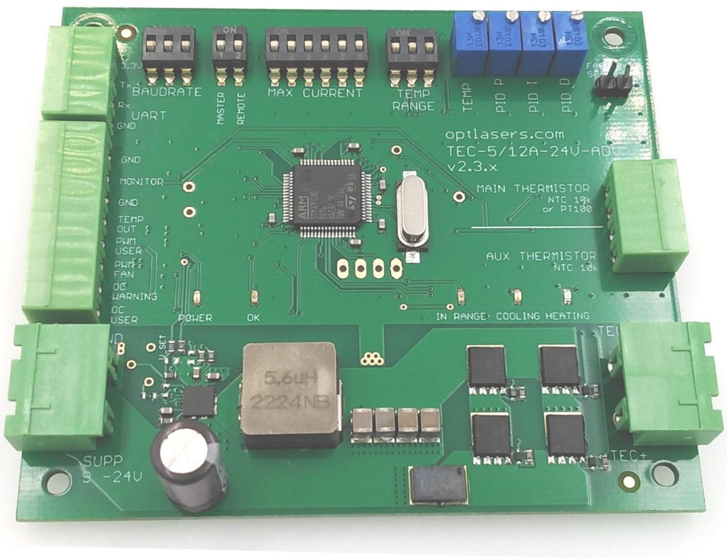
# TEC-5A-24V-ADV
# TEC-12A-24V-ADV
## Operating Manual




## Key Features

- ❍ Advanced temperature regulator for controlling TECs (Peltier modules)
- ❍ Current source TEC control mode
- ❍ Provides heating and cooling
- ❍ Applies to a wide range of TEC types
- ❍ Maximum TEC current: 5A or 12A (depending on version)
- ❍ Temperature stability: better than 0.05°C
- ❍ Supply voltage: 9…24V
- ❍ Output voltage: 0…20V
- ❍ Supports two sensor types: NTC 10k and PT100
- ❍ PID regulation with user-presettable parameters
- ❍ Programmable generator of temperature cycles
- ❍ Smart fan speed control
- ❍ Rich set of inputs and outputs

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# Product Description

TEC-5A-24V-ADV / TEC-12A-24V-ADV is an advanced digital temperature controller with PID regulation, dedicated for controlling TEC (Peltier) modules. It is an extended version of the TEC-8A-24V-PID-HC controller that Tomorrow's System® has been successfully manufacturing for many years.

TEC-5A-24V-ADV / TEC-12A-24V-ADV is referred to as "Controller" in this Manual. The Controller's printed circuit board is referred to as "PCB".

The Controller's output is bipolar (bidirectional), providing both heating and cooling. A unipolar mode, which is suitable for controlling heaters, may also be chosen. The output is a current source which is advantageous for TEC controlling efficiency. Output current does not depend on the supply voltage, making the use of different TEC types much easier than in case of voltage-output TEC controllers.

The Controller may operate as a stand-alone unit, or may be remotely controlled and inspected through the serial connection, eg. by a personal computer. This allows for easy interfacing with many computer applications like terminal programs or math packages.

The Controller is equipped with numerous inputs and outputs for high versatility.

The Controller is available in two output current versions.

# Technical data

| | | |
|---|---|---|
| TEC current | 0…5A / 0…12A (version-dependent) | |
| TEC voltage | 0…20V | |
| Supply voltage | 9…24V DC | |
| Temperature sensors | MAIN | NTC 10kΩ / BETA adjustable or PT100 (type recognized automatically) |
| | AUX | NTC 10kΩ / BETA=3950K |
| Measured temperature range | MAIN / NTC 10kΩ | -20ºC…+100ºC (-50ºC…+120ºC with reduced accuracy) |
| | MAIN / PT100 | -240ºC…+270ºC |
| | AUX / NTC 10kΩ | -20ºC…+100ºC (-50ºC…+120ºC with reduced accuracy) |
| Temperature readout accuracy | NTC 10kΩ: ±1.0°C not counting the thermistor tolerance<br>PT100: ±1.5°C not counting the thermistor tolerance | |
| Temperature stabilization accuracy | ±0.05°C | |
| Serial interface | UART, 3.3V, active LOW, 1 start bit, 8 data bits, no parity, 1 stop bit | |
| Current of open collector outputs | 30V max., 50mA max. | |
| Current of PWM and analog outputs | sinking / sourcing 1mA max. | |
| Dimensions | 90 x 80 x 20 mm | |
| Mounting holes | 4 x ∅3.2 mm, 80 x 70 mm | |

# Absolute maximum ratings

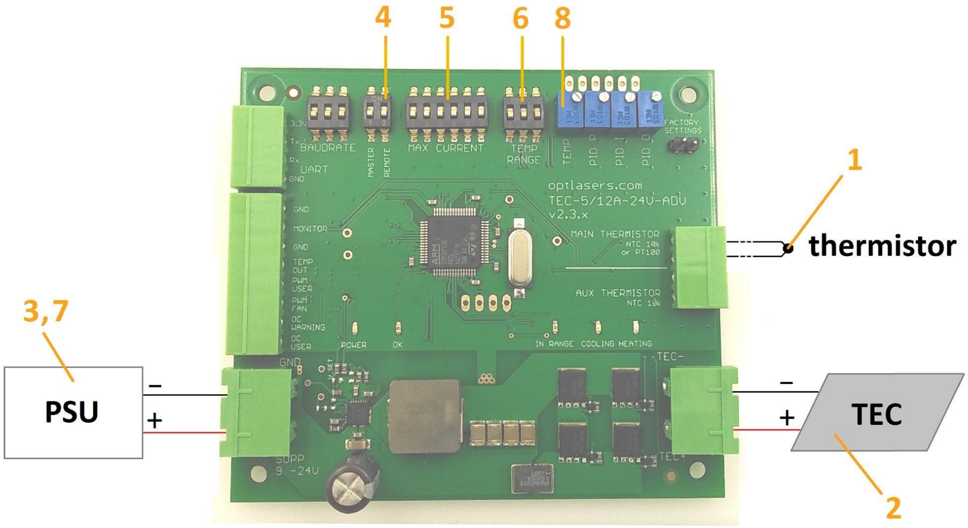
| | |
|---|---|
| TEC maximum current | 12A |
| Supply voltage | 26V DC |
| Controller’s operating temperature | 0ºC…+50ºC |
| Controller’s storage temperature | 0ºC…+70ºC |

# General Safety Warnings

1. The Controller is not intended for medical, military, or aerospace use.
2. The Controller should not operate in an environment where liquid condensation, metal shavings, dirt or other contaminants may appear.
3. The Controller should not be used for controlling other loads than TEC (Peltier) modules or heaters.
4. The Controller should be installed and operated by qualified technicians only.
5. Carefully read the manual before installing and operating the Controller.
6. Use a power supply unit (PSU) with the proper output voltage and sufficient current and power capability.
7. Observe the absolute maximum ratings of the device (see chapter **Absolute maximum ratings**).
8. Use leads with the right diameter to avoid overheating and voltage losses.
9. Use proper installation means to avoid short circuits and broken connections.
10. Use ESD (electro static discharge) protection during installation.
11. Mount the PCB in a way that excludes touching any electrically conductive surfaces by the components on the PCB.
12. Do not touch the components on the PCB during work.
13. Do not touch the TEC module, especially when a temperature warning is indicated (see chapter **General Informations on Using the Controller**).
14. Never use the Controller if it has been damaged.

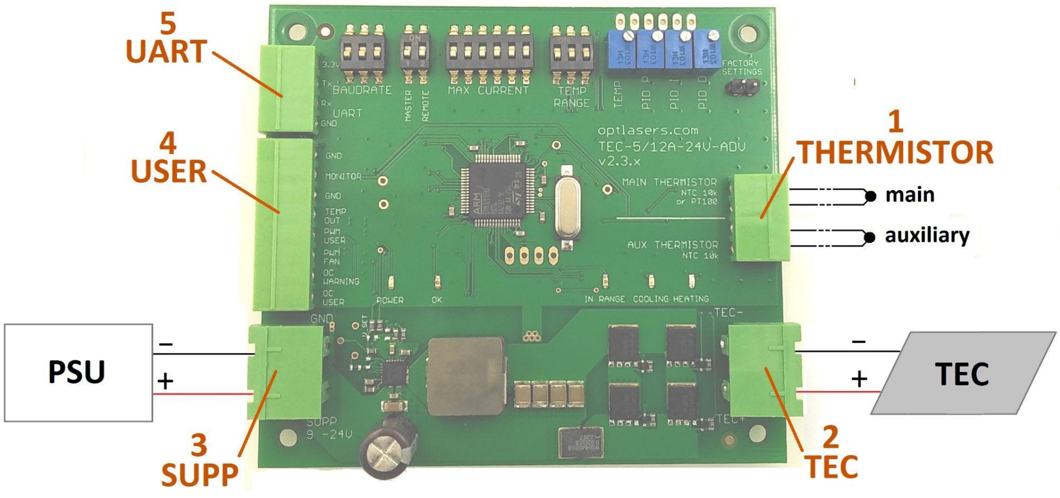
This product is compliant with the Low Voltage Directive LVD 2014/35/EU.

# Quick start guide




1. Place a thermistor at the temperature measurement point and connect it to the THERMISTOR / MAIN connector.
2. Connect a TEC (Peltier module) to the TEC+ / TEC- connector. Observe the right polarity.
3. Make sure the power supply unit (PSU) is turned off. Connect the PSU to the SUPP connector. **Observe the right polarity** to avoid damage!
4. Turn the REMOTE switch to OFF position.
5. Set the desired maximum output current with the MAX CURRENT switch. Refer to chapter **Hardware PCB Controls**, item 4.
6. Set the desired target temperature range with the TEMP RANGE switch. Refer to chapter **Hardware PCB Controls**, item 5.
7. Turn the power supply on.
8. Set the desired target temperature with the TEMP potentiometer.

# Connectors




1. **THERMISTOR** connector
   The first pair of connector contacts (MAIN) serves for attaching the main temperature sensor (thermistor). Optionally, an additional (auxiliary) thermistor may be attached to the second pair of contacts (AUX). This thermistor is intended for future use.

2. **TEC** connector
   The TEC (Peltier) module or a heater is connected here.
   Observe the right polarity (TEC+ / TEC-).

3. **SUPP** connector
   The power supply unit (PSU) is connected here.
   **Observe the right polarity (PSU+ to SUPP, PSU- to GND)**. Otherwise, the Controller may be damaged.

4. **USER** connector
   This connector contains a number of outputs that can be used either for system expansion or for getting more information about the Controller's current state. Most of the signals are programmable by the user.
   Following outputs are available (see descriptions on the PCB):

   OC USER — Open-collector user-programmable output.
   By default: system error indication (E).
   See chapter Local and Remote Operations.

   OC WARNING — Open-collector warning output. Provides warning about a dangerous temperature:
   - switched to ground when the real temperature is below -20°C or above +45°C;
   - open (high-impedance) otherwise.

   PWM FAN — PWM output for controlling a fan. User-programmable.
   By default: AUX temperature (U).

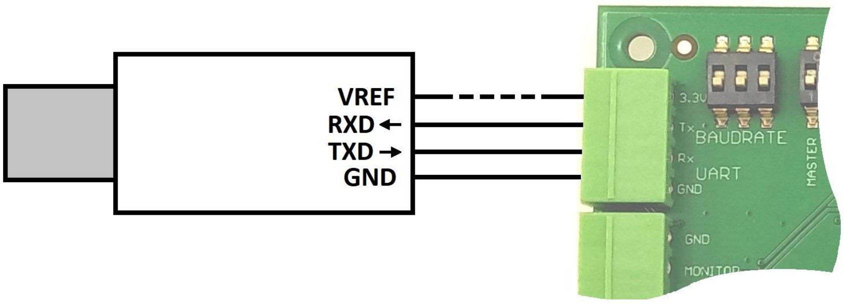
| | |
|---|---|
| | See chapter [Local and Remote Operations](). |
| PWM USER | General user-programmable PWM output. |
| | By default: turned on at heating (H). |
| | See chapter [Local and Remote Operations](). |
| TEMP OUT | General analog output. User-programmable. |
| | By default: MAIN (real) temperature (M). |
| | See chapter [Local and Remote Operations](). |
| GND | Signal ground. |
| MONITOR | Square-wave output. User-programmable. |
| | By default: 1kHz frequency (1). |
| | See chapter [Local and Remote Operations](). |
| GND | Signal ground. |

5. **UART** connector

This connector serves for connecting the Controller to a personal computer or another controlling device. The following lines of asynchronous serial communication interface (UART) are provided:

- two data lines (TXD and RXD); passive state = HIGH,
- reference voltage for logics (3.3V),
- ground (GND).

An external USB-to-UART adapter is required to make a serial link to a personal computer's USB port. Use a 3.3V logic level type. The picture below shows how to connect a USB-to-UART adapter to the Controller:



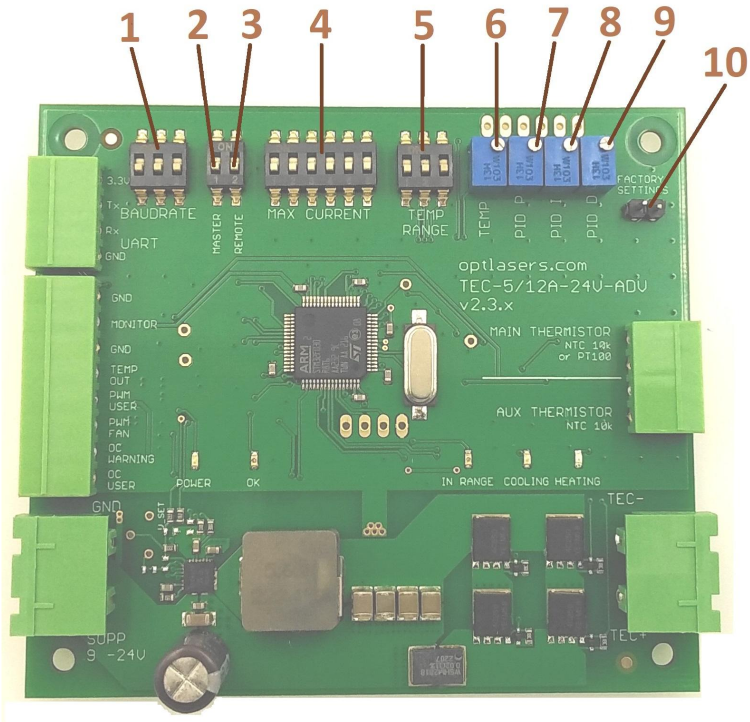

For a RS232-compatible serial link, use an external RS232-to-UART adapter.

As replacement plugs use:

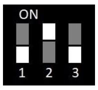
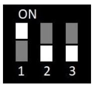
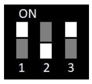
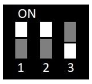
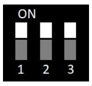
- for **THERMISTOR** and **UART**: *Phoenix Contact MC1.5/4-ST-3.5* or similar;
- for **TEC** and **SUPP**: *Degson 2EDGK-7.5-02P* or similar;
- for **USER**: *Phoenix Contact MC1.5/8-ST-3.5* or similar.

# Hardware PCB Controls

The following picture shows locations of the controls on the PCB:



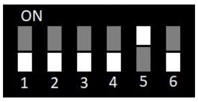

1. BAUDRATE switch
   This triple switch selects the speed of the serial connection (in baud):

| | | | |
|---|---|---|---|
|  | 1200 |  | 2400 |
|  | 4800 |  | 9600 |
|  | 19200 |  | 38400 |
|  | 57600 |  | 115200 |

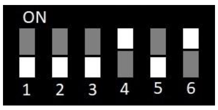
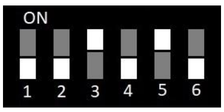
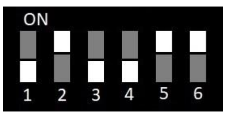
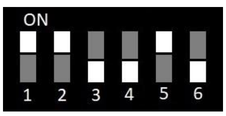
2. MASTER switch
   This switch is reserved for future use. Leave it in the OFF position.

3. REMOTE switch
   This switch selects the source of parameter values:
   OFF position: the parameters are being preset by the controls on the PCB.
   ON position: the parameter values received from the serial connection override the PCB settings.
   See chapter **Local and Remote Operations**.

4. MAX CURRENT (current range) switch
This 6-part switch presets the TEC output current range (the maximum TEC current). Each part of the switch adds some contribution to the range value according to the table below. The total range value is a sum of the contributions:

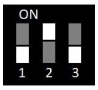
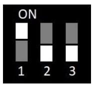
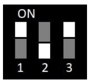
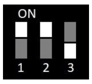
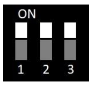
| ***part of the switch*** | ***contribution [A]*** | |
|---|---|---|
| | ***5A version*** | ***12A version*** |
|  | 0.1 | 0.2 |
|  | 0.2 | 0.4 |
|  | 0.4 | 0.8 |
|  | 0.8 | 1.6 |
|  | 1.6 | 3.2 |
|  | 3.2 | 6.4 |

Settings examples (5A output current version assumed):

| ***switch setting*** | ***output current range [A]*** |
|---|---|
|  | 0.4 + 0.1 = **0.5** |
|  | 0.8 + 0.2 = **1.0** |
|  | 1.6 + 0.2 + 0.1 = **1.9** |
|  | 3.2 + 1.6 + 0.2 = **5.0** |

Note: the actual current range will never exceed the maximum output current of the Controller version (5A and 12A respectively), regardless of the switch setting.
Note: setting the range to zero (all parts of the switch are OFF) turns the output current off.

5. TEMP RANGE switch
This triple switch selects one of eight preset ranges of the target temperature:

| | | | |
|---|---|---|---|
|  | -10 … +50°C |  | -10 … +100°C |
|  | -100 … +10°C |  | -50 … +50°C |
|  | +15 … +30°C |  | +30 … +45°C |
|  | +45 … +60°C |  | -100 … +250°C |

Note: the lower and upper temperatures can be independently set by using serial commands. See chapter **Local and Remote Operations**.

6. TEMP potentiometer
This potentiometer sets the desired target temperature within the preset temperature range. Turning clockwise increases the value.

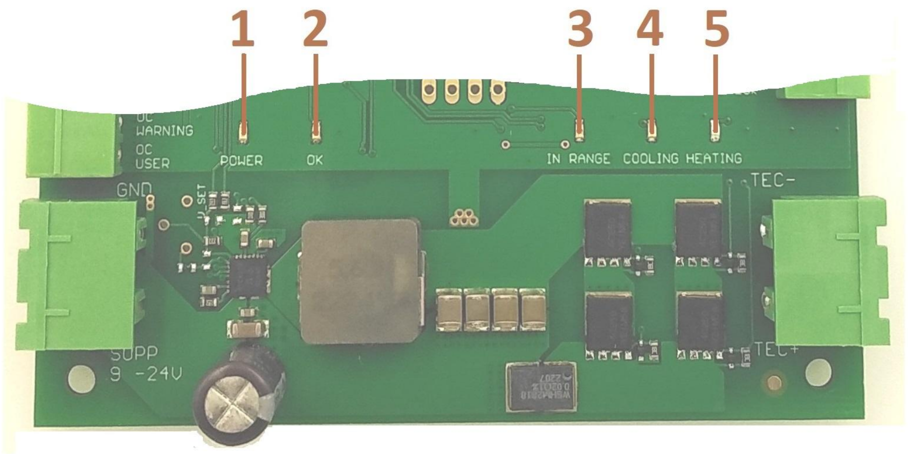
7. PID P potentiometer
8. PID I potentiometer
9. PID D potentiometer
These 3 potentiometers adjust amounts of the proportional, integral, and differential parts of the PID regulator respectively. The setting range is 0…20 each. Turning clockwise increases the value.

10. Factory settings connector
This connector serves for setting default parameter values (factory settings) for the case when the REMOTE switch is ON.
To set the default values, turn the power off and connect both pins of the connector with a jumper. Then turn the power on, wait a couple of seconds and remove the jumper.

# General Information on Using the Controller

## ON-BOARD STATUS LEDS

There are five status LEDs on the PCB:




1. POWER
   Shows the presence of the power supply.

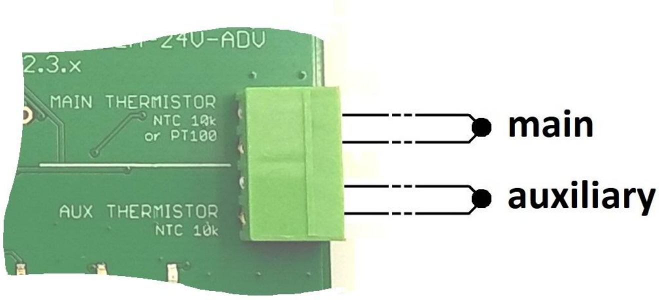
2. OK :)
   Flashes twice at power-on.
   Shows the general status of the device:
   - ON when there is no error or warning;
   - flashes at warning (when real temperature is below -20°C or above +45°C);
   - OFF at any system error.

3. IN RANGE
   Flashes twice at power-on.
   Indicates the current temperature error by flashing:
   - flashes approx. once per second at high error values;
   - flashes faster as the error decreases;
   - for errors below 0.5°C, it turns permanently ON.

4. COOLING
   Shows the cooling phase (positive output current) of TEC control.

5. HEATING
   Shows the heating phase (negative output current) of TEC control.

**MAIN THERMISTOR**
**AUX THERMISTOR**




The main thermistor (MAIN) measures the real temperature of the object controlled.
The thermistor must be either an NTC 10kΩ or a PT100 type. The type will be automatically recognized by the Controller at power-on.

An NTC is well suited for a temperature range approx. -20ºC…+100ºC. Beyond that range, using a PT100 is recommended.

The default BETA coefficient is 3950K. The coefficient may be adjusted by a serial command. See chapter **Local and Remote Operations**.

Lack of thermistor and short circuit will both be recognized. An error will be indicated in that case.

An auxiliary thermistor (AUX) may be optionally attached. It must be an NTC 10kΩ type, BETA = 3950K. This thermistor may be used for an additional temperature measurement. See chapter **Advanced Commands**.

Short circuit on this input will be recognized. An error will be indicated in that case.

**PID REGULATOR**

The PID regulator is a part of the Controller's software. It controls the TEC module according to the current temperature error (the difference between the real and the preset temperature), trying to bring the error as close to zero as possible.

The output of the regulator consists of Proportional, Integral, and Differential parts. The user may adjust the amount of each part in the range of 0…20 (**P**, **I**, and **D** parameters respectively). See chapters **Hardware PCB Controls** and **Local and Remote Operations**.

PROPORTIONAL PART

This part is proportional to the temperature error. The higher **P**, the less temperature error is required for the same output. At maximum **P** setting, an error of 0.5ºC causes the maximum output (100%).

INTEGRAL PART

The temperature error is being integrated in this part. The output will rise or fall until the error reaches zero.
The **I** parameter sets the amount of integral part and also adjusts the integrator's time constant. The higher **I**, the longer the time constant.
The integrator saturates at -100% and +100%. The integrator does not clear itself on any timeout.

At **I** settings below 0.05, the integrator is turned off and cleared.

DIFFERENTIAL PART

This part acts as a high-pass filter. When the temperature error changes, the differential part brings some amount of energy to the output and therefore "speeds up" reaching the target temperature. In the frequency domain, adding some differential part increases the phase margin of the regulator and thus improves the regulation loop stability.

The **D** parameter sets the amount of differential part and also adjusts its time constant. The higher **D**, the longer the time constant.

At **D** settings below 0.05, the differential part is turned off and cleared.

When the factory settings are programmed (see chapter **Hardware PCB Controls**), following parameter values are preset: **P** = 5, **I** = 0, **D** = 0.

The PID regulator updates the TEC output each 10ms.

## TEC (PELTIER) MODULE OUTPUT

During cooling, the output current flows from the TEC+ terminal to the TEC- terminal. During heating, the direction of the current is opposite.

The maximum TEC voltage is less by 3V than the Controller's power supply voltage.

The output can source/sink high currents. The leads between the Controller and the TEC module should have high diameter and should be kept as short as possible.

## POWER SUPPLY

Use a direct current (DC) regulated power supply unit (PSU). No adjustment of the output voltage is necessary. The output voltage should be at least by 3V higher than the TEC module voltage at its maximum current. However, it is advantageous to have the highest permitted supply voltage (24V) as it would assure less supply current at the same power. If the maximum TEC voltage cannot be determined, use 24V anyway.

The PSU maximum output power should be by at least 15W higher than the maximum power consumed by the TEC module, i.e. the product of maximum TEC current and maximum TEC voltage. The PSU maximum output current can be then calculated by dividing the maximum PSU power by the output voltage.

Example:

The Controller will supply a TEC module with 6.4A maximum current and 16.4V maximum voltage → a **24V** PSU will be used.

The TEC maximum power consumption is 6.4A * 16.4V = 105W → the PSU should provide **120W** output power and 120W / 24V = **5,0A** output current.

For connecting the PSU to the Controller use leads with high diameter and keep them as short as possible to avoid voltage loss.

**Please be aware that incorrect polarity application to the supply lines may result in damage to the Controller. Prior to initiating power supply, we strongly recommend meticulous verification of the polarity to prevent any potential harm to the device.**

# Local and Remote Operations

After attaching a temperature sensor, a TEC, and a power supply, the Controller can operate as a stand-alone device. The basic parameters are being preset by the local controls on the PCB (switches and trimming potentiometers). Extended parameters that have no controls on the PCB get their default values. This mode is chosen by turning the REMOTE switch OFF. See chapter **Hardware PCB Controls**.

The Controller can also be controlled and inspected by a personal computer or another external device. This allows for remote control of the system, synchronizing a couple of Controllers from a supervising unit, and much more. The serial connection (see UART CONNECTOR) is being used for communication.

The main function of the serial connection is to preset and change parameters of the Controller, eg. the target temperature. However, as long as the REMOTE switch is off, the received parameter values remain inactive. Turning the REMOTE switch ON activates the received parameters. Their values then override the controls on the PCB. See chapter **Hardware PCB Controls**.

A parameter value may be received any time regardless of the REMOTE switch position. The received value will be stored in the Controller's non-volatile memory which holds the value also when the power supply is turned off.

If a parameter value has never been received from the serial connection, it is still being preset by its control on the PCB even if the REMOTE switch is ON (if there is no PCB control then the parameter gets a default value).

Note that two parameters: "MAX CURRENT" and "BAUDRATE" are always being preset by switches on the PCB and cannot be changed from the serial connection.

Apart from setting parameters, the serial connection may be used for reading their actual values (regardless whether they are preset on the PCB or read from the memory). The serial connection may also serve for setting working modes and getting different state information of the Controller.

Each serial operation requires sending a character or a string of characters from the controlling device to the Controller. The Controller then replies either with a single character that acknowledges reception or with a string of characters containing information.

## Legacy Commands

The basic command set covers the legacy set of operations used in the Opt Lasers® TEC-8A-24V-PID-HC controller.

| | |
|---|---|
| SHORT DESCRIPTION | get status of temperature regulation |
| COMMAND TO CONTROLLER | o |
| REPLY FROM CONTROLLER | Tz=XXX.xx P=XX.xx I=XX.xx D=XX.xx T=XXX...XXX Tr=XXX.xx OC=X PW=XXXX |
| REPLY EXAMPLE | Tz=+40.00 P=8.55 I=2.00 D=1.24 T=-10.00…+75.00 Tr=+34.83 OC=0 PW=+87% |
| FULL DESCRIPTION | Sending basic information on the temperature regulation settings and status from the Controller. The reply consists of following fields: |

| | |
|---|---|
| | Tz: preset (target) temperature [°C]<br>P: amount of the proportional part of the PID regulator 0…20<br>I: amount of the integral part of the PID regulator 0…20<br>D: amount of the differential part of the PID regulator 0…20<br>T: temperature range [°C]<br>Tr: actual temperature [°C]<br>OC: state of the open collector output<br>PW: state of the current output (percentage of the preset range) |

| | |
|---|---|
| SHORT DESCRIPTION | get status of temperature regulation periodically |
| COMMAND TO CONTROLLER | R |
| REPLY FROM CONTROLLER | same as in the previous item |
| FULL DESCRIPTION | Turns on periodical sending of the information described in the previous item. |

| | |
|---|---|
| SHORT DESCRIPTION | turn off getting status of temperature regulation periodically |
| COMMAND TO CONTROLLER | r |
| REPLY FROM CONTROLLER | r |
| FULL DESCRIPTION | Turns off periodical sending of the information described in the previous item. |

| | |
|---|---|
| SHORT DESCRIPTION | set parameters of temperature regulation |
| COMMAND TO CONTROLLER | <T.T P.P I.I D.D L.L U.U> |
| COMMAND EXAMPLE | <+40 7.5 2.25 0.9 -5 +75> |
| REPLY FROM CONTROLLER | same as the command |
| FULL DESCRIPTION | Serves for presetting parameter values. The command consists of following fields:<br>T.T: target temperature [°C]<br>P.P: amount of the proportional part of the PID regulator 0…20<br>I.I: amount of the integral part of the PID regulator 0…20<br>D.D: amount of the differential part of the PID regulator 0…20<br>L.L: lower limit of the temperature range [°C]<br>U.U: upper limit of the temperature range [°C] |

| | |
|---|---|
| SHORT DESCRIPTION | turn regulation off |
| COMMAND TO CONTROLLER | a |
| REPLY FROM CONTROLLER | a |
| FULL DESCRIPTION | Turns off the TEC output |

| | |
|---|---|
| SHORT DESCRIPTION | turn regulation on |
| COMMAND TO CONTROLLER | A |
| REPLY FROM CONTROLLER | A |

| | |
|---|---|
| FULL DESCRIPTION | Turns on the TEC output |

| | |
|---|---|
| SHORT DESCRIPTION | show help |
| COMMAND TO CONTROLLER | H |
| REPLY FROM CONTROLLER | text string |
| FULL DESCRIPTION | Sends back a text containing help (a summary of commands) |

| | |
|---|---|
| SHORT DESCRIPTION | launch temperature cycles |
| COMMAND TO CONTROLLER | [L.LL U.UU l.ll u.uu r.rr f.ff N M] |
| COMMAND EXAMPLE | [-5.5 +40 600 1200 2.5 5.0 0 1] |
| REPLY FROM CONTROLLER | [TIME CYCLE #I PHASE (XX%) Tpreset=P.PP Treal=R.RR] |
| REPLY EXAMPLE | [1h10m45s CYCLE #57 RISING ( 60%) Tpreset=+35.5 Treal=+32.7] |
| FULL DESCRIPTION | Programming and starting execution of temperature cycles:<br>L.LL = $T_{lower}$ [°C]<br>U.UU = $T_{upper}$ [°C]<br>l.ll = $t_{lower}$ [s]; range: 0 ... 4 000 000<br>u.uu = $t_{upper}$ [s]; range: 0 ... 4 000 000<br>r.rr = $t_{rise}$ [s]; range: 0 ... 4 000 000<br>f.ff = $t_{fall}$ [s]; range: 0 ... 4 000 000<br>N = number of cycles; range: 0 ... 4 000 000 000 (0 = unlimited)<br>M = periodically send a status string to the serial link: 0=no, 1=yes<br>TIME = total time that elapsed since starting execution of temperature cycles<br>I = number of the current cycle<br>PHASE = description of the current phase<br>XX = stage of execution of the current phase [%]<br>$T_{preset}$ = target temperature [°C]<br>$T_{real}$ = actual temperature [°C]<br>See chapter **Programmable temperature cycles** |

| | |
|---|---|
| SHORT DESCRIPTION | get status of temperature cycles periodically |
| COMMAND TO CONTROLLER | M |
| REPLY FROM CONTROLLER | same as in the previous item |
| FULL DESCRIPTION | Turns on periodical sending of the information described in the previous item |

| | |
|---|---|
| SHORT DESCRIPTION | turn off getting status of temperature cycles periodically |
| COMMAND TO CONTROLLER | m |
| REPLY FROM CONTROLLER | m |
| FULL DESCRIPTION | Turns off periodical sending of the information described in the previous item. |

| | |
|---|---|
| SHORT DESCRIPTION | show firmware version |

| | |
|---|---|
| COMMAND TO CONTROLLER | V |
| REPLY FROM CONTROLLER | YYMMDDs HH:MM:SS |
| FULL DESCRIPTION | Sends back the code of the firmware version and time of compilation. |

| | |
|---|---|
| SHORT DESCRIPTION | set rate of periodic information |
| COMMAND TO CONTROLLER | PX.X |
| REPLY FROM CONTROLLER | PER=X.Xs |
| FULL DESCRIPTION | Sets the period of sending back information:<br>X.X = period [s]; range: 0.25 … 1000 |

## Advanced Commands

Apart from performing basic remote operations, there is a possibility of in-depth control over the Controller by using advanced commands.

Some of the advanced commands overlap the legacy commands but most of them are new, allowing for extended control.

Advanced commands are not necessary for standard work with the Controller. However, they might be very useful for performing non-standard actions.

The advanced commands are listed below:

| | |
|---|---|
| SHORT DESCRIPTION | set target temperature |
| COMMAND TO CONTROLLER | *SETTPRSX.X; |
| COMMAND EXAMPLE | *SETTPRS12.5; |
| REPLY FROM CONTROLLER | *TPRS X.X°C; |
| REPLY EXAMPLE | *TPRS 12.5°C; |
| FULL DESCRIPTION | Setting the target (preset) temperature:<br>X.X = temperature [°C] |

| | |
|---|---|
| SHORT DESCRIPTION | get target temperature |
| COMMAND TO CONTROLLER | *GETTPRS; |
| REPLY FROM CONTROLLER | *TPRS X.X°C; |
| REPLY EXAMPLE | *TPRS 12.5°C; |
| FULL DESCRIPTION | Reading the target (preset) temperature.<br>X.X = temperature [°C] |

| | |
|---|---|
| SHORT DESCRIPTION | get AUX temperature |

| | |
|---|---|
| COMMAND TO CONTROLLER | *GETTAUX; |
| REPLY FROM CONTROLLER | *TAUX X.X°C; |
| REPLY EXAMPLE | *TAUX 42.0°C; |
| FULL DESCRIPTION | Reading the AUX thermistor temperature.<br>X.X = temperature [°C] |

| | |
|---|---|
| SHORT DESCRIPTION | set temperature range |
| COMMAND TO CONTROLLER | *SETTRNGL.L U.U; |
| COMMAND EXAMPLE | *SETTRNG-2.5 +50; |
| REPLY FROM CONTROLLER | *TRNG L.L°C…U.U°C; |
| REPLY EXAMPLE | *TRNG -2.50°C…+50.00°C; |
| FULL DESCRIPTION | Setting the range of the target temperature:<br>L.L = lower temperature limit [°C]<br>U.U = upper temperature limit [°C] |

| | |
|---|---|
| SHORT DESCRIPTION | get temperature range |
| COMMAND TO CONTROLLER | *GETTRNG; |
| REPLY FROM CONTROLLER | *TRNG L.L°C…U.U°C; |
| REPLY EXAMPLE | *TRNG -2.50°C…+50.00°C; |
| FULL DESCRIPTION | Reading the range of the target temperature.<br>See description of the previous operation. |

| | |
|---|---|
| SHORT DESCRIPTION | set coefficients of PID regulation |
| COMMAND TO CONTROLLER | *SETCKP.P I.I D.D; |
| COMMAND EXAMPLE | *SETCK8.5 2 0.95; |
| REPLY FROM CONTROLLER | *CK P.P I.I D.D; |
| REPLY EXAMPLE | *CK 8.5 2 0.95; |
| FULL DESCRIPTION | Setting the coefficients of PID regulation:<br>P.P = amount of proportional part 0…20<br>I.I = amount of integral part 0…20<br>D.D = amount of differential part 0…20 |

| | |
|---|---|
| SHORT DESCRIPTION | get coefficients of PID regulation |
| COMMAND TO CONTROLLER | *GETCK; |
| REPLY FROM CONTROLLER | *CK P.P I.I D.D; |
| REPLY EXAMPLE | *CK 8.5 2 0.95; |

| | |
|---|---|
| FULL DESCRIPTION | Reading the coefficients of PID regulation.<br>See description of the previous operation. |

| | |
|---|---|
| SHORT DESCRIPTION | get real temperature |
| COMMAND TO CONTROLLER | *GETTACT; |
| REPLY FROM CONTROLLER | *TACT X.X°C; |
| REPLY EXAMPLE | *TACT +35.7°C; |
| FULL DESCRIPTION | Reading the real (main thermistor) temperature.<br>X.X = temperature |

| | |
|---|---|
| SHORT DESCRIPTION | get main thermistor state |
| COMMAND TO CONTROLLER | *GETMTT; |
| REPLY FROM CONTROLLER | *MTT X; |
| REPLY EXAMPLE | *MTT N; |
| FULL DESCRIPTION | Reading the state of the main thermistor:<br>X = N (NTC 10k type)<br>X = P (PT100 type)<br>X = S (short circuit failure)<br>X = O (open circuit failure)<br>X = ? (not recognized) |

| | |
|---|---|
| SHORT DESCRIPTION | set main NTC thermistor’s BETA coefficient |
| COMMAND TO CONTROLLER | *SETBTMX; |
| COMMAND EXAMPLE | *SETBTM3850; |
| REPLY FROM CONTROLLER | *BTM X; |
| REPLY EXAMPLE | *BTM 3850; |
| FULL DESCRIPTION | Setting the BETA coefficient for the main NTC 10k thermistor:<br>X = 3000…10000 [K]<br>NTC thermistors with different BETA coefficients are available on the market. The command allows for setting the BETA value and thus adjusting the resistance-to-temperature conversion in the Controller for the thermistor type used.<br>Note: the thermistor’s nominal resistance at +25°C shall be 10kΩ in any case. |

| | |
|---|---|
| SHORT DESCRIPTION | calibrate main NTC thermistor |
| COMMAND TO CONTROLLER | *CALMTTNX; |
| COMMAND EXAMPLE | *CALMTTN+25; |
| REPLY FROM CONTROLLER | *MTTN X; |
| REPLY EXAMPLE | *MTTN +25.00°C; |

| | |
|---|---|
| FULL DESCRIPTION | Calibrating the main NTC 10k thermistor in a defined temperature:<br>X = actual thermistor temperature [°C]<br>The resistance of the main NTC thermistor measured by the Controller is being multiplied by an internal scaling coefficient in order to correct an error caused by the thermistor's tolerance.<br>After receiving the command, the Controller determines the value of the coefficient so that the calculated temperature is as close as possible to the temperature given in the command. The coefficient value is stored in the memory and applies in the future. |

| | |
|---|---|
| SHORT DESCRIPTION | get actual output current |
| COMMAND TO CONTROLLER | *GETIOUT; |
| REPLY FROM CONTROLLER | *IOUT X.XA; |
| REPLY EXAMPLE | *IOUT +1.29A; |
| FULL DESCRIPTION | Reading the actual value of the output current:<br>X.XA = value |

| | |
|---|---|
| SHORT DESCRIPTION | get output current range |
| COMMAND TO CONTROLLER | *GETIRNG; |
| REPLY FROM CONTROLLER | *IRNG R.RA (M.MA); |
| REPLY EXAMPLE | *IRNG 2.40A (5.00A); |
| FULL DESCRIPTION | Reading the preset range of the output current:<br>R.R = preset range<br>M.M = maximum presettable range (5A or 12A; version-dependent) |

| | |
|---|---|
| SHORT DESCRIPTION | set output mode |
| COMMAND TO CONTROLLER | *SETGMODEX; |
| COMMAND EXAMPLE | *SETGMODEH; |
| REPLY FROM CONTROLLER | *GMODE X; |
| REPLY EXAMPLE | *GMODE H; |
| FULL DESCRIPTION | Setting the general mode of the current output:<br>X = P (bipolar mode; for driving a TEC/Peltier module)<br>X = H (unipolar mode; for driving a heater)<br>The 'P' mode is the standard mode for controlling a TEC. The output current has positive polarity for cooling and negative polarity for heating.<br>In the 'H' mode, the output current has negative polarity for heating and is turned off for cooling. |

| | |
|---|---|
| SHORT DESCRIPTION | get output mode |
| COMMAND TO CONTROLLER | *GETGMODE; |
| REPLY FROM CONTROLLER | *GMODE X; |

| | |
|---|---|
| REPLY EXAMPLE | *GMODE P; |
| FULL DESCRIPTION | Reading the general mode of the current output.<br>See description of the previous operation. |

| | |
|---|---|
| SHORT DESCRIPTION | set mode of OC USER output |
| COMMAND TO CONTROLLER | *SETOCUX; |
| COMMAND EXAMPLE | *SETOCUE; |
| REPLY FROM CONTROLLER | *OCU X; |
| REPLY EXAMPLE | *OCU E; |
| FULL DESCRIPTION | Setting the working mode of the OC USER open-collector output:<br>X = N (not active)<br>X = E (active on system error)<br>X = C (active on cooling)<br>X = H (active on heating)<br>The OC USER output is shorted to ground when active and open otherwise. |

| | |
|---|---|
| SHORT DESCRIPTION | set mode of PWM FAN output |
| COMMAND TO CONTROLLER | *SETPWMFX; |
| COMMAND EXAMPLE | *SETPWMFU; |
| REPLY FROM CONTROLLER | *PWMF X; |
| REPLY EXAMPLE | *PWMF U; |
| FULL DESCRIPTION | Setting the working mode of the PWM FAN output:<br>X = N (not active)<br>X = A (always active)<br>X = U (20%...100% duty at AUX temperature +20ºC…+50ºC)<br>X = R (0%...100% duty at PID regulator output -1.0…+1.0) |

| | |
|---|---|
| SHORT DESCRIPTION | set mode of PWM USER output |
| COMMAND TO CONTROLLER | *SETPWMUX; |
| COMMAND EXAMPLE | *SETPWMUH; |
| REPLY FROM CONTROLLER | *PWMU X; |
| REPLY EXAMPLE | *PWMU H; |
| FULL DESCRIPTION | Setting the working mode of the PWM USER output:<br>X = N (not active)<br>X = C (active on cooling)<br>X = H (active on heating) |

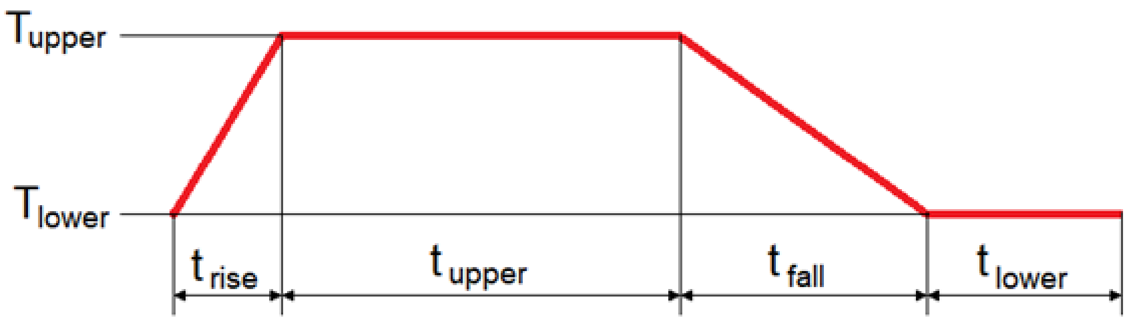
| | |
|---|---|
| SHORT DESCRIPTION | set mode of TEMP OUT output |
| COMMAND TO CONTROLLER | *SETANLUX; |

| | |
|---|---|
| COMMAND EXAMPLE | *SETANLUO; |
| REPLY FROM CONTROLLER | *ANLU X; |
| REPLY EXAMPLE | *ANLU O; |
| FULL DESCRIPTION | Setting the working mode of the TEMP OUT analog output:<br>X = N (zero)<br>X = P (proportional part of PID regulator) (a)<br>X = I (integral part of PID regulator) (a)<br>X = D (differential part of PID regulator) (a)<br>X = O (output of PID regulator) (a)<br>X = M (real temperature) (b)<br>X = S (preset temperature) (b)<br>(a) 0V for -100% … +1.65V for 0% … +3.3V for +100%<br>(b) voltage[V] = temperature[ºC] * 0.01;<br>the output voltage range is 0V…+3.3V ie. negative temperatures will be output as 0V. |

| | |
|---|---|
| SHORT DESCRIPTION | set frequency of MONITOR output |
| COMMAND TO CONTROLLER | *SETKHZX; |
| COMMAND EXAMPLE | *SETKHZ0.1; |
| REPLY FROM CONTROLLER | *KHZ X; |
| REPLY EXAMPLE | *KHZ 0.1; |
| FULL DESCRIPTION | Setting the frequency of the MONITOR pulse output:<br>X = frequency [kHz] 0.04…1000<br>The duty cycle is 50% for all frequencies. |

# Programmable Temperature Cycles

The Controller can automatically perform programmable temperature cycles. During execution of the cycles, the target temperature is being changed according to the graph below where a single cycle is shown:




The parameters (Tupper, Tlower, trise, tupper, tfall, tlower) as well as the number of cycles are all programmed by the user.

Programming and starting execution of the temperature cycles is done by sending a string of parameter values to the Controller through the serial connection. A status string is then being periodically sent back from the Controller. See chapter **Local and Remote Operations**.

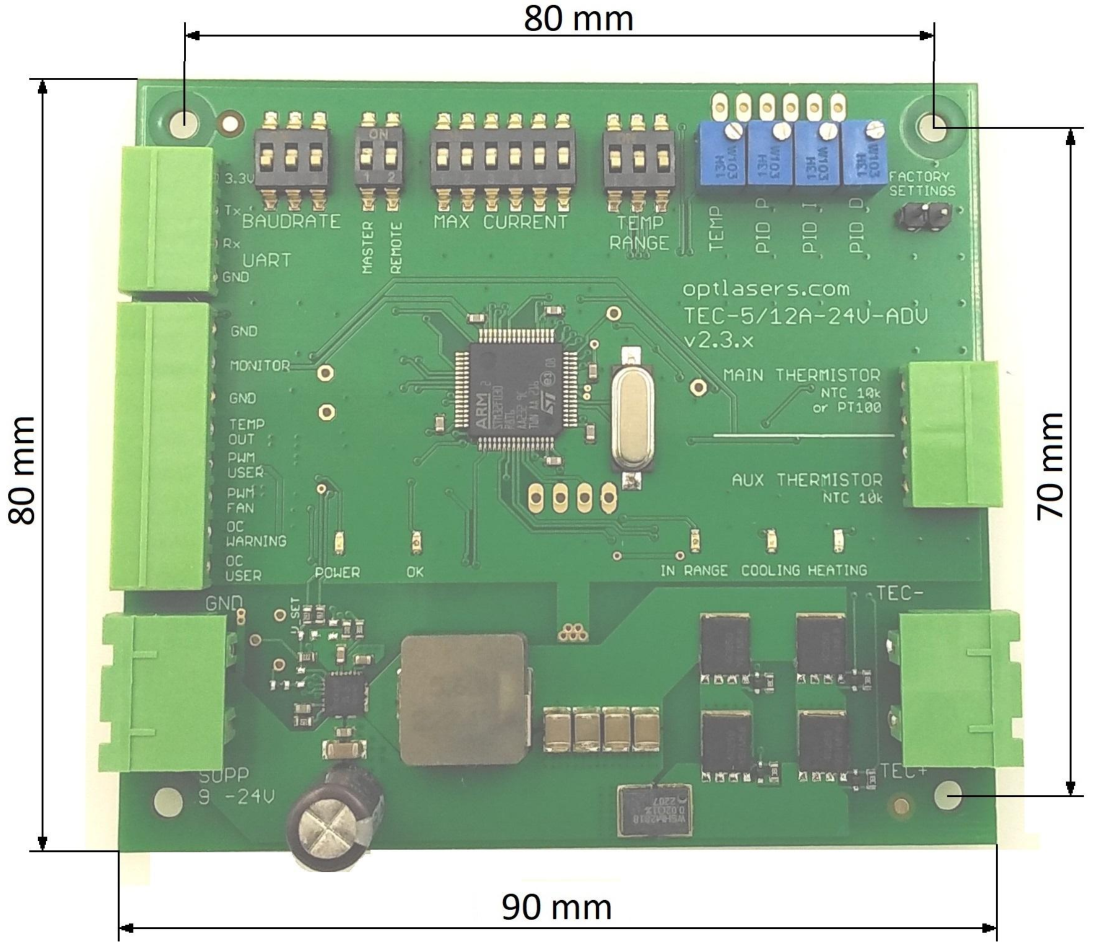
NOTES:

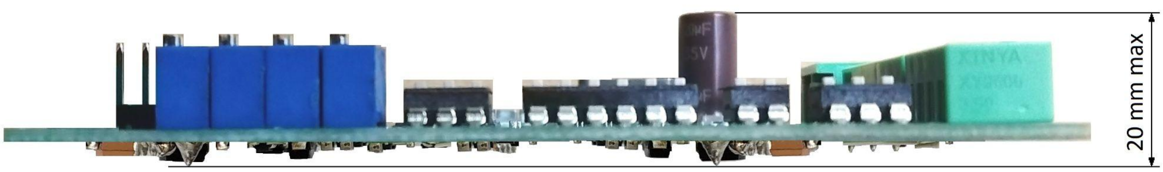
- the execution of temperature cycles starts immediately after the reception of the parameter string in the Controller;
- any time during the execution of temperature cycles, sending back the status string through the serial connection may be disabled or enabled; see chapter **Local and Remote Operations**;
- stopping temperature cycles is done either automatically after programmed number of cycles or by turning the Controller off;
- after turning the Controller off during the execution of temperature cycles, and turning it on again, the Controller starts its regular function and does not perform temperature cycles anymore; the parameters of the temperature cycles are lost; restarting temperature cycles would require renewed sending of a parameter string to the Controller;
- $T_{lower}$ may be set higher than $T_{upper}$; in such case, the temperature is actually falling down to $T_{upper}$ during $t_{rise}$ and rising up to $T_{lower}$ during $t_{fall}$ in each temperature cycle; i.e. temperature cycles are being performed correctly, just the descriptions may be confusing.

# Troubleshooting

| MALFUNCTION | POSSIBLE CAUSE | SOLUTION |
|---|---|---|
| all LEDs are OFF after power-on | broken/unconnected leads from PSU to Controller | turn power off, reconnect the leads and turn power on |
| | bad SUPP plug | turn power off, replace the plug and turn power on |
| | PSU failure | replace the PSU |
| | Controller's failure | send the Controller for repair |
| LED "OK" is OFF | lack of MAIN thermistor | turn power off, attach the thermistor and turn power on |
| | short circuit at MAIN thermistor | turn power off, remove the short circuit and turn power on |
| | short circuit at AUX thermistor | turn power off, remove the short circuit and turn power on |
| | Controller's failure | send the Controller for repair |
| LED "IN RANGE" is permanently off | lack of MAIN thermistor | turn power off, attach the thermistor and turn power on |
| | short circuit at MAIN thermistor | turn power off, remove the short circuit and turn power on |
| | Controller's failure | send the Controller for repair |
| no output current regardless of amount of temperature error | extreme settings of PID coefficients | adjust the PID coefficients |
| | broken/unconnected leads from Controller to TEC module | turn power off, reconnect the leads and turn power on |
| | bad TEC plug | turn power off, replace the plug and turn power on |
| | TEC module failure | replace the TEC module |
| | Controller's failure | send the Controller for repair |
| the real temperature is changing in wrong direction; temperature error is always increasing | strong "overshoot" at PID regulation | adjust the PID coefficients: try to decrease **I** |
| | bad polarization of TEC module | exchange leads of the TEC module |
| the real temperature is "swinging" and does not stabilize | bad settings of PID coefficients | adjust the PID coefficients: try to decrease **P** and/or decrease **I** |
| reaching the target temperature takes too long | bad settings of PID coefficients | adjust the PID coefficients: try to decrease **I** and/or turn on/increase **D** |
| the real temperature stabilizes yet the target temperature is not reached; temperature error is too high | bad settings of PID coefficients | adjust the PID coefficients: try to increase **P** and/or turn on **I** |

# Mounting Guidelines




The PCB can be mounted on a solid base with four M3 screws and spacer studs with at least 3 mm length.

Free air flow in the PCB area should be allowed in order to provide cooling. If the PCB has to be mounted in an enclosure, it should contain holes/slits allowing for ventilation. If the Controller is expected to output high currents (8A and more), it is strongly recommended to provide forced air flow near the top of the PCB by using a fan.