



## **LASER DIODE CONTROL**

part of the Laser Lab Source Group

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## Overview:

The LDI, LDC and TEC series laser diode drivers and TEC controllers are designed to precisely and reliably drive diode lasers and Peltier / TE cooler elements. They are available as benchtop units and as OEM units. All laser diode current sources have an integrated QCW pulse generator and can be run from QCW pulse to CW mode. External digital and analog modulation functionality is also included on all models. The standard RS232 interface can be used for configuration, operation and monitoring. A USB interface is optionally available on all models. Every unit passes a burn-in inspection, a full functional test and a final calibration prior to shipment.

## Laser Diode Current Source Features:

- Full digital control, standard interface RS232 or USB
- Non volatile pre-configuration (EEPROM)
- Controllable internal and external fan supplies
- Hardware interlock
- Over-temperature and over-current protection
- Precise current controlled CW and pulsed laser operation modes
- Low power dissipation by active voltage control in CW mode
- Multiple laser diode safety features
- Internal and external modulation functions

## TEC Controller Features:

- Thermosensor input for NTCs (standard 10 k $\Omega$ ), PT100, PT1000 or others
- Polynomial and Steinhart-Hart sensor model
- PID temperature controller for TEC coolers
- Voltage, current and temperature limits
- Target temperature sequencer on request



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## **1. Introduction**

The LDI, LDC and TEC series precision laser diode drivers and TEC controllers offer the user full control of all configuration parameters through a front panel and/or through a serial interface. It is important to read this manual thoroughly before turning on the device for the first time. The operating instructions should be followed for safe operation and optimum performance of the laser diode.

**In case of questions or problems, please contact Laser Lab Source in North America or OsTech in Europe.**

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Please note that unauthorized opening of the device enclosure cancels the warranty.  
Please not break the calibration and warranty seal.



## 2. Technical Parameters

### 2.1 General Parameters FOR ALL MODELS

|                                 |                                                          |
|---------------------------------|----------------------------------------------------------|
| input voltage                   | DS01: 24 V DC $\pm$ 10%<br>DS11: 110–220 V AC            |
| ambient temperature             | 0 ... 40 °C                                              |
| humidity                        | < 95%                                                    |
| <i>housing size</i>             | <i>width × height × depth (depth without connectors)</i> |
| o44 housing                     | 105 mm × 44 mm × 160 mm<br>(4.1 in × 1.7 in × 6.3 in)    |
| o85 housing                     | 105 mm × 85 mm × 160 mm<br>(4.1 in × 3.3 in × 6.3 in)    |
| t85 housing                     | 105 mm × 85 mm × 200 mm<br>(4.1 in × 3.3 in × 7.9 in)    |
| t95 housing                     | 119 mm × 95 mm × 235 mm<br>(4.7 in × 3.7 in × 9.3 in)    |
| t127 housing                    | 200 mm × 127 mm × 277 mm<br>(7.9 in × 5.0 in × 10.9 in)  |
| t192 housing<br>(19 inch, 2 HU) | 483 mm × 89 mm × 266 mm<br>(19 in × 3.5 in × 10.5 in)    |
| t193 housing<br>(19 inch, 3 HU) | 483 mm × 133 mm × 266 mm<br>(19 in × 5.25 in × 10.5 in)  |
| remote control                  | PC serial interface RS232                                |

### 2.2 (Model Specific) Laser Diode Current and Voltage

|                     |            |                                                      |
|---------------------|------------|------------------------------------------------------|
| laser diode current | range      | 1.5   2.5   5   8   12   16   24   32   40 ... 100 A |
|                     | resolution | $I_{\max} / 4000$                                    |
|                     | accuracy   | $\pm 0.5 \%$                                         |
| laser current limit | range      | 0 ... $I_{\max}$                                     |
|                     | resolution | $I_{\max} / 4000$                                    |



|                            |                            |                                                                        |
|----------------------------|----------------------------|------------------------------------------------------------------------|
|                            | accuracy                   | $\pm 2\%$                                                              |
| laser diode voltage        | min.                       | 1.2 V                                                                  |
|                            | max.                       | 3   6   9   12   15   18   24   48 V                                   |
| current noise              |                            | 1 % ... 0.01 % of $I_{\max}$ rms                                       |
| <i>internal pulse mode</i> |                            |                                                                        |
| pulse width                | range                      | (model specific) $10\ \mu\text{s} \dots 2^{32}\ \mu\text{s}$ (71 min)  |
| pulse period               | range                      | (pulse width + $100\ \mu\text{s}$ ) ... $2^{32}\ \mu\text{s}$ (71 min) |
| time base                  | accuracy                   | $\pm 1\%$                                                              |
| pulse to pulse             | accuracy                   | $30\ \mu\text{s}$                                                      |
| rise time                  | at 2.5 A                   | $< 2\ \mu\text{s}$                                                     |
|                            | $I_{\max}$                 |                                                                        |
|                            | at 4 A $I_{\max}$          | $< 3\ \mu\text{s}$                                                     |
|                            | at 8 A $I_{\max}$          | $< 10\ \mu\text{s}$                                                    |
|                            | at 12 A $I_{\max}$         | $< 15\ \mu\text{s}$                                                    |
|                            | at 16 A $I_{\max}$         | $< 18\ \mu\text{s}$                                                    |
|                            | $> 16\ \text{A } I_{\max}$ | 25–40 $\mu\text{s}$                                                    |
|                            | on request                 | $< 1\ \mu\text{s} \dots 3\ \mu\text{s}$                                |
| fall time                  |                            | 70 % ... 100 % of $T_{\text{rise}}$                                    |
| <i>laser fan control</i>   |                            |                                                                        |
| voltage                    | range                      | 1.2 V ... 24 V (adjustable by software)                                |
| current                    | max.                       | 300 mA                                                                 |

### 2.2.1 Security Shut-Down Conditions

- Interlock open
- Internal supply failure
- Abnormal transients
- Open circuit / no laser connected
- Internal overtemperature
- Beyond max. power dissipation



## 2.3 (Model Specific) TEC Controller

|                        |          |                                                                                            |
|------------------------|----------|--------------------------------------------------------------------------------------------|
| peltier current        | range    | $\pm 1.5 \mid \pm 2.5 \mid \pm 4 \mid \pm 8 \mid \pm 10 \mid \pm 12 \mid \pm 16 \text{ A}$ |
|                        | accuracy | $\pm I_{\text{max}}/4000$                                                                  |
| peltier voltage        | max.     | $4 \mid 8 \mid 14 \mid 18 \mid 24 \mid 48 \text{ V}$                                       |
| temperature controller | range    | $-25^\circ\text{C} \dots 150^\circ\text{C}$ , larger on request                            |
|                        | accuracy | typical: $< 10 \text{ mK}$                                                                 |
|                        |          | max.: $< 100 \text{ mK}$                                                                   |
| temperature limits     | range    | $-25^\circ\text{C} \dots 150^\circ\text{C}$                                                |
| default lower limit    |          | $5^\circ\text{C}$                                                                          |
| default upper limit    |          | $35^\circ\text{C}$                                                                         |



## 3. Keypad and Display Menus

### 3.1 Keypad

---

|                            |             |                                                                                                                                                        |
|----------------------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> ▲ | UP          | ▪ increases the digit under the cursor                                                                                                                 |
| <input type="checkbox"/> ▼ | DOWN        | ▪ decreases the digit under the cursor                                                                                                                 |
| <input type="checkbox"/> ◀ | LEFT        | ▪ moves to the previous input field, unsaved changes are discarded                                                                                     |
| <input type="checkbox"/> ▶ | RIGHT       | ▪ moves to the next input field, unsaved changes are discarded                                                                                         |
| <input type="checkbox"/> ● | OK or Enter | ▪ triggers actions<br>▪ toggles checkboxes<br>▪ saves a changed value<br>▪ moves the cursor position if pressed on an unchanged or already saved value |

---

### 3.2 Display Menus

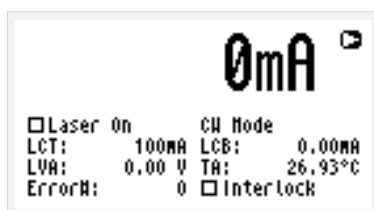
After power-on, the main menu is shown on the display. Some fields can be used to change settings of the device, others only show the current values. You can switch to the next menu with the arrow in the upper right corner. The laser menu is next. Then follow the TEC menus. The last menu is the device menu for general settings.

#### 3.2.1 Main Menu

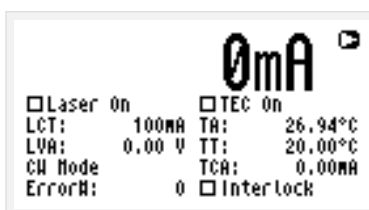
The main menu gives an overview over the current state and allows you to control basic settings. The layout of the main menu depends on the model. It is shown in [figure 3.1](#). The large number show the present laser current in laser drivers and the current temperature in TEC controllers. The following fields may be available in the main menu:



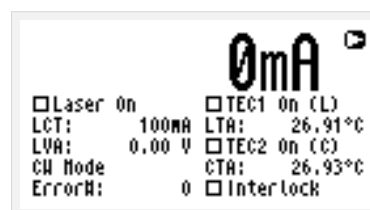
|                   |                                                                                             |
|-------------------|---------------------------------------------------------------------------------------------|
| Laser On          | switch the laser on and off, can only be changed if the device has no separate laser switch |
| LCT               | laser current target                                                                        |
| LVA               | laser voltage actual                                                                        |
| LCB               | laser current bias (for modulation)                                                         |
| CW Mode, ... Mod. | modulation mode                                                                             |
| TEC On            | switch the TEC controller on and off                                                        |
| TT, LTT, CTT      | target temperature                                                                          |
| TA, LTA, CTA      | temperature actual                                                                          |
| TCA, LTCA, CTCA   | TEC current actual                                                                          |
| TVA               | TEC voltage actual                                                                          |
| TCL               | TEC current limit                                                                           |
| Error#            | error number (0 = no error)                                                                 |
| Interlock         | if the interlock is closed                                                                  |



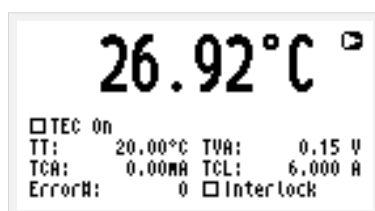
(a) Laser driver without TEC controller.



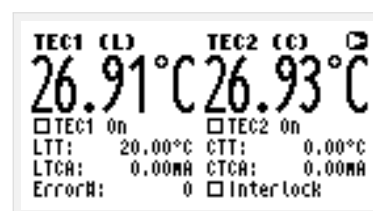
(b) Laser driver with one TEC controller.



(c) Laser driver with two TEC controllers.



(d) Controller for one TEC.



(e) Controller for two TECs.

Figure 3.1: Main menu layout depending on the modules in the device

### 3.2.2 Laser Menu

The laser menu is shown in [figure 3.2](#). This is where the user can change laser current settings. The following fields are included:



|         |                                                                                                                                                                                      |
|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| LCL     | laser current limit                                                                                                                                                                  |
| LVC     | compliance voltage ( $\geq$ LVA)                                                                                                                                                     |
| LVA     | laser voltage actual                                                                                                                                                                 |
| LCB     | laser current bias (for modulation)                                                                                                                                                  |
| LCLM    | limit for average laser current (for modulation)                                                                                                                                     |
| LTM     | laser temperature maximum, laser stops above this temperature                                                                                                                        |
| Error#  | error number (0 = no error)                                                                                                                                                          |
| CW Mode | no modulation                                                                                                                                                                        |
| LMAX    | external analog modulation                                                                                                                                                           |
| LMDX    | external digital modulation                                                                                                                                                          |
| LMDI    | internal digital modulation                                                                                                                                                          |
| LMW     | laser modulation width                                                                                                                                                               |
| LMP     | laser modulation period                                                                                                                                                              |
| PC      | pulse count (= LMDIC command) <ul style="list-style-type: none"> <li>▪ PC = 1: single pulse</li> <li>▪ PC = 2: burst of 2 pulses ...</li> <li>▪ PC = 0: continuous pulses</li> </ul> |
| LG      | gate option                                                                                                                                                                          |

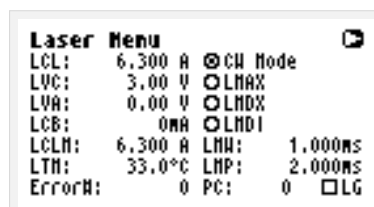


Figure 3.2: Laser menu

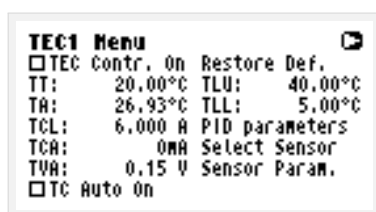
### 3.2.3 TEC Menu

The TEC menu is shown in [figure 3.3a](#). This is where the user can change TEC controller settings. The following fields are included:

|            |    |                                      |
|------------|----|--------------------------------------|
| TEC Contr. | On | switch the TEC controller on and off |
| TT         |    | target temperature                   |
| TA         |    | temperature actual                   |
| TCL        |    | TEC current limit                    |
| TCA        |    | TEC current actual                   |



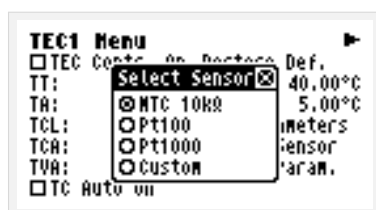
|                |                                                                                              |
|----------------|----------------------------------------------------------------------------------------------|
| TVA            | TEC voltage actual                                                                           |
| TC Auto On     | TEC controller is automatically activated when the temperature is within limits              |
| Restore Def.   | restores the default settings for the TEC controller                                         |
| TLU            | upper temperature limit                                                                      |
| TLL            | lower temperature limit                                                                      |
| PID parameters | set the PID coefficients (see <a href="#">figure 3.3b</a> )                                  |
| Select Sensor  | select one of some predefined temperature sensor settings (see <a href="#">figure 3.3c</a> ) |
| Sensor Param.  | manually set the temperature sensor settings (see <a href="#">figure 3.3d</a> )              |



(a) TEC menu.



(b) Dialog: PID Parameters.



(c) Dialog: Select Sensor.



(d) Dialog: Sensor Parameters.

**Figure 3.3:** TEC Menu and dialogs in it.

### 3.2.4 Device Menu

The device menu is shown in [figure 3.4](#). This is where the user can change general settings and find out the type and serial number of your device. You find the following fields in this menu:

|                            |                                                                                            |
|----------------------------|--------------------------------------------------------------------------------------------|
| External Control on Start  | Switch to external control automatically after power-on. You get the chance to abort this. |
| Switch to External Control | You can control the device over the RS232 interface after activating this.                 |
| Pilot laser                | Switch the pilot laser on and off.                                                         |
| Intensity                  | pilot laser intensity (0...16)                                                             |



|                          |                                                              |
|--------------------------|--------------------------------------------------------------|
| GFD                      | default fan voltage                                          |
| Restore Default Settings | Reset all settings in the device to their default values.    |
| Service                  | Show type, serial number and software version of the device. |

---

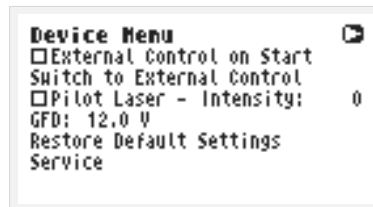


Figure 3.4: Device menu.



## 4. Hardware Set-Up Preparation

These steps must be followed:

- Make sure that the power supply is disconnected from your main power supply.
- Use an approved personal grounding bracelet or other means for ESD protection during the assembly of the laser or other electronics.
- Connect your laser to the proper connectors of the driver unit.
- Remove the shorting clip from the laser. While turned off, the laser output of the driver unit is internally shorted.
- Connect the power supply unit to the proper supply voltage.
- Make sure that the interlock connector is closed.
- Make sure that the emergency button (the large red button on the front) is unbolted / pulled out.
- Make sure that an appropriate temperature sensor for the laser is connected.  
**The laser driver needs a temperature signal to active the drive current.**
- Please note laser safety regulations!
- Turn the key switch on.



## 5. Laser Diode Current

### 5.1 Preparations

First the laser current limit and the laser compliance voltage must be configured. To adjust the laser current limit using the display:

- go to the Laser Menu by pressing and
- go to the LCL input field by pressing to adjust the laser current limit
- to move the cursor position press several times
- to increase/decrease the digit press / as often as necessary
- after adjusting the value press to enter the new value

After the step above, the user should adjust the laser compliance voltage (LVC input field) to an expected voltage drop slightly above the laser's rating.

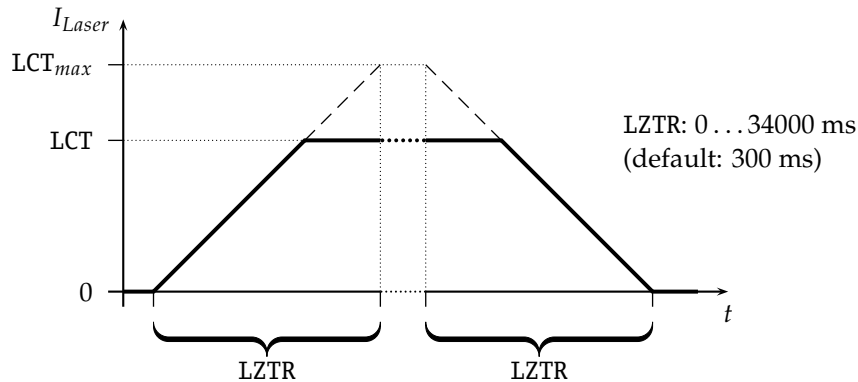
These values can also be set by using the RS232 interface (see [chapter 7](#)). To do this use the commands LCL and LVC.

### 5.2 CW Mode

The mode of operation can be selected in the laser menu. The CW mode is active by default when all of the modulation modes (LMDI, LMDX and LMAX) are unchecked.

#### 5.2.1 Switching on the Laser Diode

Go to the main menu and adjust the laser current target in the LCT input field. The selected value must be under the laser current limit and the maximum operating current of your laser module. Enable the LON/OFF input field to switch on current to the laser. The LED on the front panel will start blinking and the actual current will be displayed. Disabling it switches off the laser and causes the red LED on the front panel to stop blinking. The actual current 0.00 A will be displayed. Pressing the emergency button on the front panel interrupts the power supply immediately. Unbolt it by twisting.



**Figure 5.1:** Laser current on-off ramp in CW mode. The ramp is active at any change of laser current.

When using the RS232 interface the command LR may be used to switch the laser on. The command LS switches the laser off.

### 5.2.2 Current Ramp to Laser Current Set-Point

In CW mode the ramp on laser run and stop is activated by default. However, this function is not available over the display menus. To use this feature, you need to control the driver over an RS232 interface. With e. g. LZTR2000 you can set the time to reach the maximum current set-point for your laser diode. The slope of the ramp will be  $LCT_{max}/2000 \text{ ms}$  in this example. During the laser stop ramp, you can turn off the laser immediately by sending LS command again. You can disable the ramp with LZTR0. The default value for LZTR is 300 ms. Figure 5.1 shows how LZTR works. For a list of other commands see chapter 9.

### 5.2.3 Laser APC Power Control Mode

The power control mode is only available in CW mode and consists of two independent parts:

- The photo-current control loop
- The laser power coefficients which do a translation from a power value into a value for the photo-current

To initiate the APC power control you must first prepare the laser for proper operation in CW mode (see section 5.1). Don't forget to adjust the laser current limit.



Before turning the laser diode on you must connect the photo-sensor between the PDC (cathode) and the GND (anode) pins at the laser connector. After this you should test whether the sensor is working. For this step, run the laser and check with the LPCA command (laser photo-current actual). The default maximum photo current is 700  $\mu$ A, but can be increased on request. Enter your target photo-current with the LPCT command. Initialize the photo-current control mode by the command LPCCR (laser photo current control run). Now you can run and stop the laser by LR and LS. As soon as you start the laser the driver begins continuously to track and control the photo current. The second step is to adjust the power coefficients so that you can use power values in Watts. For this, do as follows:

- adjust the LPT value (laser power target), it should have a typical or a maximum value
- run the laser in normal CW mode and set the current to the point that the laser emits exact the target laser power. An external power meter is necessary for this. Now execute the LPF command to fix the actual photo-current value to this laser power.

You can now you can get the laser power by the command LPA, set the power target by the LPT command, run the power control mode by the LPCCR command. Start and stop the laser by LR and LS.

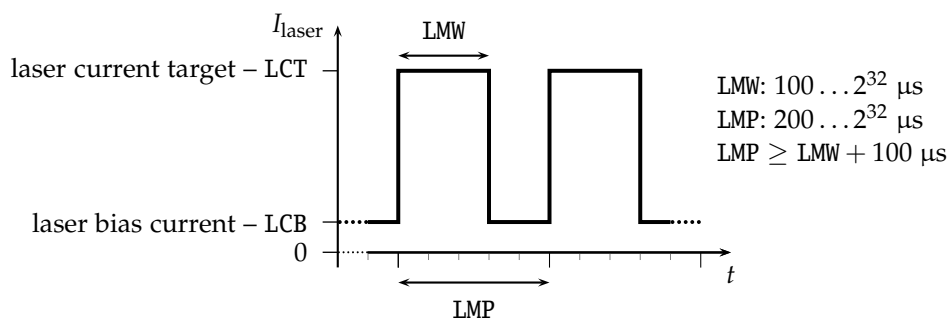
### 5.3 Gate Option

There is a gate option which can be used in CW mode as well as in internal digital modulation mode. You may switch on and off the internally generated laser current by the modulation input. Optionally, a separate gate pin may be used. In this case the gate option is also available in the external modulation modes. The gate option is activated by the command LGR and deactivated by LGS. Additionally, the LMDXNR command can be used to negate the modulation input.

### 5.4 Modulation Modes

The modulation modes can be selected in the laser menu. Changing modulation modes turns off the laser. You may start the laser again the main menu.

Please note that the preparations—as described in [section 5.1](#)—have to be done first. In modulation modes the measured currents and voltages displayed in the main



**Figure 5.2:** continuous pulse mode

menu **show the mean values** not the peak values. These measured values may differ from the adjusted ones caused by the low speed of the AD converter. Don't care about this. The real values are within the limits as described above.

### 5.4.1 Internal digital modulation mode

The driver is able to modulate the laser current by internally generated pulses. This internal modulation mode may be activated by checking the LMDI input field in the laser menu or entering the LMDIR command.

#### Continuous pulse mode

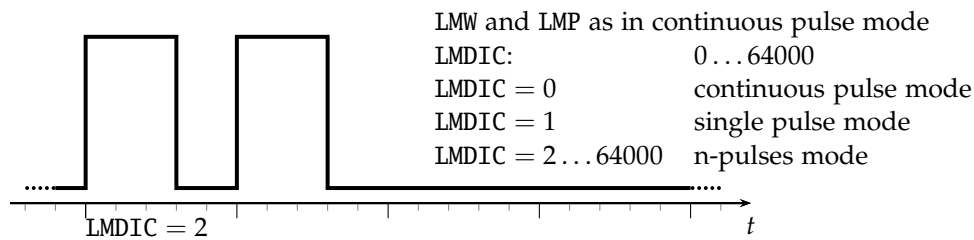
Unless configured otherwise, pulses are generated continuously as you can see in [figure 5.2](#). You have to enter the pulse width (duration) and pulse period in  $\mu\text{s}$ . Take care of the right proportions of these values. The pulse width is in the range of  $100 \mu\text{s} \dots 4 \times 10^9 \mu\text{s}$  and may be changed by the LMW command. The pulse period (LMP command) is in the range of  $(\text{LMW} + 100 \mu\text{s}) \dots 4 \times 10^9 \mu\text{s}$ , so it is always at least  $100 \mu\text{s}$  larger than the pulse width.

Newer devices are not subject to these limitations. Here, LMW and LMP can be set freely in steps of  $1 \mu\text{s}$ .

You can run and stop the laser by the commands LR and LS.

#### Single pulse mode, n-pulses mode

This mode—which is illustrated in [figure 5.3](#)—is useful if you want to generate only a single pulse or a certain number of pulses. To activate it first select the internal digital modulation mode as stated above. Then enter the command LMDIC  $n$  where  $n$  is the number of pulses you want to be generated. After entering the LR command



**Figure 5.3:** single pulse mode, n-pulses mode

the number of pulses will be generated. Afterwards, the driver enters the *OFF state* automatically. You don't need to enter LS.

Assigning 0 to LMDIC switches to the continuous pulse mode described above.

### External trigger mode

To switch to this mode activate the gate option in single pulse mode/n-pulses mode. The gate option (see [section 5.3](#)) has a different meaning in this mode. Activating it enables you to trigger the beginning of the generated pulses externally. If LGR is activated and LR was entered the driver generates the defined number of pulses as soon as a low-high transition at the modulation input occurs.

## 5.4.2 External Digital Modulation

The external digital modulation mode may be activated by entering the LMDX command. If this mode is active and the laser is run (LR) then the laser is activated by a TTL high-level at the modulation input and vice versa. The command LMDXNR negates this logic so that the laser will be activated by TTL low-level. This mode is similar to the CW mode with the gate option activated. However, in this mode you can set a laser bias current (LCB).

## 5.4.3 External Analog Modulation

The external analog modulation mode is selected by entering the LMAX command. In this mode the laser current can be controlled by the voltage at the AMOD input where 4 V corresponds to  $I_{\max}$ . The compliance voltage (LVC) has to be set before and the laser has to be run by LR.

The input has an internal terminating resistor of 10 k $\Omega$ . If you want to connect e.g. a 10 V signal, you should use a 15 k $\Omega$  resistor in series externally.



## 5.5 Pilot Laser Control

These laser diode drivers support an internal pilot laser. One pin on the laser & peltier connector is reserved for this purpose. In *ON state* a voltage between 4.0 and 5.0 V is applied. The maximum output current is 150 mA. In *OFF state* the output is near 0 V level. With PLR and PLS you can turn the pilot laser *ON* and *OFF*. With the command PP  $n$  you may set the pulse width modulation value with a base frequency of 62 Hz. The modulation parameter  $n$  can take values between 0 and 16. The meaning of those values is as follows:

|          |                                       |
|----------|---------------------------------------|
| $n = 0$  | pilot laser OFF                       |
| $n = 1$  | duty cycle 6.25 % - ON duration 16 ms |
| $n = 2$  | duty cycle 12.5 % - ON duration 32 ms |
| ...      | ...                                   |
| $n = 16$ | pilot laser ON                        |



## 6. TEC Controller and Temperature Sensors

As some models may have more than one TEC controller, the temperature sensor or TEC controller is selected by a prefix, in this chapter written as  $x$ . So,  $x$  has to be replaced by a digit (or letter) to select the temperature sensor or TEC. The first temperature sensor or TEC corresponds to 1, the second to 2, the third to 3 and so on. As the first temperature sensor or TEC is usually used for a laser and the second for a crystal, a deprecated option for selecting them is the use of the letters L and C, respectively.

### 6.1 PID Controller Parameters

The temperature controller in devices with TEC support has a PID structure with the common formulas:

$$G_c(s) = k_p \left( 1 + \frac{1}{T_n s} + T_v s \right)$$

$$u(t) = k_p \left( e(t) + \frac{1}{T_n} \int e(t) dt + T_v \frac{de(t)}{dt} \right)$$

$$\begin{array}{ll} k_p & - \text{proportional gain} - x\text{TCCK} \\ T_n = T_i & - \text{integral time} - x\text{TCCN} \\ T_v = T_d & - \text{derivative time} - x\text{TCCV} \end{array}$$

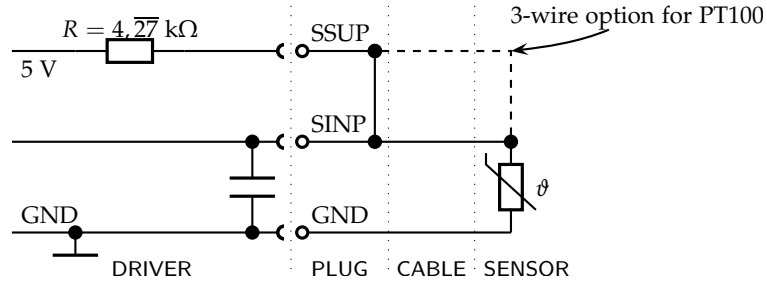
The values of these three variable parameters have to be found. After Ziegler-Nichols for example you can calculate

$$k_p = 1.2 \cdot \frac{T}{L}$$

$$T_n = 2 \cdot L$$

$$T_v = 0.5 \cdot L$$

Here,  $T$  is the base time constant and  $L$  is the delay time, both derivated from a step response. Note that the so found parameters differ slightly from the theoretical values. In practice typical value ranges for a TEC circuit are:



**Figure 6.1:** schematic for connecting a temperature sensor

$xTCCk$ : 0.2...5  
 $xTCCN$ : 5...50  
 $xTCCV$ : 0.2...2

If you don't know anything about the TEC circuit, you may set  $xTCCk = 0.2$ ,  $xTCCN = 2$  and  $xTCCV = 0.1$ . Then increase  $xTCCk$  slowly by 1 as long as the circuit stays stable. When it becomes unstable, half the  $xTCCk$  value. Here the controller is operating primarily as "P" proportional controller. After this try to find the value for  $xTCCN$  in the same way. However, you may increase it by larger steps. At this point, the controller behaves like a "PI" controller. Finally, you may increase  $xTCCV$  by steps of 0.3 until you find an optimum value for response time and eliminate overshooting.

Note that you must stop and restart the temperature controller after changing those values to make sure that the controller is initialized with the new values.

## 6.2 Temperature Sensor

The temperature sensor is connected over three pins of the laser & peltier interface: GND, SINP and SSUP. The schematic in [figure 6.1](#) shows the internal part of the driver on the left hand side and a typical NTC thermistor connected to it on the right hand side. In newer models, the SSUP and SINP are connected internally. Only the pins SINP and GND are available externally.

The temperature is calculated by measuring the voltage using a voltage divider. After a 24 bit AD conversion the temperature  $T$  is calculated from the measured voltage  $V$ . For this purpose the Steinhart-Hart equation is used by default.

$$T(R_{NTC}) = \frac{1}{c_1 + c_2 \cdot \ln(R_{NTC}) + c_3 \cdot (\ln(R_{NTC}))^3} + c_0 \quad (\text{TSM1})$$



The default coefficients  $c_0$ ,  $c_1$ ,  $c_2$  and  $c_3$  of this polynomial correspond to an NTC with 10 k $\Omega$  at 25 °C which is a wide spread standard. You may adjust these coefficients to a different sensor by the commands  $xTSC$  [0 ... 3 ].

Additionally, the driver can be set to calculate the temperature using the following third-order polynomial:

$$T(V) = c_3 \cdot V^3 + c_2 \cdot V^2 + c_1 \cdot V + c_0 \quad (\text{TSM0})$$

The model switching is done with the  $xTSM$  command. Here,  $xTSM0$  causes the polynomial model to be used and  $xTSM1$  switches to the Steinhart-Hart equation.

The coefficients for some common sensors are given in the table below.

The settings for a PT100 or PT1000 sensor can be calculated from its resistance using the following formulas:

$$R_0 = 100 \, \Omega \quad (\text{at } 0 \, ^\circ\text{C})$$

$$R(T) = R_0 \cdot (1 + A \cdot T - B \cdot T^2) \quad (T: \text{temperature in } ^\circ\text{C})$$

As  $B$  is commonly neglected you can calculate them using

$$R(T) = R_0 \cdot (1 + A \cdot T)$$

and using the divider network which leads to the coefficients shown in the following table:

|                                                     | $xTSC0$  | $xTSC1$                | $xTSC2$                | $xTSC3$                |
|-----------------------------------------------------|----------|------------------------|------------------------|------------------------|
| <i>polynomial model (<math>xTSM0</math>)</i>        |          |                        |                        |                        |
| NTC 10 k $\Omega$ B3980                             | 135.83   | -63.2256               | 15.3332                | -1.80043               |
| NTC 10 k $\Omega$ B3450                             | 156.089  | -74.4317               | 17.5466                | -1.99111               |
| PT100 TK3850                                        | -266.475 | 2330.44                | 0                      | 0                      |
| PT1000 TK3850                                       | -327.084 | 344.924                | 0                      | 0                      |
| AD590 (1 $\mu$ A/K)                                 | -897.065 | -234.043               | 0                      | 0                      |
| <i>Steinhart-Hart equation (<math>xTSM1</math>)</i> |          |                        |                        |                        |
| NTC 10 k $\Omega$ B3980                             | -273.15  | $1.0832 \cdot 10^{-3}$ | $2.4141 \cdot 10^{-4}$ | $6.505 \cdot 10^{-8}$  |
| NTC 10 k $\Omega$ B3450                             | -273.15  | $1.1293 \cdot 10^{-3}$ | $2.3411 \cdot 10^{-4}$ | $8.7755 \cdot 10^{-8}$ |

The settings for the AD590 (1  $\mu$ A/K) sensor can be calculated using

$$U(T) = U_{\text{ref}} - (4272.72 \cdot 10^{-6} \cdot T) \quad (T: \text{temperature in } ^\circ\text{C})$$



For tolerances of real sensors you may need to calibrate the setup point of your sensor by adding the difference between the real temperature and the shown temperature to the absolute part  $xTSC0$ .

If you need assistance in connecting your sensors or you want to assemble any other sensor to the driver we would be pleased to assist you in finding the appropriate coefficients.



## 7. Remote Control

All models may be controlled over a serial interface. The transfer parameters of the serial interface are fixed to 9600 baud 8N1.

### 7.1 Standard Mode

In *standard mode* you can send commands and parameters to the device in text format and the device answers in the same way. The answer of the device always contains comments and the parameters and values are given back. This mode is optimal for working on a PC using any terminal program.

After sending a character you will receive an echo of your input, i.e. all sent characters return immediately. All characters are changed to upper case. All inputs have to be finished by `(CR)` to process the input; `(CR)` is also returned. If a command returns a value, the answer is also finished by `(CR)`. No linefeed `(LF)` is added after the `(CR)`, but most terminals are able to generate this automatically. You may invalidate any sequence by sending `(Esc)`. Single characters may be deleted from the buffer by backspace `(←)`. Between commands and their parameters you can insert as many spaces as you want (no space is also okay). But note that the whole command line must not be longer than 14 characters.

```
sent command:    LCT222.3 (CR)                every character is returned
received answer: Laser Current Target:  222.3 mA (CR)    verbose answer
```

### 7.2 Reduced Mode

The *reduced mode* works similarly to the standard mode. The difference is that you merely receive the values and numbers without any comment or unit.

```
sent command:    LCT222.3 (CR)                every character is returned
received answer: 222.3 (CR)                    short answer
```

For a single command this mode can be reached by simply adding the prefix R. So LCT222.3 would become RLCT222.3. To switch to this mode permanently use the command GMS32768. The command GMC32768 switches back to standard mode.



## 7.3 Binary Mode

In *binary mode* no comments are returned and values are sent binary coded (MSB first) with a checksum following. This mode is optimal if you want to control the device automatically by a master computer. The checksum is computed by adding every single byte of a word or float value to the fixed value 0x55 (ignoring the overflow). For e. g. a float value whose four bytes are all 0x00 (= 0.0) the checksum is 0x55. If all bytes are 0x01 then the checksum would be 0x59.

|                  |                                                                                               |                             |
|------------------|-----------------------------------------------------------------------------------------------|-----------------------------|
| sent command:    | LCT222.3 <span style="border: 1px solid black; border-radius: 50%; padding: 0 2px;">CR</span> | every character is returned |
| received answer: | MSB ... LSB, checksum                                                                         | binary coded answer         |

There are four data types with the following return structure:

- float                      4 bytes + checksum
- short or word          2 bytes + checksum
- string                    0...255 bytes + 0x00
- boolean                1 byte:    • 0xAA for *run* or *on*  
                                                           • 0x55 for *stop* or *off*

The device always starts in standard mode. Binary mode is initialized by setting a bit in the general mode variable of the device as follows:

|               |                                                                                           |                               |
|---------------|-------------------------------------------------------------------------------------------|-------------------------------|
| sent command: | GMS8 <span style="border: 1px solid black; border-radius: 50%; padding: 0 2px;">CR</span> | set bit 0x08 of mode variable |
|---------------|-------------------------------------------------------------------------------------------|-------------------------------|

To return to standard mode this bit has to be cleared:

|               |                                                                                           |                                 |
|---------------|-------------------------------------------------------------------------------------------|---------------------------------|
| sent command: | GMC8 <span style="border: 1px solid black; border-radius: 50%; padding: 0 2px;">CR</span> | clear bit 0x08 of mode variable |
|---------------|-------------------------------------------------------------------------------------------|---------------------------------|

## 7.4 Software

At <http://www.ostech.de> you may download software to interact with OsTech devices.

- the terminal program *OSTERM*
- LabVIEW™ VIs, including a runtime version

Sample routines in C and C++ are also available on request.



## 8. Error Codes

When an error occurs, the driver generates an error code. The error code can be determined by the GE command. Furthermore, the error is shown on the display. A list of error codes and their causes follows:

| error code | cause                                                         |
|------------|---------------------------------------------------------------|
| 0          | no error                                                      |
| 1          | interlock open                                                |
| 2          | laser compliance voltage not acceptable or no laser connected |
| 3          | internal supply voltage not acceptable                        |
| 4          | laser temperature sensor open                                 |
| 5          | crystal temperature sensor open                               |
| 6          | laser temperature exceeds upper limit                         |
| 7          | laser temperature lower than lower limit                      |
| 8          | laser short-circuit or no laser connected                     |
| 9          | device temperature (GT) too high                              |
| 10         | laser temperature exceeds maximum laser temperature (LTM)     |
| 11         | crystal temperature exceeds upper limit                       |
| 12         | crystal temperature lower than lower limit                    |
| 16         | laser current greater than maximum current limit (LCLM)       |
| 17         | current error                                                 |
| 18         | total power limit exceeded                                    |



## 9 Command References

### 9.1 Laser Commands (L)

| cmd | type  | min | max | default | unit | description               |
|-----|-------|-----|-----|---------|------|---------------------------|
| L   | bool  | S   | R   | S       |      | laser stop/run            |
| LTM | float | −99 | 200 | 35      | °C   | laser temperature maximum |
| LG  | bool  | S   | R   | S       |      | gate option               |

#### 9.1.1 Laser Current Commands (LC)

| cmd | type  | min              | max              | default          | unit | description          |
|-----|-------|------------------|------------------|------------------|------|----------------------|
| LCL | float | 0                | $I_{\max} + 5\%$ | $I_{\max} + 5\%$ | mA   | current limit        |
| LCT | float | 0                | $I_{\max}$       | 0                | mA   | current target       |
| LCA | float | — no parameter — |                  |                  | mA   | actual current       |
| LCB | float | 0                | $I_{\max}$       | 0                | mA   | base or bias current |

#### 9.1.2 Laser Coltage Commands (LV)

| cmd | type  | min              | max | default | unit | description          |
|-----|-------|------------------|-----|---------|------|----------------------|
| LVA | float | — no parameter — |     |         | V    | actual laser voltage |
| LVC | float | 1.3              | 6   | 3       | V    | compliance voltage   |

#### 9.1.3 Laser Photo-Current (LPC) and Power (LP) Commands

| cmd  | type  | min              | max | default | unit | description                 |
|------|-------|------------------|-----|---------|------|-----------------------------|
| LPCA | float | — no parameter — |     |         | μA   | laser photo current actual  |
| LPCT | float | 0                | 20  | 0       | μA   | laser photo current target  |
| LPCC | bool  | S                | R   | S       |      | laser photo current control |
| LPA  | float | — no parameter — |     |         | W    | laser power actual          |
| LPT  | float | 0                |     | 0       | W    | laser power target          |
| LPF  | bool  | — no parameter — |     |         |      | laser power fix procedure   |



### 9.1.4 Laser Modulation Commands (LM)

| cmd   | type  | min       | max       | default | unit | description                 |
|-------|-------|-----------|-----------|---------|------|-----------------------------|
| LMDI  | bool  | S         | R         | S       |      | internal digital modulation |
| LMDX  | bool  | S         | R         | S       |      | external digital modulation |
| LMAX  | bool  | S         | R         | S       |      | external analog modulation  |
| LMW   | float | 100       | 1000000   | 1000    | μs   | pulse width                 |
| LMP   | float | LMW + 100 | 600000000 | 2000    | μs   | pulse period                |
| LMDIC | word  | 0         | 65534     | 0       |      | number of pulses            |
| LMDIO | word  | 0         | 65534     | 0       |      | number of suppressed pulses |
| LMDXN | bool  | R         | S         | S       |      | negate modulation input     |

### 9.1.5 Laser Sequencer Commands (LZ)

The LZTR command is available in every laser driver:

| cmd  | type  | min | max   | default | unit | description                       |
|------|-------|-----|-------|---------|------|-----------------------------------|
| LZTR | float | 300 | 34000 | 300     | ms   | ramp time (refers to $I_{\max}$ ) |

The following commands are optionally available on request:

| cmd  | type  | min              | max | default | unit | description                  |
|------|-------|------------------|-----|---------|------|------------------------------|
| LZR  | bool  | — no parameter — |     |         | ms   | sequencer run (stop with LS) |
| LZP  | word  |                  |     |         | ms   | sequencer point select       |
| LZPT | word  |                  |     |         | ms   | subsequence time (duration)  |
| LZPC | float |                  |     |         | ms   | subsequence current (end)    |

### 9.1.6 Pilot Laser Commands (P)

| cmd | type | min | max | default | unit | description            |
|-----|------|-----|-----|---------|------|------------------------|
| PL  | bool | S   | R   | S       |      | pilot laser stop/run   |
| PP  | word | 0   | 16  | 0       |      | pilot laser modulation |

## 9.2 Temperature Sensor and TEC Commands (xT)

In these commands  $x$  has to be replaced by a digit (or letter) to select the temperature sensor or TEC. The first temperature sensor or TEC corresponds to 1, the second to 2, the third to 3 and so on.



As the first temperature sensor or TEC is usually used for a laser and the second for a crystal, a deprecated option for selecting them is the use of the letters L and C, respectively.

## 9.2.1 Temperature Sensor Commands

In new firmware versions the sensor commands are also available with prefix  $nS$  instead of  $xT$  where  $n$  corresponds to the number of the temperature sensor.

| cmd     | type  | min              | max | default      | unit | description                                                                                                                              |
|---------|-------|------------------|-----|--------------|------|------------------------------------------------------------------------------------------------------------------------------------------|
| $xTA$   | float | — no parameter — |     |              | °C   | actual temperature                                                                                                                       |
| $xTLU$  | float | −99              | 200 | 40           | °C   | upper temperature limit                                                                                                                  |
| $xTLL$  | float | −99              | 200 | 0            | °C   | lower temperature Limit                                                                                                                  |
| $xTSCk$ | float |                  |     | NTC<br>B3980 |      | sensor coefficients,<br>$k = 0 \dots 3$                                                                                                  |
| $xTSM$  | word  | 0                | 1   | 0            |      | sensor approximation model <ul style="list-style-type: none"> <li>▪ 0: polynomial model</li> <li>▪ 1: Steinhart-Hart equation</li> </ul> |

## 9.2.2 TEC Commands

| cmd    | type  | min              | max           | default       | unit | description                     |
|--------|-------|------------------|---------------|---------------|------|---------------------------------|
| $xTC$  | bool  | S                | R             | S             |      | temperature controller stop/run |
| $xTT$  | float | −99              | 200           | 20            | °C   | temperature target              |
| $xTCA$ | float | — no parameter — |               |               |      | actual current                  |
| $xTCL$ | float | 0                | $I_{P_{max}}$ | $I_{P_{max}}$ | mA   | current limit                   |
| $xTVA$ | float | — no parameter — |               |               | V    | actual voltage                  |
| $xTCK$ | float | 0                | 255           | 2             |      | PID parameter: gain factor      |
| $xTCN$ | float | 0                | 255           | 60            | s    | PID parameter: reset time       |
| $xTCV$ | float | 0                | 99            | 1             | s    | PID parameter: rate time        |

## 9.3 General Commands

| cmd | type  | min              | max | default | unit | description               |
|-----|-------|------------------|-----|---------|------|---------------------------|
| GD  | bool  | — no parameter — |     |         |      | set defaults              |
| GF  | float | 1.2              | 24  | 5       | V    | fan voltage (max. 300 mA) |



| cmd | type  | min              | max | default | unit | description               |
|-----|-------|------------------|-----|---------|------|---------------------------|
| GFD | float | 1.2              | 24  | 5       | V    | default fan voltage       |
| GX  | bool  | S                | R   | S       |      | external control stop/run |
| GT  | float | — no parameter — |     |         | °C   | device temperature (head) |
| GVS | word  | — no parameter — |     |         |      | software version          |
| GVN | word  | — no parameter — |     |         |      | serial number             |

### 9.3.1 Status Commands

| cmd | type | min              | max | default | unit | description |
|-----|------|------------------|-----|---------|------|-------------|
| GS  | word | — no parameter — |     |         |      | get status  |

The status bits have the following meanings:

|        |                       |        |              |
|--------|-----------------------|--------|--------------|
| 0x0001 | interlock OK          |        |              |
| 0x0004 | driver supply OK      | 0x0400 | LT sensor OK |
| 0x0008 | driver temperature OK | 0x0800 | CT sensor OK |
| 0x0010 | LTLU not OK           |        |              |
| 0x0020 | LTLI not OK           | 0x2000 | LTM not OK   |
| 0x0040 | CTLU not OK           | 0x4000 | LC ON        |
| 0x0080 | CTLI not OK           | 0x8000 | LC error     |

### 9.3.2 Mode Commands

| cmd | type | min              | max | default | unit | description        |
|-----|------|------------------|-----|---------|------|--------------------|
| GM  | word | — no parameter — |     |         |      | get mode           |
| GMC | word |                  |     |         |      | clear mode bit(s)  |
| GMS | word |                  |     |         |      | set mode bit(s)    |
| GMT | word |                  |     |         |      | toggle mode bit(s) |

The mode bits have the following meanings:

|        |                           |        |                                      |
|--------|---------------------------|--------|--------------------------------------|
| 0x0001 | laser current ON          | 0x0100 | first TEC (laser) ON                 |
| 0x0002 | input echo OFF            | 0x0200 | second TEC (crystal) ON              |
|        |                           | 0x0400 | pilot laser ON                       |
| 0x0008 | binary mode               | 0x0800 | laser current control (LCC) OFF      |
| 0x0010 | laser voltage control OFF | 0x1000 | use external interface after startup |
| 0x0020 | LMDI ON                   | 0x2000 | LMDX OFF                             |



0x0040 LMDX ON

0x4000 gate option

0x0080 LMAX ON

0x8000 reduced mode



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