 at chapter Operating elements at the front panel) is flashing and the temperature protection indicator flashes up.
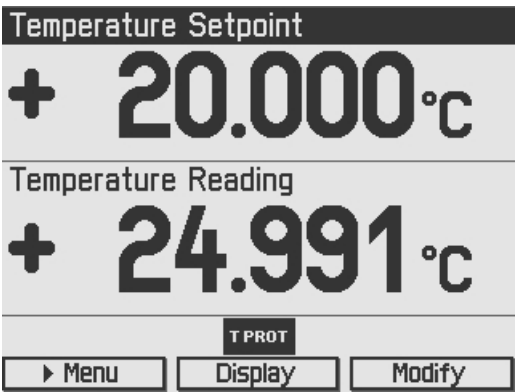

To avoid multiple sets and resets of the window protection error in transient oscillation or during tuning steps, you can adjust an appropriate **Protection Reset Delay**. A value between 50% and 100% of the oscillation period is recommended. With this setting, the window protection will reset only if the actual temperature remains inside the window for a sufficient time, indicating a stable settling to the temperature set point.
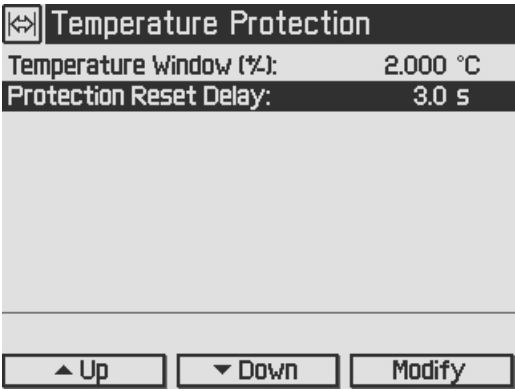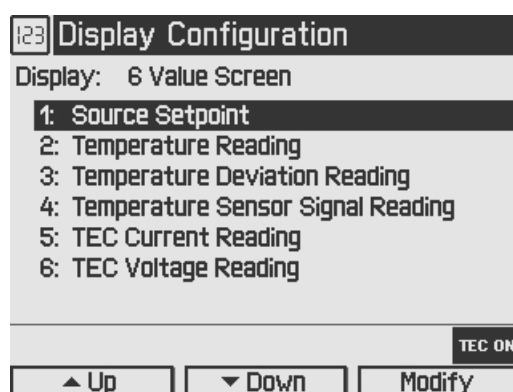
3.9   Display Configuration

The display can be configured to show two, four or six values on the screen. Factory setting is the two value screen.
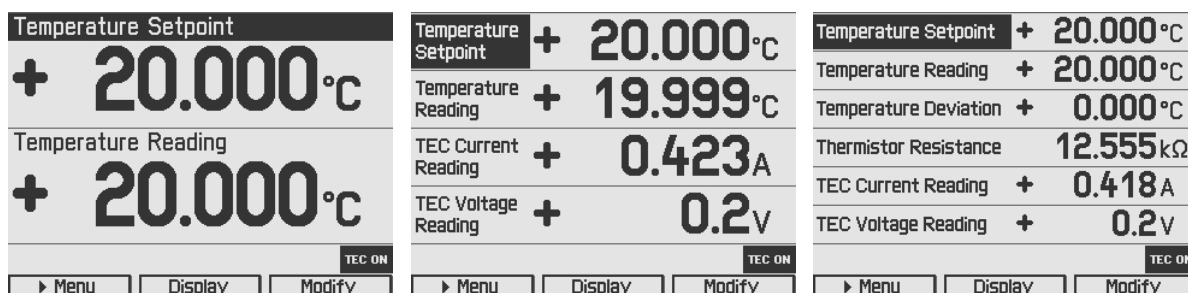
You can select your favored measurement screen by pressing the **Display** button or in the Display Configuration menu. Press the **Menu** button, scroll to the Display Configuration and press the **Enter** button or the adjustment knob. You get the following display configuration:

In the **Display configuration** menu you can select the favorite screen configuration with two, four or six values. For each value number (depending on selected values per screen), you can choose one of the following setpoints or readings:

- Source Setpoint; shown value dependent on selected operating mode (Temperature Setpoint if constant temperature mode or TEC Current Setpoint if constant current mode)
- Temperature Setpoint
- TEC Current Setpoint
- Temperature Reading
- Temperature Deviation Reading
- Temperature Sensor Signal Reading
- TEC Current Reading
- TEC Voltage Reading
- TEC Power Reading

For choosing the desired values please select the appropriate line by turning the adjustment knob. Then press **Modify** or the adjustment knob and choose your desired value. Confirm your selection by pressing **Done** or the adjustment knob again.

3.10 Settings Memories

With the exception of the "TEC ON"state, all settings will be saved when the TED4015 controller is powered down.

Additionally, the **Settings Memories** menu can be useful in saving several sets of specific settings like: current limit, temperature limits, sensor input settings etc. for the connected TEC setup. Consequently, you can reload the saved setup parameters from one of the eight memory spaces in the **Settings Memories** menu.
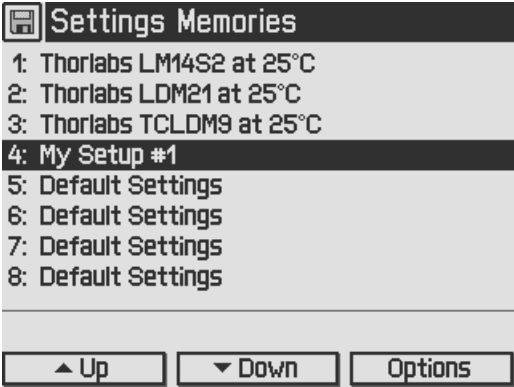

At the positions 1 ... 3, the parameters (for a temperature setpoint of about 25°C) are pre-saved for the Thorlabs laser mounts. The parameter sets # 4...8 can be used to save your personal setups. If more space is required, and you don't need the pre-saved parameter sets # 1...3, you may overwrite them.

Select the desired data set by turning the adjustment knob or by pressing **Up / Down**. Enter the menu for the respective data set by pressing the **Options** key or the adjustment knob.
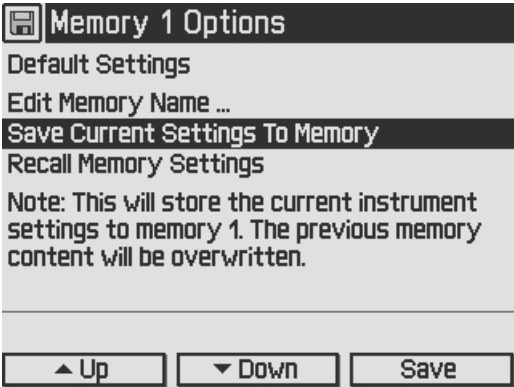

Save Current Settings To Memory allows to save all current temperature controller settings. Note that this will overwrite the settings stored in the selected data set.
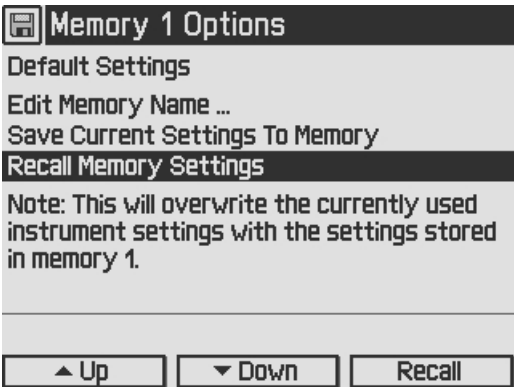
Via **Recall Memory Settings** you can load a saved laser setup. Note that this will overwrite your currently used instrument settings.

Before recalling data from the memory, the laser and TEC outputs must be switched off (if on) by means of the LD ON / TEC ON buttons (F6 and F7, see section Operating elements at the frontOperating Elements panel).
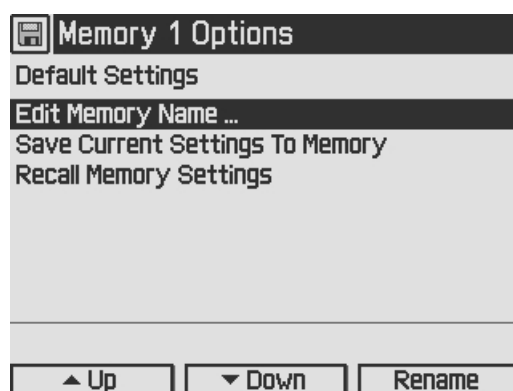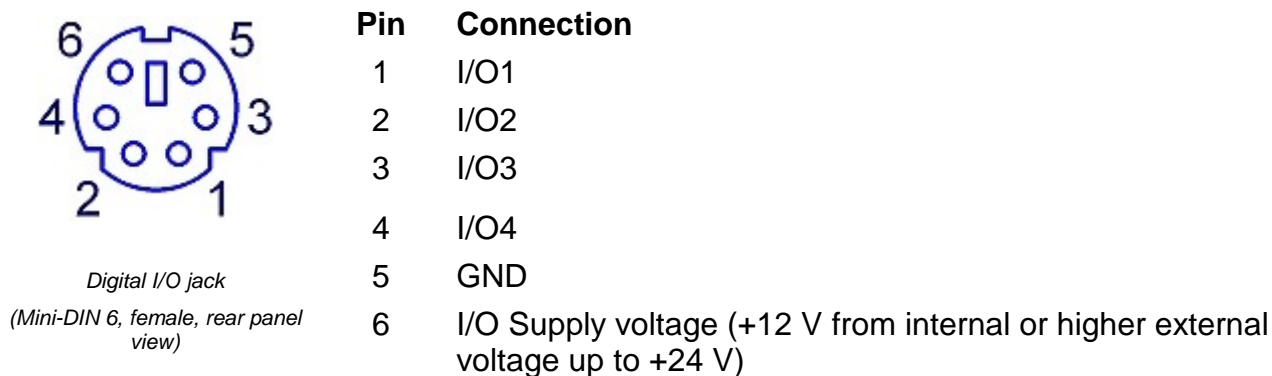
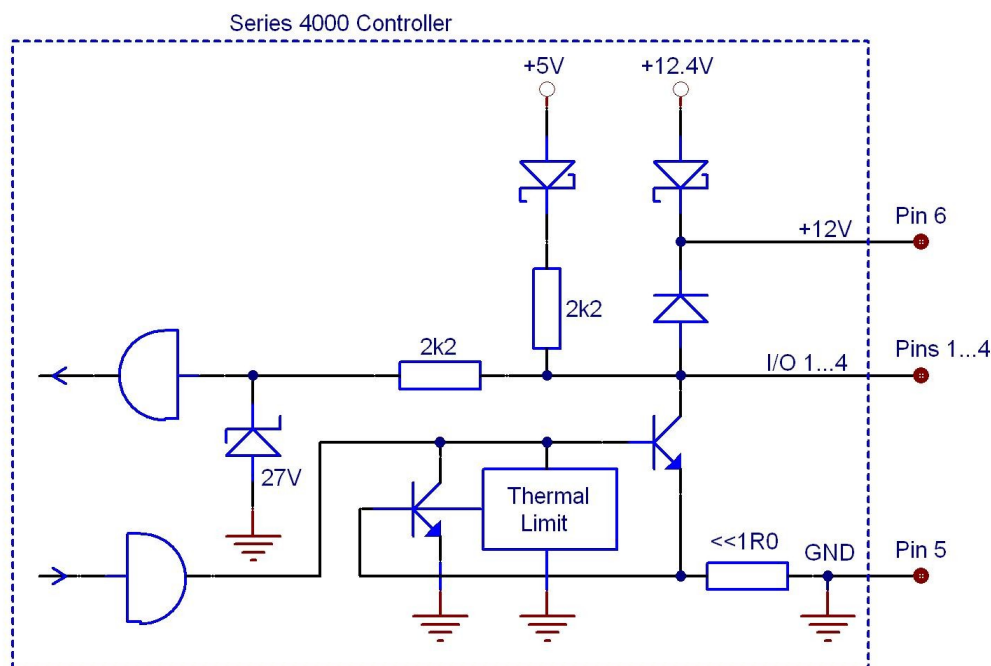The name of the data set can be changed in the **Edit Memory Name …** menu.
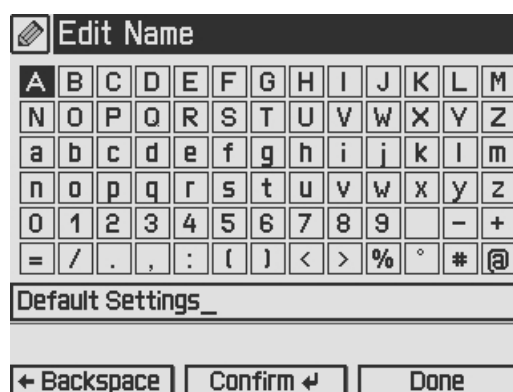
In the **Edit Memory Name…** menu you get a table of characters. Select a character by turning the adjustment knob (F8) and then press **Confirm**. The selected character will be inserted in the text field. Delete mistyped characters by pressing **Backspace**. When you are finished, confirm with **Done**.

3.11 Digital I/O ports

The tempererature controllers of the TED4015 series have a very versatile digital port providing four separately configurable Input / Output lines. This feature allows control of external circuitry from the unit, or control of the unit from external circuitry (via PC software). Figure 58 shows the pin layout of the 6 pin Mini-DIN jack (R13, see section Operating elements at the rear panel).

Pin	Connection
1	I/O1
2	I/O2
3	I/O3
4	I/O4
5	GND
6	I/O Supply voltage (+12 V from internal or higher external voltage up to +24 V)

Digital I/O jack

(Mini-DIN 6, female, rear panel view)

The figure below shows the I/O port basic circuit (applicable for each channel).

Any I/O line configured as input accepts TTL levels (0 V / +5 V) and is tolerant of higher voltages up to +24 V. When the input is left open, an internal +5 V pull-up resistor in series with a diode shifts the input to high level.

Any I/O line configured as output can source up to 2 mA when high (+5 V) and sink up to 400 mA when low.

The outputs are current-limited and infinitely short-circuit proof.

Additionally a +12 V supply output is provided to drive a relay or other external circuitry. The maximum output current is 500 mA. This supply output is current-limited and infinite short-circuit proof.

The following figures show three typical output configurations.

I/O port source operation
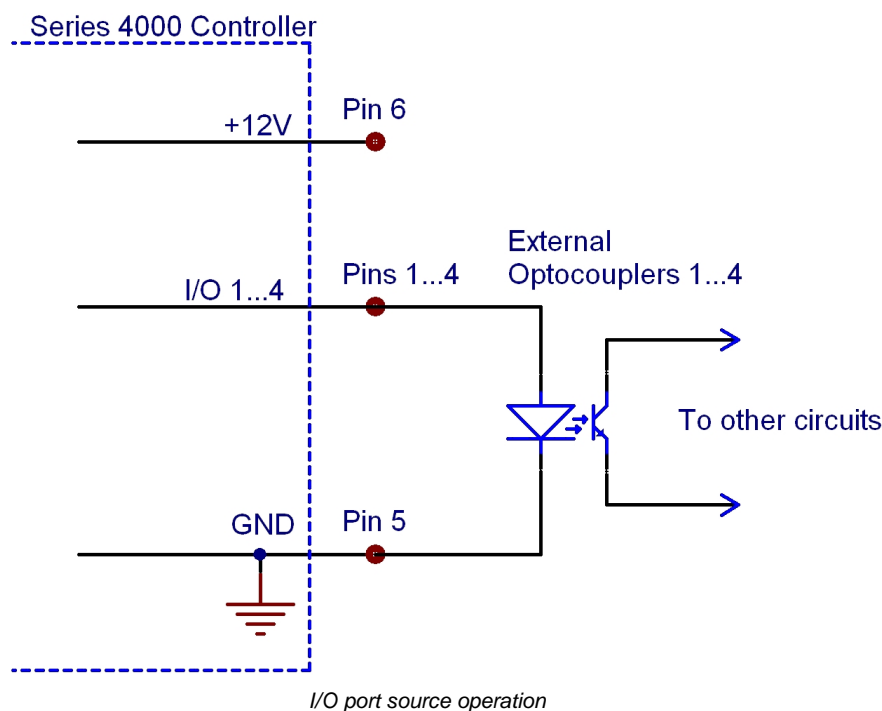
In above circuit, the output drives an optocoupler in source operation. This component may be replaced by a LED or a switching transistor. To switch the connected device to on-state, the output level of the digital I/O line must be set HIGH. The maximum source current is 2 mA.

I/O port sink operation
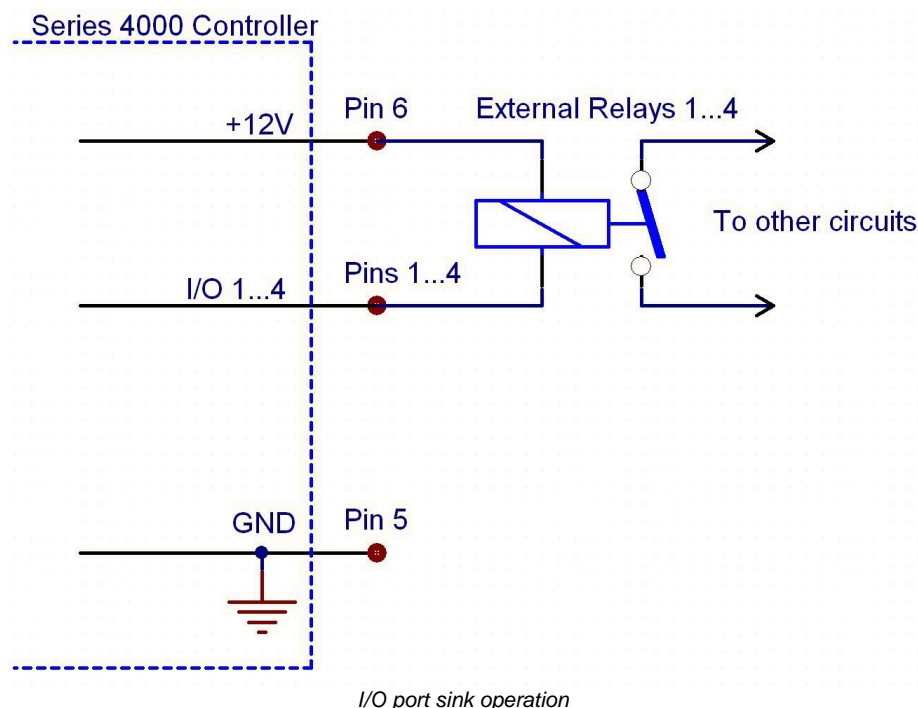
In above schematic, the output drives a relay in sink operation. Note that the external relay coil is connected between the digital I/O line (pins 1 …4) and +12 V (pin 6).

To energize the external relay, the output level of the digital I/O line must be set LOW. The maximum sink current is 400 mA.

If a lower supply voltage is required for the relay, a standard voltage regulator may be inserted between pin 6 and the relay coil contact.

I/O port with external supply
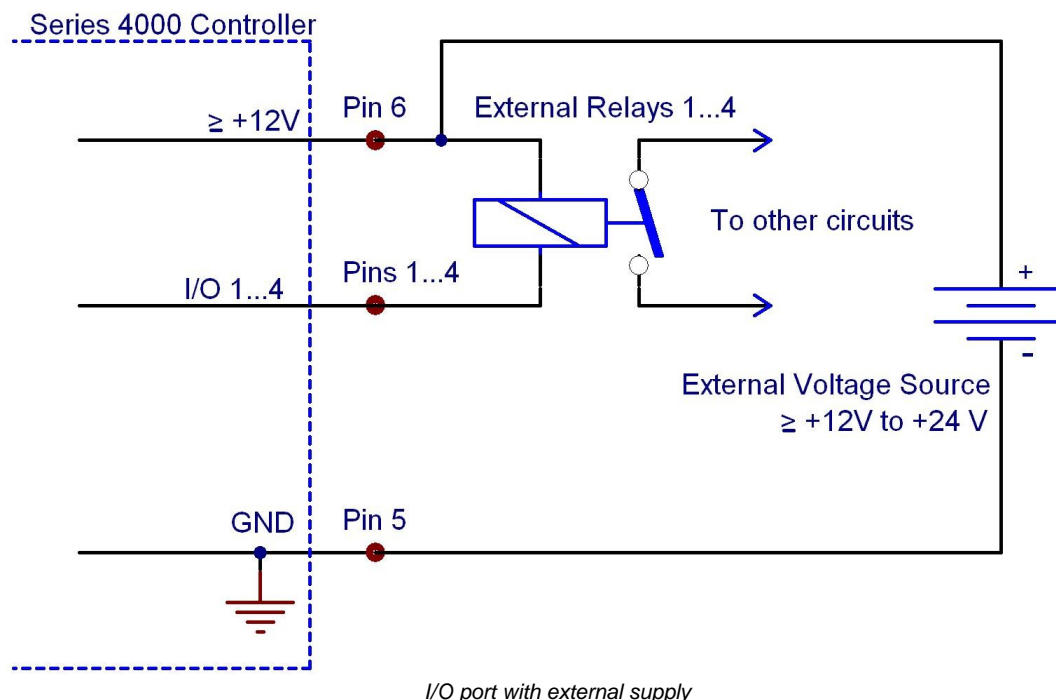
In the figure above, the output drives a relay in sink operation using a higher external voltage supply (≥ +12V to +24V). To energize the external relay, the output level of the digital I/O line must be set LOW. The maximum sink current is 400 mA.

When driving a relay, connect your external supply voltage also to pin 6 of the digital I/O jack in order to connect the internal de-spiking clamping diode in parallel to the relay coil. The internal +12 V supply (which passes a serial diode) is overridden and non-effective in this case.

In **Digital I/O Port** menu the direction of each port can be set to input or output.

In addition the output level of each I/O port can be set, if configured as output. The actual pin level of each port pin is monitored and displayed in the third line.

For enhanced controlling, please use the remote control interface from an external PC or Laptop. See the *Thorlabs "Series 4000 Programmers Reference Manual"* on the included "Series 4000 Instrumentation CD".

3.12 Systems Preferences

The System Preferences menu allows to select different settings concerning your TED4015 system configuration, including Message Handling, Display Brightness, Display Contrast, Sound Signals, and Update Capability.

For detailed explanations please see section Getting Started - System Preferences.

3.13 Remote Control
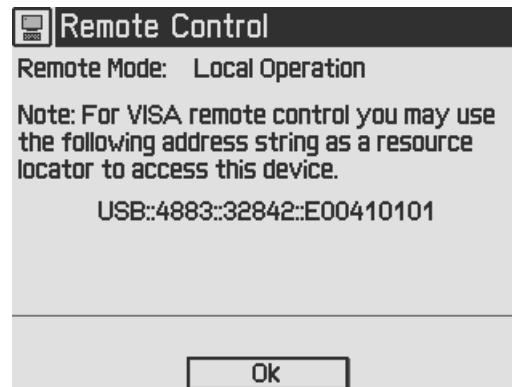
This menu displays the remote control state of the device.

3.14 Information

The last menu topic displays important information on the unit, such as type, serial number, date of last calibration and software versions.

4 Computer interface

4.1 Using the USB Iinterface

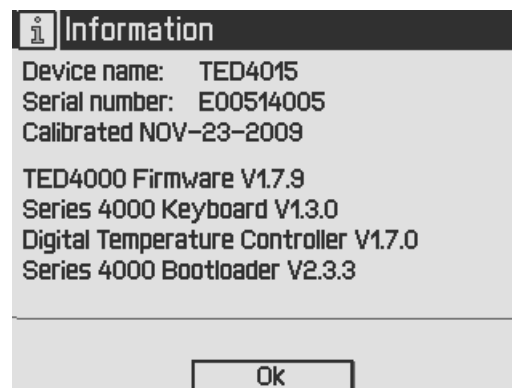The instrument provides a USB 2.0 Full Speed link according to the USB 2.0 specification, the USBTMC specification and the USBTMC USB488 specification. It allows sending commands from a host computer to the instrument. The connection to the PC is accomplished by a USB cable with a type 'A' connector at the PC side and a type 'B' connector on the instrument side.

When connecting the instrument to the PC the first time, on Windows systems the "New Hardware Found" wizard will be displayed. Proper installation requires a VISA library with USBTMC support to be installed on your system in advance (e.g. NI-VISA available at the National Instruments website www.ni.com or from the data carrier that comes with the instrument. Allow the installation and follow the dialog instructions).

Via the instrument's USB interface you may easily connect to third party data logging, data acquisition and data analysis software (e.g. MATLAB, NI LabVIEW Signal Express, Agilent VEE). For basic instrument communication you may also use the *Thorlabs Instrument Communicator 2* Software from the accompanying data carrier. Please see also the *SCPI Programmers Reference Manual* for a detailed description of the instrument's command set.

When receiving a command, the TED4015 will enter its **Remote** mode.This will be indicated by the REMOTE Symbol in the Status Bar. The right softkey (F4) will serve as a Local button, which switches back from Remote mode to Local operations mode. In Remote mode, the front panel setup of the instrument is disabled to avoid accidental entries and settings conflicts. This also includes the LD ON key and the TEC ON key..
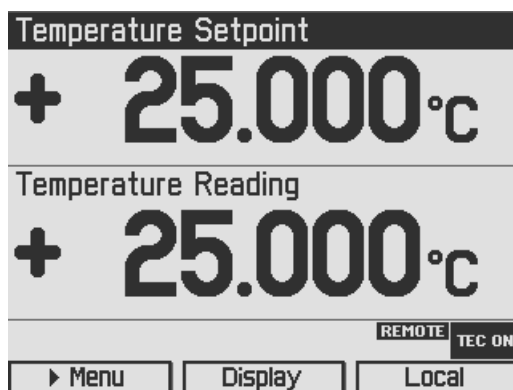
4.2 Instrument Driver Installation

The software package that comes with the device contains a VXIpnp instrument driver. This instrument driver library simplifies the instrument control and reduces test program development time. It is suitable for various programming environments including NI-LabVIEW, NI-LabWindows/CVI and MS-Visual Studio.

Prior to connecting the instrument to a PC, please check if a VISA engine is installed on the PC, otherwise install the NI-VISA engine that is available for free from the National Instruments website www.ni.com or from the included data carrier.

Note

To complete the installation of the TED4015 USB driver successfully, you must have Administrator privileges on the PC on which you are performing the installation.

After successfully installing the drivers connect the TED4015 to a USB port of your PC. The PC will find a test and measurement device. Please follow the instructions of the dialog screens and allow the installation.

Various programming examples demonstrate how to use the instrument driver and how to communicate successfully with your instrument. The examples are installed with the instrument driver and may be found in the drivers installation directory.

4.3 Firmware Update

Firmware upgrades can be accomplished by the user via the USB interface using the software "Thorlabs DFU Wizard".

NOTE

To install the Thorlabs DFU wizard successfully, you must have Administrator privileges on the PC, and the instrument must be powered down or disconnected from the USB.

Follow the instructions below to upgrade your instrument:

- Install the Thorlabs DFU Wizard on your PC.
- Download the new Firmware file from the Thorlabs web site (www.thorlabs.com).
- Switch on your instrument and connect it to a USB port of your PC.
- Make sure the Update Capability is "enabled" or "enabled once" in the System Preferences Menu (refer to chapter System preferences)
- Launch the DFU Wizard from the start menu. Follow the DFU Wizard instructions.

- During the process a new DFU capable device will be recognized by the PC. Make sure to install this device properly.
- If the following error message appears, click "Yes" to retry finding the device and continue the installation of the new firmware.
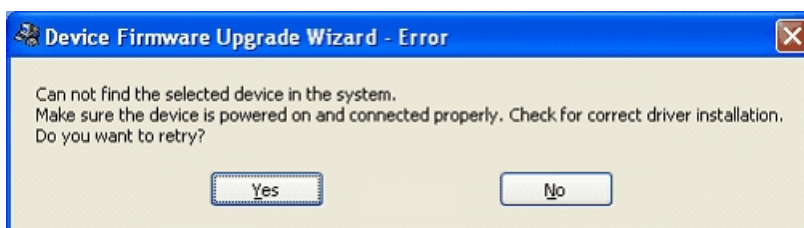
NOTE

Do not switch off the instrument or disconnect the USB cable during the firmware download.

5 Maintenance and Repair

5.1 General Remarks

The TED4015 temperature controllers does not need regular maintenance by the user. It does not contain any modules that could be repaired by the user himself. If a malfunction occurs, the whole unit has to be sent back to *Thorlabs*. Do not remove covers!

If any disturbances in function occur, please refer first to chapter Troubleshooting.

If you don't find the error source by means of the trouble shooting list please first contact *Thorlabs* before sending the TED4015 temperature controller for checkup and repair to *Thorlabs* (refer to section Thorlabs Worldwide Contacts).

If highest precision of measurements is vital to you, you should have the temperature controller recalibrated by *Thorlabs* about every two years.

General care

Protect the unit from adverse weather conditions. The TED4015 temperature controllers are not water resistant.

Attention

To avoid damage to the TED4015 temperature controllers, do not expose it to spray, liquids or solvents!

Cleaning

The unit and the display can be cleaned with a cloth dampened with water. You can use a mild 75% Isopropyl Alcohol solution for more efficient cleaning.

5.2 Line Voltage Settings

The TED4015 temperature controller operates from line voltages 100 ... 120 V AC and 200 ... 240 V AC ±10%. The line frequency range is 50 ... 60 Hz, thus it can be operated worldwide without any adjustment or voltage setting.

5.3 Replacing the Mains Fuses

The two power input fuses are externally accessible. If they have opened due to line disturbance or other influences from the outside, they can be replaced at the rear without opening the unit.

Warning

To avoid fire hazard, replace the two mains fuses with fuses of the specified type and rating only. Fuse Type: IEC60127-2/1 (High breaking capacity!), F10 H 250V, fast acting (F) 10 Amperes, size 5 x 20 mm

Instructions:

1. Power off the TED4015 and disconnect the mains cable.
2. The fuse holder (R10, see Figure 17) is located below the 3-terminal power connector of the mains jack (R9). Release the fuse holder by bending its two plastic retainers with the aid of two small screwdrivers. The retainers must be pressed towards the center of the fuse holder.
3. Replace the defective fuses (R11). We recommend changing both fuses, even if only one fuse has opened. Press in the fuse holder until locked on both sides.
4. Switch on the unit. If it cannot be switched on, please contact your supplier or *Thorlabs*.
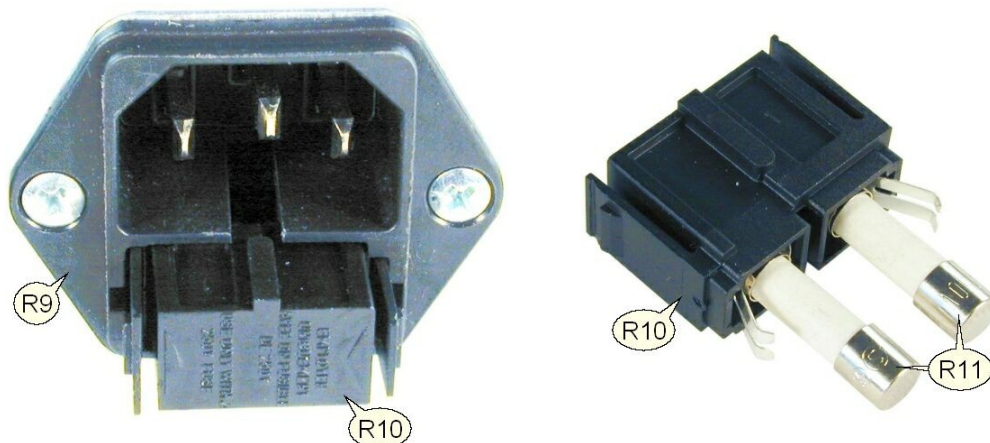
5.4 Troubleshooting

In case that your TED4015 shows malfunction, please check the following items:

➢ **Unit does not work at all (nothing is shown on the display at the front):**
- Is the TED4015 connected to the mains properly?
- Is the TED4015 turned on?
- Check the fuses on the rear panel (see section Replacing the mains fuses). If blown, please replace the fuses by the correct type.
- Check via SCPI interface if the unit works (see section Computer Interface). If you can connect to the unit properly, please check display settings via remote control (brightness and contrast).

➢ **The display works, but you don't get the desired operation temperature, current or power:**
- Are the corresponding hardware limits set correctly? Please refer to section Setting the TEC source parameters
- Is the TEC setup connected correctly to the 17W2 DSUB jack at the rear panel?
- Is the interlock circuit close? Please refer to section Connecting Interlock and TEC ON Monitoring
- Please check all cables and the TEC polarity. Please refer to section Connecting a TEC element
- Is a temperature sensor been connected properly, and has the sensor type been selected correctly? Check the corresponding connections and polarities of the temperature sensor (please refer to chapter Connecting a temperature sensor). Check the temperature sensor settings (please refer to chapter Temperature sensor setup)

➢ **The temperature in constant temperature mode is oscillating.**

- Please check the PID settings in section PID control loop settings

If you don't find the error source with the help of the troubleshooting list, please contact the Thorlabs (see Thorlabs Worldwide Contacts before sending the unit to Thorlabs for checkup and repair.

- Please check the error messages before calling.
- For information about the installed firmware, please check the current firmware versions on the Information screen before calling:.
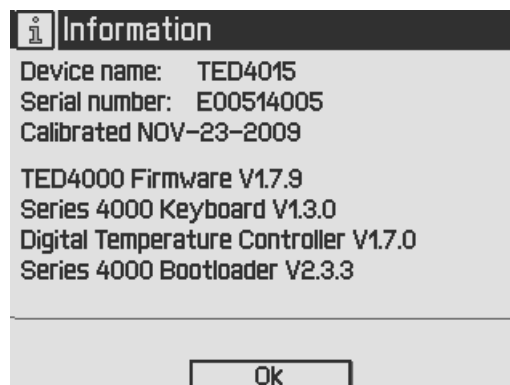
6   Appendix

6.1   Technical Data

	TED4015	
	Front Panel	Remote Control
TEC Current Output		
Current range	-15 to +15 A	
Compliance voltage	15 V	
Max. TEC output power	225 W	
Setting resolution	1 mA	0.1 mA
Accuracy	±(0.2% reading + 20 mA)	
Ripple and noise (10 Hz to 10MHz, rms, typ.)	<10 mA	
TEC Current Limit		
Setting range	0.1 to 15 A	
Setting resolution	1 mA	0.1 mA
Accuracy	±(0.2% reading + 10 mA)	
NTC thermistor sensors		
Resistance measurement ranges	100 Ω to 100 kΩ / 1 kΩ to 1 MΩ	
Temperature control range (max.) [1]	-55°C to + 150°C	
Resolution 100 kΩ range	0.1 Ω	0.03 Ω
Resolution 1 MΩ range	1 Ω	0.3 Ω
Accuracy [2]	±(0.06% reading + 1 Ω / + 5 Ω)	
Temperature stability (24 hours typ.) [1]	< 0.002° C	
Temperature coefficient	< 5 mK/°C	
IC sensors		
Supported current temperature sensors	AD590, AD592	
Supported voltage temperature sensors	LM35, LM335, LM235, LM135	
Temperature control range AD590	-55 to +150 °C	
Temperature control range AD592	-25 to +105 °C	
Temperature control range LM35	-55 to +150 °C	
Temperature control range LM335	-40 to +100 °C	
Temperature control range LM235	-40 to +125 °C	
Temperature control range LM135	-55 to +150 °C	
Resolution	0.001 °C	0.0001 °C
Accuracy AD590 current	±(0.04% reading + 0.08 µA)	
Accuracy LM335/LM35 voltage	±(0.03% reading + 1.5 mV)	
Temperature stability (24 hours typ.)	< 0.002 °C	
Temperature coefficient	< 5 mK/°C	
Pt100 / Pt1000 RTD sensors		
Temperature control range	-55 to +150 °C	
Resolution	0.001 °C	0.0003 °C

	TED4015	
	Front Panel	Remote Control
Accuracy	± 0.3 °C	
Temperature stability (24 hours typ.)	< 0.005 °C	
Temperature coefficient	< 20 mK/°C	
Temperature Window Protection		
Setting range T_{WIN}	0.01 to 100 °C	
Protection reset delay	0 to 600 s	
Window protection output (TEMP OK)	BNC, TTL 5V (open collector with internal pull-up resistor 2 kΩ)	
Temperature Deviation Output		
Load resistance	>10 kΩ	
Transmission coefficient (temperature deviation scaled to temperature window)	$T * 5V / T_{WIN} \pm 0.2\%$.	
TEC voltage measurement		
Measurement principle	4-wire / 2-wire	
Measurement range	-16.5 to +16.5 V	
Resolution	100 mV	40 mV
Accuracy (4-wire)	± 50 mV	
Digital I/O port		
Number of I/O lines	4 (separately configurable)	
Input level	TTL or CMOS, voltage-tolerant to max.24 V	
Output level (source operation)	TTL or 5 V CMOS, 2 mA max.	
Output level (sink operation)	open collector, up to 24 V, 400 mA max.	
Interface		
USB 2.0	according to USBTMC/USBTMC-USB488 specification Rev. 1.0	
Protocol	SCPI compliant command set	
Drivers	VISA VXIpnp™, MS Visual Studio™, MS Visual Studio.net™, NI LabView™, NI LabWindows/CVI™	
Connectors		
Connector for TEC element, temperature sensors, 12VDC, interlock	17W2 mixed DSUB jack (female)	
Connectors for DEVIATION OUT and TEMP OK OUT	BNC	
Chassis ground connector	4 mm Banana jack	
Connector for USB interface	USB type B	
Connector for Digital I/O	Mini DIN 6	
Mains input	IEC 60320	
Safety features		
Keylock switch	yes	
Sensor failure protection	yes	

	TED4015	
	Front Panel	Remote Control
Over temperature protection	yes	
Short circuit when TEC off	yes	
Temperature setpoint limit	yes	
Temperature window protection	yes	
TEC current limit	yes	
TEC open circuit protection	yes	
General Data		
Line voltage	100 to 120V ±10% / 200 to 240V ±10%	
Line frequency	50 to 60 Hz ±5%	
Maximum power consumption	600 VA	
Supply mains over-voltage	Category II (Cat II)	
Operating temperature (non condensing)	0 to +40°C	
Storage temperature	-40 to 70°C	
Relative humidity	max. 80% up to 31°C, decreasing to 50% at 40°C	
Pollution degree (indoor use only)	2	
Operation altitude	< 2000 m	
Warm-up time for rated accuracy	30 min	
Weight	5.3 kg	
Dimensions (WxHxD) without operating elements	263 x 122 x 307 mm³	
Dimensions (WxHxD) with operating elements	263 x 122 x 345 mm³	

[1] control range and thermal stability dependent on thermistor parameters

[2] depending on the selected measurement range

All technical data are valid at 23 ± 5°C and 45 ± 15% rel. humidity (non condensing)

6.2 Setup and Function of a Temperature Controller

When devices are tempered normally, the following components are involved:

- The component to be tempered (i.e. a laser diode)
- A sensor measuring the temperature of the component
- A heat source or sink (air or water / cooling element)
- A heat conductor connecting the component to the source / sink (copper, aluminium)
- A "propulsion" to lead the flow of heat (TEC element)
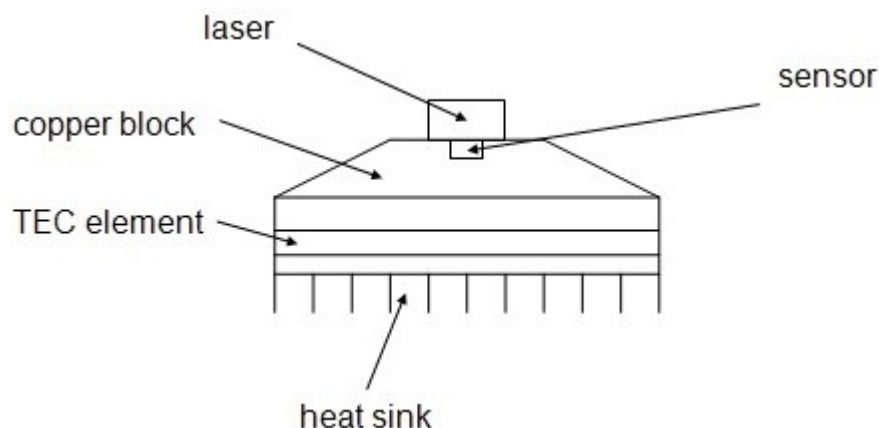
Statements and implications

- The temperature of the laser can be measured with the sensor.
- In the copper block, there is a heat flow between laser and TEC element.
- In the TEC element, there is a heat flow between copper block and heat sink.
- In the heat sink, there is a heat flow between TEC element and environment.
- The temperature difference in the TEC element can be controlled by the TEC current. This has a direct influence on the heat flow in the copper block and in the heat sink.

Hence the temperature of the laser can be influenced by the TEC current. The quantity of heat flowing from the laser into the copper block and the size of the block impacts the reaction speed of the setup.

Usually very small components (laser diodes) are tempered with relatively large cooling elements (TEC elements). Thus the dissipated power must be lead away quickly, and the components are to be kept at the same temperature as close as possible.

Demands to the ideal temperature control loop

1. Knowledge of the absolute laser temperature
2. Stability of the laser temperature under any influence
3. Immediate settling to a new laser temperature when changing the set value of the temperature

Influences on the real temperature control loop

To 1:

The sensor cannot be fixed to the laser chip in such a way that it will measure it's temperature exactly. The reason is, that the temperature in the heat sink has a gradient due to the heat flow. Further, even within the laser chip the temperature is not homogeneous.As for this, offset and gain errors of the sensor lead to deviation in laser temperature measurement.

Possible solution: sensor calibration

To 2.

If the internal power dissipation changes (e.g. the laser current is changed), the temperature gradient between laser and sensor changes as well. This results in a measurement error depending on the mechanical setup laser/sensor. Changes in the ambient temperature however will be compensated well by the control loop since they will almost only have an effect on the heat slope between TEC element and cooling element.

Possible solution: improved thermal design

To 3.

The transient response after setting a new temperature is limited since the heat transport in the heat sink is relatively slow. Furthermore the temperature slope in the heat sink must form anew. The sensor (which also possesses a significant heat capacity) must settle to the laser temperature.

Possible solution: PID controller adjustment

6.3 PID Controller Theory

The temperature controller in the TED4015 series is using a digital proportional-integral-derivative controller (PID controller) to correct the difference between a measured temperature and a desired temperature set point. The temperature can be adjusted accordingly by calculating and then outputting a corrective current.

The PID controller calculation (algorithm) involves three separate parameters; the Proportional, the Integral and Derivative values. The Proportional value determines the reaction to the current temperature error, the Integral value determines the reaction based on the sum of recent temperature errors, and the Derivative value determines the reaction based on the rate at which the temperature error has been changing. The weighted sum of these three terms is used to adjust the temperature via the current supply of a cooling/heating element (Thermo Electric Cooler (TEC) – Peltier Element).

The PID control scheme is named after its three correcting terms, whose sum constitutes the manipulated variable (MV). Hence:

$$ \mathrm{MV(t)} = P_{\mathrm{out}} + I_{\mathrm{out}} + D_{\mathrm{out}} $$

where P_{out}, I_{out}, and D_{out} are the contributions to the output from the PID controller from each of the three terms.
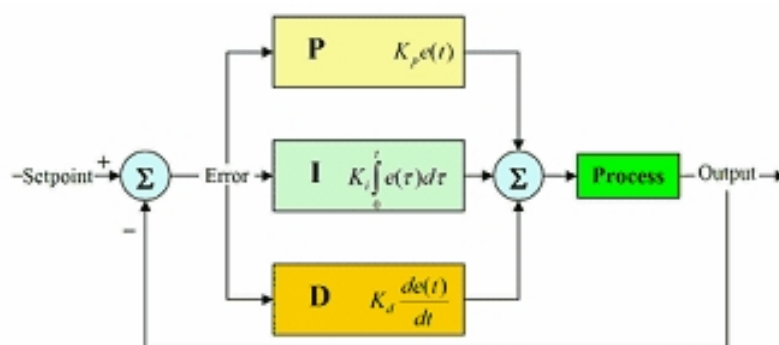
By "tuning" the three constants in the PID controller algorithm, the controller can provide control action designed for specific process requirements. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the set point and the degree of system oscillation.

You can set every constant (P, I, D) to zero to disable it. That means you can use the PID controller only as PI controller by setting the Derivative value to zero. This may be useful in a noisy environment since derivative action is very sensitive to measurement noise. On the other hand, the absence of an integral value may prevent the system from reaching its target temperature and is not recommended.

6.4 Menu Structure Overview

Menu topic	description
TEC Source Setup	TEC current limit, Temperature set point limits, temperature set point, and current set point can be changed
Temperature Sensor Setup	a temperature sensor can be selected and the sensor offset can be adjusted
Thermistor Settings	the parameters for the thermistor temperature calculation can be entered
PID Control Loop	the PID control loop parameters can be shown and changed manually
PID Auto-Tune	the PID auto-tune process can be started and the found parameters can be applied to the PID control loop settings
Temperature Protection	the TEC's temperature protection window can be defined and the error behavior can be set
Display Configuration	two, four or six value measurement screen can be picked and the displayed set points or readings can be changed
Settings Memories	8 different Laser setups can be saved or reloaded
Digital I/O Port	the direction and the levels of the digital I/Os can be read or written
System Preferences	the system settings like message handling, display brightness and contrast, sound signal on/off, line frequency and update capability can be changed.
Remote Control	contains the address string for use of VISA remote control
Information	contains device specific information like device name, serial number, calibration date, and the current firmware version

6.5 Factory Settings for Thorlabs TED4015 Controllers

Set Value	Factory Setting
TEC Operating Mode	constant temperature
TEC Current Limit	0.1A
set point Low Limit	-55°C
set point High Limit	+150°C
Temperature set point	+25°C
Current set point	0A
Temperature Sensor	thermistor (low)
Sensor Offset	0°C
Exponential R0 value	10.000kΩ
Exponential T0 value	25.000°C
Exponential β value	3977
Steinhart-Hart parameter A	1.129241 EXP-3
Steinhart-Hart parameter B	2.341077 EXP-4
Steinhart-Hart parameter C	0.087755 EXP-6
PID Proportional value	1.000 A/K
PID Derivate value	0.1 A/Ks
PID Integral value	0.0 As/K
PID Oscillation Period	0.2 seconds
TEC Temperature Window	5.000°C
TEC Protection Reset Delay	1.0 second
Display	2 value screen
Display Value 1	Source set point
Display Value 2	Temperature Reading
Display Brightness	100%
Display Contrast	65%
Sound Signals	Enabled
Line Frequency	Auto
Update Capability	Disabled

6.6 Error Messages

6.6.1 LED Status Messages

TEC ON switch LED	Description
Green	TEC output ON
Green flashing	- Temperature out of window (temperature protection) - PID Auto-Tune is running
Red	Critical errors: - No sensor - No cable - TEC open
Red flashing	Internal device overtemperature (OTP)

6.6.2 Status Indicators

The TED4015 has various status indicators in the bottom line.

The meanings are:

Status indicator	description
OTP	The unit is internally overheated. The TEC output is switched off and can be switched on again after a temperature drop of about 10 degrees
REMOTE	The unit is in remote operation
TMC-ID	The unit is in TMC identification (via remote)
LOCK	The unit is in remote operation and a local operation is locked.
ERROR	Interface error indicator. There are errors stored in the device's error queue. They can be read using the syst:err? command
PID	The PID auto-tune process is running
CABLE	Indicates an incorrect wiring to the TEC setup
SENSOR	A wrong sensor is selected or the sensor lines are broken
T PROT	The current TEC temperature is outside the preselected temperature window and the temperature protection is active.

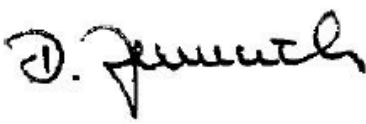## 6.6.3 Instrument Errors

Switch Off / Output Protection Errors

Error	Description
The instrument is too hot	The TEC output was switched off because the instrument is internally overheated
TEC output voltage protection was tripped	The TEC output was switched off because the output compliance voltage was exceeded
Temperature sensor failure detected	The TEC output was switched off because a temperature sensor error occured
TEC cable connection failure detected	The TEC output was switched off because the interlock connection was opened
PID Auto-Tune finished	The PID Auto-Tune procedure is finished, check the status information in the Auto-Tune Menu

Other Instrument Errors

Error	Description
Instrument is overheated	The units internal temperature is too high. The laser output and the TEC output are switched off and can be switched on again after a temperature drop of about 10 degrees.
Value is not editable	The selected display item (e.g. measurement reading) can't be adjusted
Not permitted with TEC output on	Operation is not allowed while the TEC output is switched on. This is valid e.g. for the TEC current limit and the temperature sensor selection.
Wrong TEC source operating mode	Operation is not allowed in current TEC source operating mode, please check the selected operating mode in the TEC source setup
PID auto-tune is currently running	Operation is not permitted during a running PID auto-tune process
PID auto-tune value error	The values of the PID auto-tune process are out of the specified range, please try a manuel tuning (refer to chapter PID control loop settings)
TEC open circuit detected	The connection to the TEC element is broken or the resistance of the TEC element is too high, the TEC output cannot be switched on.
Temperature sensor failure	In case of an incorrect wiring to the temperature sensor or the selected temperature sensor does not match
TEC cable connection failure	The TEC setup is not connected to the unit correctly
Value is out of range	A sent numerical value in remote mode is out of range, check the allowed min/max values for the parameter to be changed

Error	Description
Value minimum/maximum reached	Occurs when the range limits of the setpoints are reached
Operation is not applicable	Occurs in Edit Name menu if characters can't be deleted (with backspace) anymore
FPGA configuration error	A FPGA configuration failure has occurred during the boot procedure, please switch the unit off and on again. If this error is shown again contact the Thorlabs Hotline
Nonvolatile checksum error	A general EEPROM checksum error has occured, please switch the unit off and on again. If this error will be appeared again contact the Thorlabs Hotline
General keyboard bootloader error	The keyboard bootloader is not running after the boot procedure, please switch the unit off and on again. If this error is shown again contact the Thorlabs Hotline
Hardware error	A device internal hardware error has occurred, please switch the unit off and on again. If this error continues contact the Thorlabs Hotline
Calibration memory lost	The calibration data in the EEPROM is invalid, please switch the unit off and on again. If this error is still present contact the Thorlabs Hotline
Save/recall memory lost	The saved user setup data in the EEPROM is invalid, please switch the unit off and on again. If this error is shown again contact the Thorlabs Hotline
Configuration memory lost	The last saved setup before power down is invalid, please switch the unit off and on again. If this error is still present contact the Thorlabs Hotline
Self test failed	The device self test procedure has failed, please switch the unit off and on again. If this error continues contact the Thorlabs Hotline

6.7 Certifications and Compliances

<div style="border:1px solid">

EU Declaration of Conformity

in accordance with EN ISO 17050-1:2010

We: Thorlabs GmbH

Of: Hans-Boeckler-Str. 6, 85221 Dachau/München, Deutschland

in accordance with the following Directive(s):

2014/35/EU	Low Voltage Directive (LVD)
2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)

hereby declare that:

Model: **TED4015**

Equipment: **Benchtop TEC Controller**

is in conformity with the applicable requirements of the following documents:

EN 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use.	2010
EN 61326-1	Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements	2013

and which, issued under the sole responsibility of Thorlabs, is in conformity with Directive 2011/65/EU of the European Parliament and of the Council of 8th June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, for the reason stated below:

does not contain substances in excess of the maximum concentration values tolerated by weight in homogenous materials as listed in Annex II of the Directive

I hereby declare that the equipment named has been designed to comply with the relevant sections of the above referenced specifications, and complies with all applicable Essential Requirements of the Directives.

Signed: *On:* 29 January 2016

CE 16

Name: Dorothee Jennrich

Position: General Manager *EDC - TED4015 -2016-01-29*

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This product was tested for and complies with the following standards:

- CAN/CSA-C22.2 No. 61010-1-04
- ANSI/UL 61010-1-2004

6.8 Warranty

Thorlabs warrants material and production of the TED4015 for a period of 24 months starting with the date of shipment. During this warranty period Thorlabs will see to defaults by repair or by exchange if these are entitled to warranty.

For warranty repairs or service the unit must be sent back to Thorlabs. The customer will carry the shipping costs to Thorlabs, in case of warranty repairs Thorlabs will carry the shipping costs back to the customer.

If no warranty repair is applicable the customer also has to carry the costs for back shipment.

In case of shipment from outside EU duties, taxes etc. which should arise have to be carried by the customer.

Thorlabs warrants the hard- and/or software determined by Thorlabs for this unit to operate fault-free provided that they are handled according to our requirements. However, Thorlabs does not warrant a fault free and uninterrupted operation of the unit, of the software or firmware for special applications nor this instruction manual to be error free. Thorlabs is not liable for consequential damages.

Restriction of Warranty

The warranty mentioned before does not cover errors and defects being the result of improper treatment, software or interface not supplied by us, modification, misuse or operation outside the defined ambient stated by us or unauthorized maintenance.

Further claims will not be consented to and will not be acknowledged. Thorlabs does explicitly not warrant the usability or the economical use for certain cases of application.

Thorlabs reserves the right to change this instruction manual or the technical data of the described unit at any time.

6.9 Exclusion of Reliability and Copyright

Thorlabs has taken every possible care in preparing this document. We however assume no liability for the content, completeness or quality of the information contained therein. The content of this document is regularly updated and adapted to reflect the current status of the hardware and/or software. We furthermore do not guarantee that this product will function without errors, even if the stated specifications are adhered to.

Under no circumstances can we guarantee that a particular objective can be achieved with the purchase of this product.

Insofar as permitted under statutory regulations, we assume no liability for direct damage, indirect damage or damages suffered by third parties resulting from the purchase of this product. In no event shall any liability exceed the purchase price of the product.

Please note that the content of this document is neither part of any previous or existing agreement, promise, representation or legal relationship, nor an alteration or amendment thereof. All obligations of *Thorlabs* result from the respective contract of sale, which also includes the complete and exclusively applicable warranty regulations. These contractual warranty regulations are neither extended nor limited by the information contained in this document. Should you require further information on this product, or encounter specific problems that are not discussed in sufficient detail in the document, please contact your local *Thorlabs* dealer or system installer.

6.10 Thorlabs "End of Life" Policy (WEEE)

As required by the WEEE (Waste Electrical and Electronic Equipment Directive) of the European Community and the corresponding national laws, Thorlabs offers all end users in the EC the possibility to return "end of life" units without incurring disposal charges.

This offer is valid for Thorlabs electrical and electronic equipment

- sold after August 13th 2005
- marked correspondingly with the crossed out "wheelie bin" logo (see figure below)
- sold to a company or institute within the EC
- currently owned by a company or institute within the EC
- still complete, not disassembled and not contaminated

As the WEEE directive applies to self contained operational electrical and electronic products, this "end of life" take back service does not refer to other Thorlabs products, such as

- pure OEM products, that means assemblies to be built into a unit by the user (e. g. OEM laser driver cards)
- components
- mechanics and optics
- left over parts of units disassembled by the user (PCB's, housings etc.).

Waste treatment on your own responsibility

If you do not return an "end of life" unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

WEEE Number (Germany) : DE97581288

Ecological background

It is well known that waste treatment pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS Directive is to reduce the content of toxic substances in electronic products in the future.

The intent of the WEEE Directive is to enforce the recycling of WEEE. A controlled recycling of end-of-life products will thereby avoid negative impacts on the environment.

Crossed out
"Wheelie Bin" symbol

6.11   List of Acronyms

AC	Alternating Current
CDRH	Center for Devices and Radiological Health
DC	Direct Current
DDS	Digital Direct Synthesizer
LED	Light Emitting Diode
NTC	Negative Temperature Coefficient
OTP	Over Temperature
PC	Personal Computer
QCW	Quasi Continuous Wave
RF	Radio Frequency
RMS	Root Mean Square
TEC	Thermo Electric Cooler
TED	Thermo Electric Driver
USB	Universal Serial Bus
U_{TH}	U (voltage) Thermopile

6.12 Thorlabs Worldwide Contacts

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www.thorlabs.us (West Coast)
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