User Manual

LDP-QCW-II 600-50
LDP-QCW-II 600-120

![PicoLAS]

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LDP-QCW-II 600-50

Rev. 1905

QCW Driver for High Power Laser Diodes

- Output current: 60 .. 600 A
- Compliance voltage: 0 .. 50 V
- Internal isolation
- Prepulse option included
- Compact design
- Baseplate cooling
- Optional: External Capacitor Bank

Figure: Output signal for a 50 µs / 50 A prepulse and 200 A / 500 µs main pulse

Technical Data*

Output current	60 .. 600 A
Max. compliance voltage	0 .. 50 V
Min. pulse duration	< 100 µs
Max. pulse duration	5 ms**
Max. repetition rate	> 1 kHz**
Max. duty cycle	10 %**
Max. rise time	< 25 µs
Current overshoot	< 5 %**
Current monitor	Typical 200 A/V
Voltage monitor	Typical 0.025 V/V
Pulse trigger input	5 V TTL
Connectivity	RS-232, optional: LDP-C BOB
Supply voltage	48 V DC
Max. power dissipation	TBD**
Dimensions in mm	295 x 150 x 160
Weight	3.32 kg
Operating temperature	0 to +55 °C

* Specifications measured with a fast recovery diode instead of a laser diode.
** See manual for details

Product Description

The LDP-QCW-II 600-50 is a compact and efficient current supply to drive high power laser diodes in qcw operation.

It is designed for high currents of up to 600 A with an output voltage of up to 50 V. With its compact design the LDP-QCW-II 600-50 can achieve a peak power of 72 kW leading to an excellent power to size ratio.

It needs only one supply voltage for the control logic and the power stage. The driver settings and output is controlled by a RS-232 interface. As the LDP-QCW-II 600-50 is capable of generating pulses on its own, no external pulse generator is required and all parameters can be easily adjusted.

The LDP-QCW-II 600-50 is the perfect choice for a wide range of applications. The high maximum power makes the driver especially suitable for medical applications.

- Overtemperature shutdown
- Enable/Disable input
- Driver status output
- Protection of the laser diode against reverse currents
- Baseplate cooling, internal fans preventing local hot spots on the driver
- Two independent interlock circuits for systems with high safety requirements

Optional Accessories: LDP-C BOB

Rev. 1905

LDP-QCW-II 600-120
QCW Driver for High Power Laser Diodes

- Output current: 60 .. 600 A
- Compliance voltage: 0 .. 120 V
- Internal isolation
- Prepulse option included
  Compact design
- Baseplate cooling
- Optional: External Capacitor Bank

Technical Data*

Output current	60 .. 600 A
Max. compliance voltage	0 .. 120 V
Min. pulse duration	< 100 µs
Max. pulse duration	5 ms**
Max. repetition rate	> 1 kHz**
Max. duty cycle	10 %**
Max. rise time	< 25 µs
Current overshoot	< 5 %**
Current monitor	Typical 200 A/V
Voltage monitor	Typical 0.025 V/V
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Figure: Output signal for a 50 µs / 50 A prepulse and 200 A / 500 µs main pulse

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** See manual for details

Product Description

The LDP-QCW-II 600-120 is a compact and efficient current supply to drive high power laser diodes in qcw operation.

It is designed for high currents of up to 600 A with an output voltage of up to 120 V. With its compact design the LDP-QCW-II 600-12 can achieve a peak power of 72 kW leading to an excellent power to size ratio.

It needs only one supply voltage for the control logic and the power stage. The driver settings and output is controlled by a RS-232 interface. As the LDP-QCW-II 600-120 is capable of generating pulses on its own, no external pulse generator is required and all parameters can be easily adjusted.

The LDP-QCW-II 600-120 is the perfect choice for a wide range of applications. The high maximum power makes the driver especially suitable for medical applications.

- Overtemperature shutdown
- Enable/Disable input
- Driver status output
- Protection of the laser diode against reverse currents
- Baseplate cooling, internal fans preventing local hot spots on the driver
- Two independent interlock circuits for systems with high safety requirements

Optional Accessories: LDP-C BOB

How to use the Manual

⚠️ **Remark:** The LDP-QCW-II 600 described in this manual is a primarily baseplate cooled laser diode driver. Improper cooling may cause an internal overtemperature shutdown. The two fans in one side of the unit prevent local thermal hot spots inside the unit. They can not compensate improper baseplate cooling. The air inside an enclosure within an OEM application is usually enough to yield enough air flow. Please do not cover any ventilation slots.

Heat sink cooling with fans: Depending on the final application and operation regime a sufficient airflow created by the fans through the heat sink must be possible.

Please refer to section "Cooling" for more details about the thermal power losses during operation.

You may use a passive or an active air/water cooler.

Housing: All units are delivered with housing. Changes are possible; the units can be delivered without housing upon request.

Before powering on your unit, read this manual thoroughly and make sure you understood everything.

⚠️ Please pay attention to all safety warnings.
If you have any doubt or suggestion, please do not hesitate to contact us!

Overview

The LDP-QCW-II 600 (LDP-QCW for short) is a high power linear regulated laser diode driver. It supports the following features:

o Supports up to 50 V / 120 V compliance voltage
o Two independent output stages which can be used to generate a pulse step. Can be combined if dual pulse is not required.
o Linear output driver for rectangular current pulses with ripple < 1 %
o Multiple trigger modes for external and internal triggering
o Plastic optical fiber (POF) control interface
o Interlock input for safety
o Supports connection of an external capacitor bank for longer pulse durations (limited only by power losses)
o Software controllable input current limitation.

Technical Specifications

Output current	Combined mode: 50 .. 600 A Independent mode: 20 .. 220 A pre pulse 50 .. 600 A main pulse
Compliance voltage	0 .. 50 V / 0 .. 120 V
Min. pulse duration	< 100 µs
Max. pulse duration	500 ms
Max. repetition rate	> 1 kHz
Max. duty cycle	10 %
Max. rise time	< 25 µs
Current overshoot	< 5 % (depending on regulator settings)
Pulse trigger input	Analog Interface: TTL
Connectivity	Analog interface, RS-232
Supply voltage	48 V DC
Max. input current limitation	1 .. 80 A
Max. power dissipation	TBD
Dimensions in mm	295 x 150 x 160
Weight	~ 5.6 Kg
Operating temperature	0 to +55 °C

Functional Description

The driver uses a DC-DC converter to load a capacitor bank to a defined voltage. It provides a galvanic isolation barrier between the input clamps and the rest of the driver. It can provide a maximum voltage of 160 V and up to 40 A to load the connected storage capacitor bank Cb.

Two independent P-I regulators using T_1 and T_2 are controlling the current flow through the laser diode. These regulators are triggered by an internal timing generator that is triggered by either an external trigger signal or via software through the RS-232 interface.

Several security features protect the laser diode and the driver from damage. D_1 protects the laser diode from reverse currents. The switch S_1 is automatically opened when an overcurrent as well as an internal failure or an interlock condition is detected.
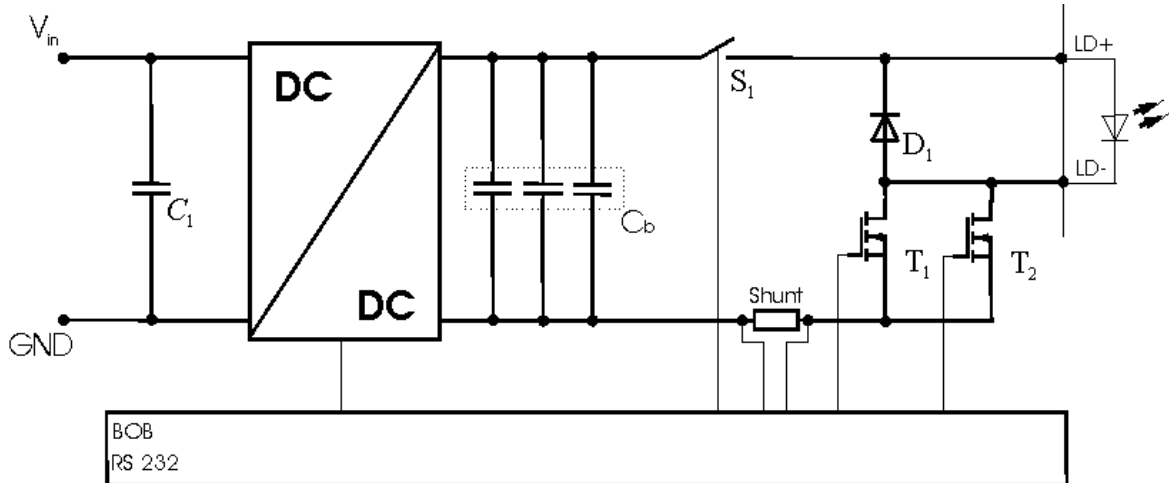
Operation Principle of LDP-QCW Driver
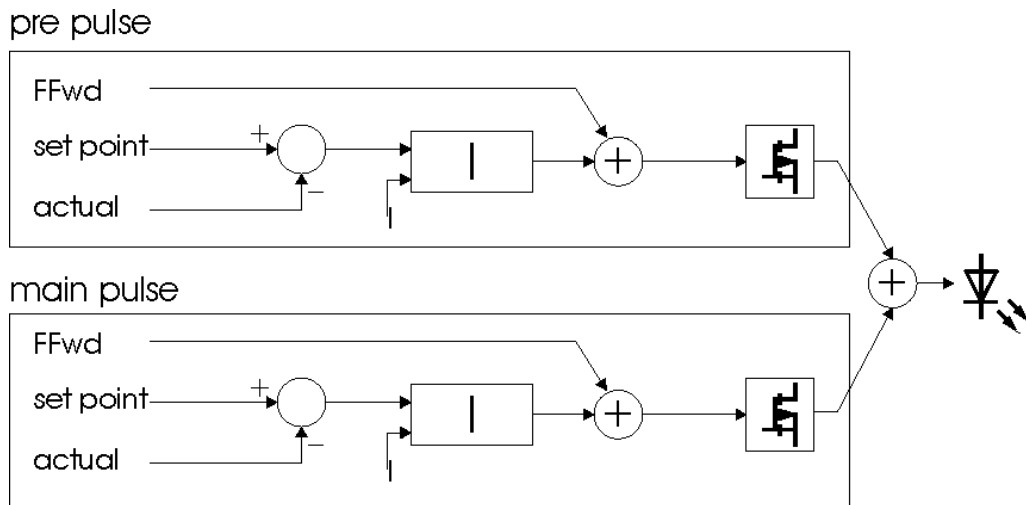
Element	Function
C_1	Input buffer capacitor
Cb	Capacitor bank
S_1	Security switch
D_1	Laser diode protection diode
T_1, T_2	Current regulation MosFET
Shunt	LD current monitor

Current Regulator

The LDP-QCW implements two proportional integral (PI) regulators to control the current flow through the connected load. The following diagram shows a simplified layout:

Depending on the chosen operating mode the user has the possibility to modify all relevant parameters to a specific need. This is done through the digital interface (RS-232). Both regulators can be independently configured for a pre and main pulse or combined for a single rectangular pulse. See below for more information.

The "I" value defines the strength of the integral part of the current regulator. This value ranges from 0 to 4095. A recommended value for normal operation is 30 .. 60. If this value is too high it may lead to a current overshoot.

PicoLAS implemented an active nonlinearity compensation of the output stage. This speeds up the device, prevents excessive current overshoots and yields a better accuracy with high impedance loads.
The influence of this part of the regulator can be user defined and is called FFwd.
However, the interconnection between the voltage and the current flow on the output is calibrated during fabrication. This is used in operating mode 1 and 3. So it is not necessary to change this value if only these operating modes are used. If needed, it can be adjusted between the values 0 to 7.5 by the customer.

Be careful if changes are performed with the FFwd value. The effect is high and may cause damage to the connected load if not adjusted properly. Wrong settings are not covered by warranty.

Description of available Connectors

Front side:
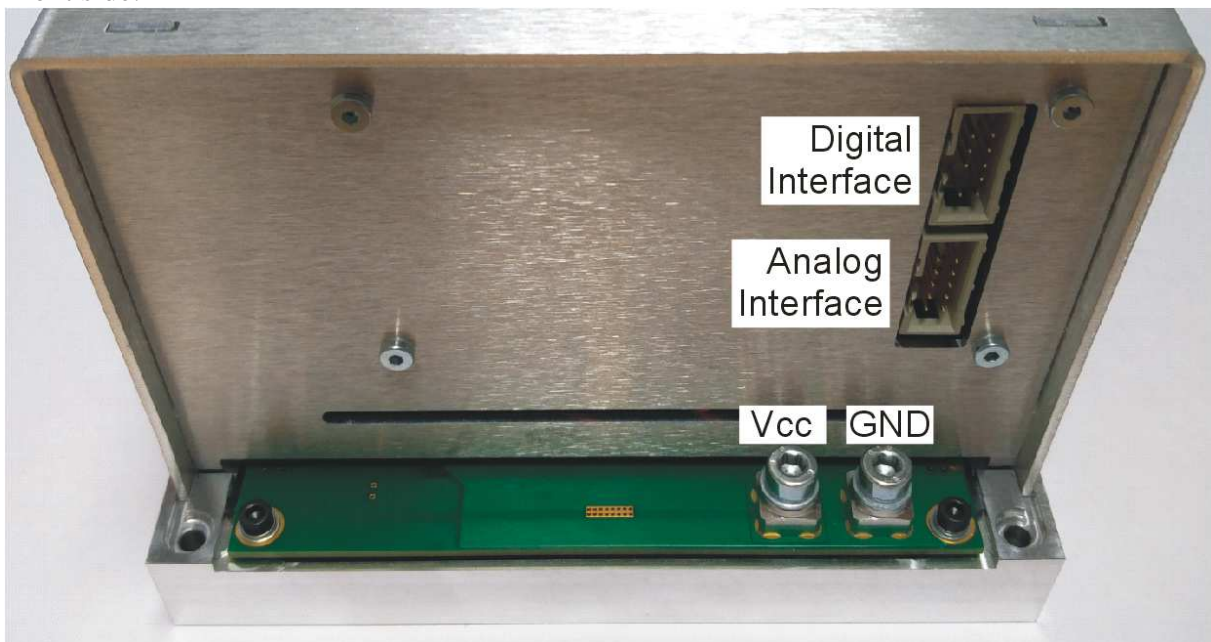
Back side:

Analog Interface Specifications

All electrical user interfaces are galvanic isolated from the power input and the laser output.

The following figure shows the input and output signals of the external analog BOB connector.

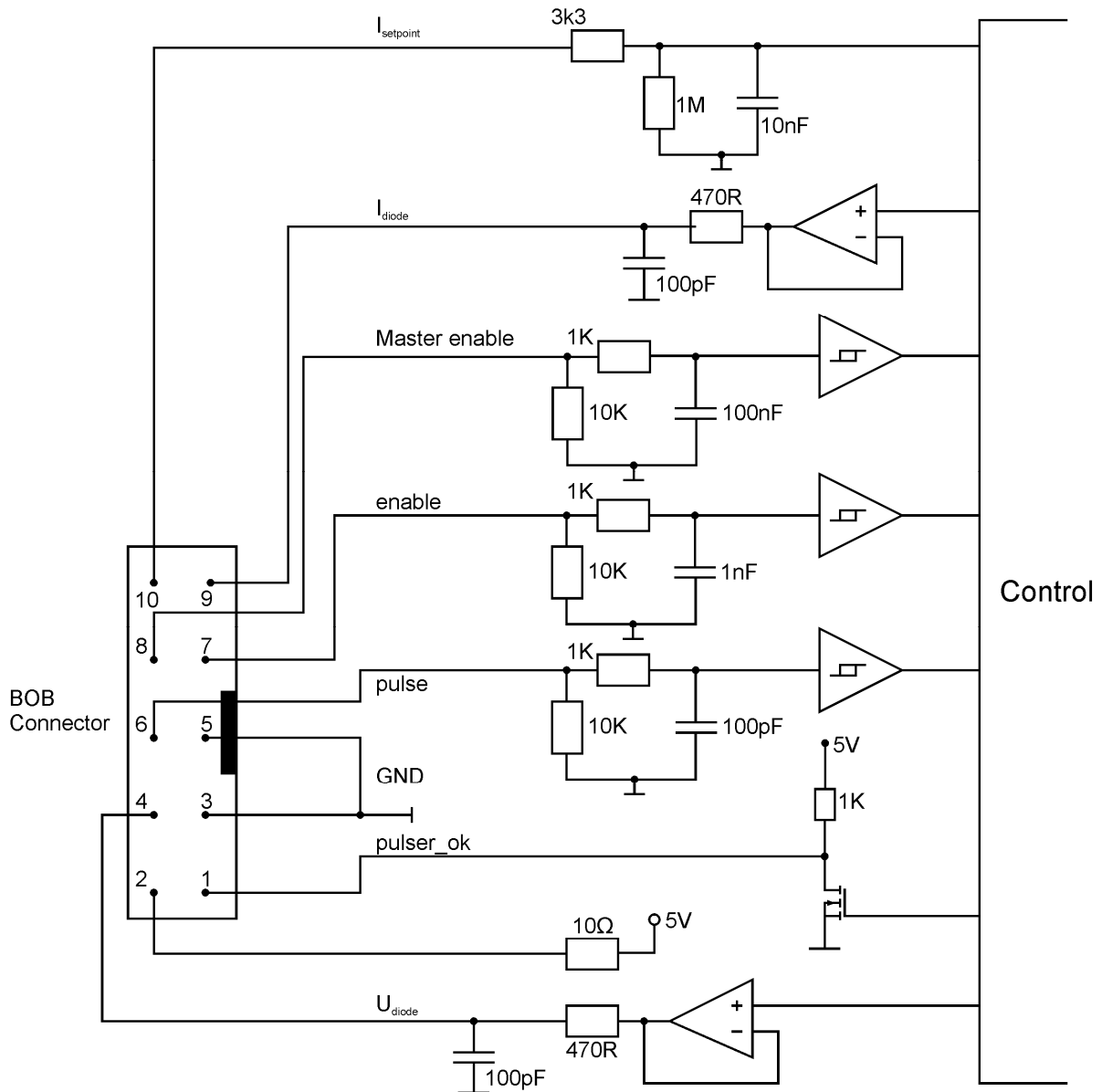The LDP-C BOB (Breakout board) is recommended for easy testing of the driver. It will be replaced in the application by your machine interface.

Functional Description of BOB Connector Interface

Pin Description (numerical assorted)

Pin 1: Pulser OK
The state of this signal indicates weather the driver is ready (5 V) or it has an error pending (0 V).

Pin 2: 5 V
This pin provides 5 Volts for external usage. Please note that the load should not exceed 10 mA, otherwise the voltage will drop.

Pin 3: GND
This pin is connected to ground.

Pin 4: U_{diode}
This signal provides near real time measurement of the laser diodes compliance voltage. The scaling is 10 Volts per Volt measured into 1 MOhm.

Pin 5: GND
This pin is connected to ground.

Pin 6: Pulse
This signal is used in the external end external controlled trigger mode. Connect your external trigger source to this pin. The signal amplitude should be within 3 to 6 Volts.

Pin 7: Enable
This signal is used to enable / disable the current output of the driver during operation.
It must be pulled low to reset an error condition or to re-enable the driver after Master Enable was pulled low.

Pin 8: Master Enable
This signal is used as an interlock safety feature that disables the complete driver if set to 0 V during operation. In order to re-enable the driver after this emergency shutdown the enable signal must first set to 0 V.
If this feature is not required this pin can be connected to pin 2 (5 V).
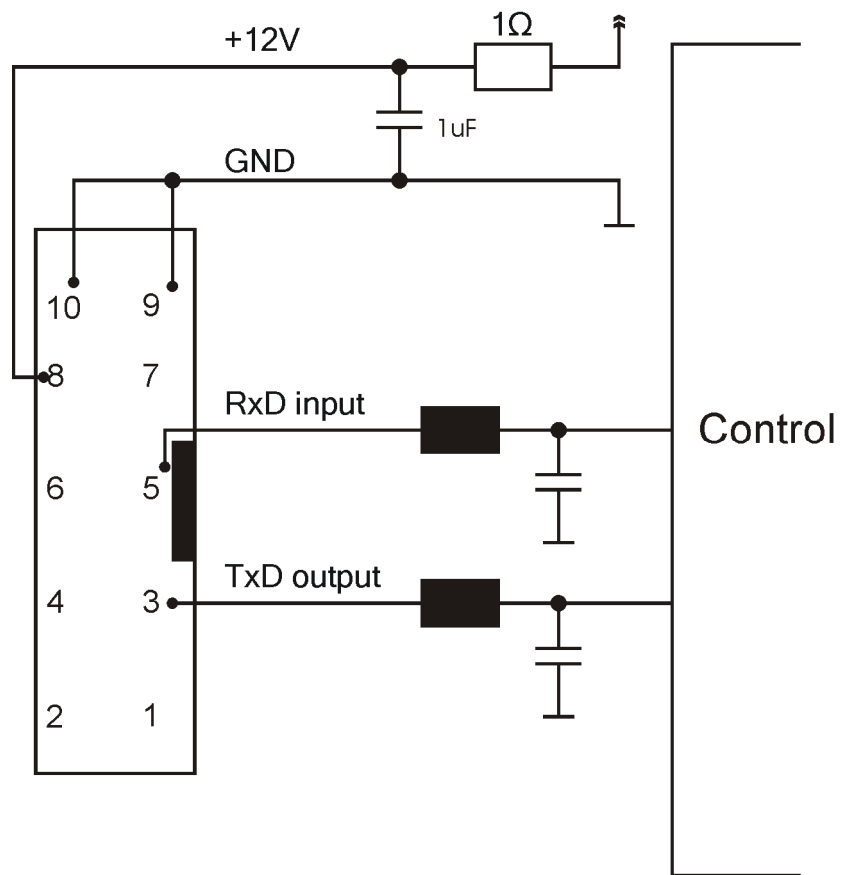
Pin 9: I_{diode}
This signal provides near real time measurement of the laser diodes current flow. The scaling is 200 Amperes per Volt measured into 1MOhm.

Pin 10: $I_{setpoint}$
This pin is not used in this driver.

The interface is a standard RS-232 interface connection. It can be used to connect the PC to the driver.

How to get started

Step	What to do	Check
1	Unpack your device and place it in front of you as shown on the next page.	
2	Connect a load (for example your laser diode) to the output.	⚠ Make sure to use both anode and cathode connectors in parallel.
3	Connect the RS-232 cable.	See section "Controlling the LDP-QCW via RS-232" for more information.
4	Connect the input power supply. Make sure that polarity is correct. The supply voltage is 48 V.	⚠ Make sure that your power supply does not have any voltage overshoots when switching on or off. Do not exceed the maximum operating voltage of 52 V.
5	Switch the power supply on.	
6	Set all required parameters using the RS-232 interface. Make sure that the capacitor voltage is set to a safe value.	See section "Controlling the LDP-QCW via RS-232" for more information.
7	Apply +5 V to the interlock pin of the BOB connector. This will enable internal power conditioner.	See section "Interface Specifications" for more information.
8	Apply +5 V to the Enable pin of the BOB connector. This will enable the output.	See section "Interface Specifications" for more information.
9	Monitor the current pulses using an oscilloscope connected to the current monitor output.	See section "Interface Specifications" for more information.

Cooling

The maximum thermal dissipation of the LDP-QCW-II depends on the configured pulse length, repetition rate and capacitor bank voltage. The driver is cooled by a heat sink and two fans for continuous high power operation. The maximal thermal dissipation can be estimated by:

$$P_L = ((V_{cap} - V_{LD}) \cdot I_{LD} \cdot d) + 0.1 \cdot I_{LD} \cdot d + P_S$$

where

P_L	Thermal dissipation loss in W
V_{cap}	Capacitor voltage in V
V_{LD}	Compliance voltage of the LD in V
d	Duty cycle in percent
I_{LD}	Laser diode current
P_S	Static operation losses ~ 20 W

This is only an approximation and achieved values can differ. Carefully monitor the temperature of the driver and the heat sink for new operational conditions.

Test Load

A common method to test the driver is to connect a regular silicon rectifier diode to the driver output. Please pay attention to the junction capacitance of the diode. Only fast recovery diodes (or similar) have a low parasitic capacitance comparable to laser diodes. To achieve reasonable test results, the parasitic elements of the test diode and the connection must be very similar to a laser diode approach. Regular silicon rectifier diodes have a junction capacitance of several microfarads and are not a suitable test load! The use of these diodes will yield in incorrect current measurement at the pulse edges!

It is also possible to test the driver using a shortcut. This will not damage it, but result in an incorrect measurement for the rise and fall time of the current pulse.

Digital Interface Specifications

The interface provides the following connections:

- o   RS-232 interface
- o   Interlock input
- o   Enable input
- o   Trigger input

The RS-232 interface gives access to all internal settings and registers. It uses a communication speed of 115200 baud with 8 data bits, 1 stop bit and even parity. In order to test the interface connection, the PING command may be used. It does not change any settings of the driver.

The interlock input signal controls the internal power conditioner as well as the pulse output stage. It must be enabled before the enable signal. Otherwise the driver enters an error condition and will not produce any output current. If the interlock drops during normal operation, the power conditioner as well as the current output is disabled and the capacitor bank is discharged. The enable signal must be disabled before the interlock can be re-enabled.

⚠️ The storage discharge slowly. Be careful when powering off the driver as they may still hold a high voltage. Touching them might result to an electrical shock.

The enable input controls the current regulator and the internal trigger generator. When it is enabled, the driver will generate output pulses according to the configured settings.

The trigger input is used in the external trigger mode. When configured, it will control the output current generation.

The trigger output signal provides a signal with the same pulse width and repetition rate as the current output.

Power Supply

To obtain a good pulsing performance with the driver, it requires an appropriate power supply unit (PSU). The PSU has to supply not only the power that is delivered to the laser diode but also the power to compensate for the losses in the driver itself. The device is equipped with a buck-boost DC-DC converter which allows it to generate a capacitor voltage that is higher than the input voltage.

PC Interface

As described in the interface specifications the PC interface uses the RS-232 standard with the connection settings of 115200 baud, 8 data bits, 1 stop bit and even parity.
In order to initialise the protocol, the PING command is used. The acknowledgement of this command indicates a successful communication.

Pulse Shape

The driver is able to generate either a single rectangular shaped pulse or a combination of a lower rectangular shaped pre pulse followed by a higher rectangular shaped main pulse. These two modes are called "combined channels" and "separated channels". The CH_LOCKED bit in the LSTAT register defined which mode is used.

Please note that the operation mode cannot be changed while the drivers output is enabled.

To change the CH_LOCKED bit the LSTAT register must be reading the register the GETLSTAT command, modify the appropriate bit and writing back the resulting value. Writing only the CH_LOCKED bit will result in a possible changing of all the other bits.

Combined Channels

In this mode the driver will generate a single rectangular current pulse on each trigger event:

The output current is controlled by the SCUR, GCUR, GCURMIN and GCURMAX commands, while the pulse width (for trigger modes 0, 2 and 3) is controlled by SWIDTH, GWIDTH, GWIDTHMIN and GWIDTHMAX commands.
While the driver is in this mode, all commands regarding pre and main pulse are disabled and will be answered with an UNAVL.

In order to put the driver into the combined channel mode, the CH_LOCKED bit in the LSTAT register must be set to "1". This cannot be done while the driver is enabled.

Independent Channels

In this mode the driver will generate a pre pulse followed by a main pulse on each trigger event.

The current of the pre pulse is controlled by the SCURVP, GCURVP, GCURVPMIN and GCURVPMAX commands, while the main pulse is controlled by the SCURHP, GCHRHP, GCURHPMIN and GCURHPMAX commands. The pulse width of both pulses (for trigger modes 0, 2 and 3) is controlled accordingly by the SWIDTHVP, GWIDTHVP, GWIDTHVPMIN, GWIDTHVPMAX, SWIDTHHP, GWIDTHHP, GWIDTHHPMIN, GWIDTHHPMAX commands.
While the driver is in this mode, all commands regarding combined channels are disabled and will be answered with an UNAVL.

The current values set by these commands are absolute values. Setting a pre pulse current of 50 A and a main pulse current of 100 A will lead to a pulse that increases from 50 A to 100 A after the width of the pre pulse.

The current of the pre and main pulse can be set independently, however there is a connection between both: The pre pulse regulator can deliver any current between 20 A and 220 A while the main pulse regulator can deliver between 30 A and 250 A. This leads to the following limitation:

- Setting the pre pulse to 20 A limits the main pulse to be anything between 50 A and 220 A.
- Setting the pre pulse to 150 A limits the main pulse to anything between 180 A and 250 A.

In order to put the driver into the separated channel mode, the CH_LOCKED bit in the LSTAT register must be set to "0". This cannot be done while the driver is enabled.

Regulator Operation Modes

Independent from the two pulse shape modes mentioned above, the driver's current regulator offers four different operation modes, which applies to both pulse shape modes.

Mode 0: manual
In this operation mode all parameters can be modified.

> ⚠️ This mode is recommended only for experienced users as any wrong setting may lead to a significant current overshoot at the output.

Mode 1: semi-auto
In this operation mode the feed forward (FFwd) value is automatically chosen in dependence of the current setpoint. This is recommended for normal operation as it guarantees minimal current overshoot at the output.

Mode 2: manual + VCAP tracking
This mode is similar to mode 0 but the driver tracks the compliance voltage and modifies the VCAP value accordingly. For safety reasons the driver is only able to vary the capacitor voltage within the range of -20 V to +5 V of the configured VCAP value.
In the current firmware version this feature is considered experimental and should be used with caution!

Mode 3: semi-auto + VCAP tracking
This mode is similar to mode 1, but the driver tracks the compliance voltage and modifies the VCAP value accordingly. For safety reasons the driver is only able to vary the capacitor voltage within the range of -20 V to +5 V of the configured VCAP value.
In the current firmware version this feature is considered experimental and should be used with caution!

Register Limits

The driver has a settings limiting function. With these registers the operator can actively limit the valid maximum value of the pulse current, pulse width and repetition rate. These are pure software limits and provide no hardware safety.

If a limit is set that lowers the valid range below the actual value, the actual value will be set to the new limit. For example if the pulse current is configured to be 200 A and the new limit is set to 150 A, the pulse current will be lowered to 150 A.

Current Limit

If the driver is configured for "Combined Channels", the commands are GETCURMAXLIMIT and SETCURMAXLIMIT for reading and writing the allowed maximum value of the pulse current and GETCURMAXLIMITMIN and GETCURMAXLIMITMAX to read the minimum and maximum valid values for the limit itself.

If the driver is configured for "Independent Channels", the commands GETCURVPMAXLIMIT and SETCURVPMAXLIMIT are used for reading and writing the allowed maximum value of the pre pulse current and GETCURVPMAXLIMITMIN and GETCURVPMAXLIMITMAX to read the minimum and maximum valid values for the limit. The main pulse commands are GETCURHPMAXLIMIT, SETCURHPMAXLIMIT, GETCURHPMAXLIMITMIN and GETCURHPMAXLIMITMAX.

Pulse Width Limit

If the driver is configured for "Combined Channels", the commands are GETWIDTHMAXLIMIT and SETWIDTHMAXLIMIT for reading and writing the allowed maximum value of the pulse width and GETWIDTHMAXLIMITMIN and GETWIDTHMAXLIMITMAX to read the minimum and maximum valid values for the limit itself.

If the driver is configured for "Independent Channels", the commands GETWIDTHVPMAXLIMIT and SETWIDTHVPMAXLIMIT are used for reading and writing the allowed maximum value of the pre pulse width and GETWIDTHVPMAXLIMITMIN and GETWIDTHVPMAXLIMITMAX to read the minimum and maximum valid values for the limit. The main pulse commands are GETWIDTHHPMAXLIMIT, SETWIDTHHPMAXLIMIT, GETWIDTHHPMAXLIMITMIN and GETWIDTHHPMAXLIMITMAX.

Repetition Rate Limit

The repetition rate limit is controlled by the GETREPRATEMAXLIMIT and SETREPRATEMAXLIMIT, while the valid borders of these commands are defined by GETREPRATEMAXLIMITMIN and SETREPRATEMAXLIMITMAX.

Trigger Modes

The LDP-QCW supports four different trigger modes as explained below. In order to change the trigger mode, the driver must be disabled (enable = 0) and the TRG_MODE and TRG_EDGE bits in the LSTAT register must be set accordingly.

Internal (trgmode = 0)

The pulse generation is performed by an internal pulse generator. The pulse width and repetition rate is user configurable via the serial interface. In addition, the number of pulses that will be generated when the driver is enabled can be set from a single pulse to a continuous pulse generation while the driver is enabled.

The following diagram shows an example of generated pulses. The lower graph shows the internal pulse generator, the upper two graphs the trigger pulses generated out of it.
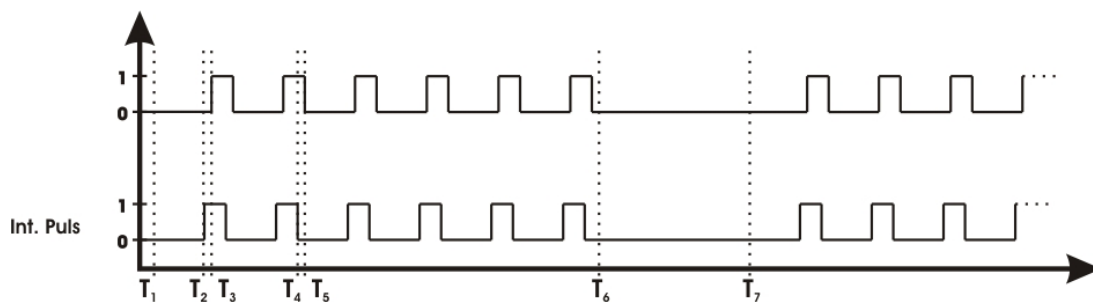
Symbol	Meaning
T_1	Enabling of the output.
T_1-T_2	Delay between output enable and the first generated pulse depends on the configured repetition rate. It nearly equals the pulse pause time.
T_2-T_3	Pulse rise time. It depends on the load inductance.
T_4-T_5	Pulse fall time. It depends on the load inductance.
T_6	Disabling of the output.
T_7	Re-enabling of the output.

External (trgmode = 1)

The pulse generation is performed by an external pulse generator connected to the pulse input on the POF connector. The pulse width and repetition rate is defined by the trigger signal. The pulses can be inverted by setting the TRG_EDGE bit in the LSTAT register to "0" or "1".

The following diagram shows an example of generated pulses. The lower graph shows the external pulse input, the upper two graphs the trigger pulses generated out of it.

Symbol	Meaning
T_1	Enabling of the output.
T_2-T_3	Pulse rise time. It depends on the load inductance.
T_4-T_5	Pulse fall time. It depends on the load inductance.
T_6	Disabling of the output.
T_7	Re-enabling of the output.

External controlled (trg mode = 2)

This trigger mode uses the external trigger input to control the internal pulse generator. It is used to generate a number of pulses per rising or falling edge of the external trigger input. The pulse width and repetition rate is defined by the internal pulse generator and can be set using the serial interface. Hence, only the edge of the trigger signal is utilized. Setting the TRG_EDGE bit in the LSTAT register to "1" uses the rising edge, setting it to "0" uses the falling edge.

The number of pulses and the repetition rate can be set via software.

The following diagram shows an example of generated pulses. The lower graph shows the external pulse input, the upper two graphs the trigger pulses generated out of it.

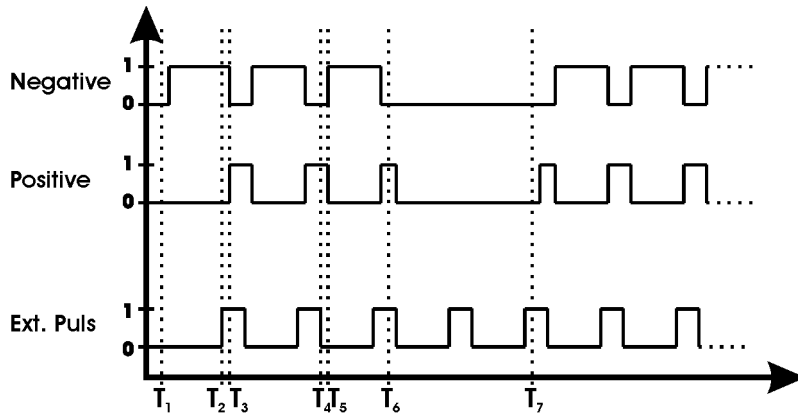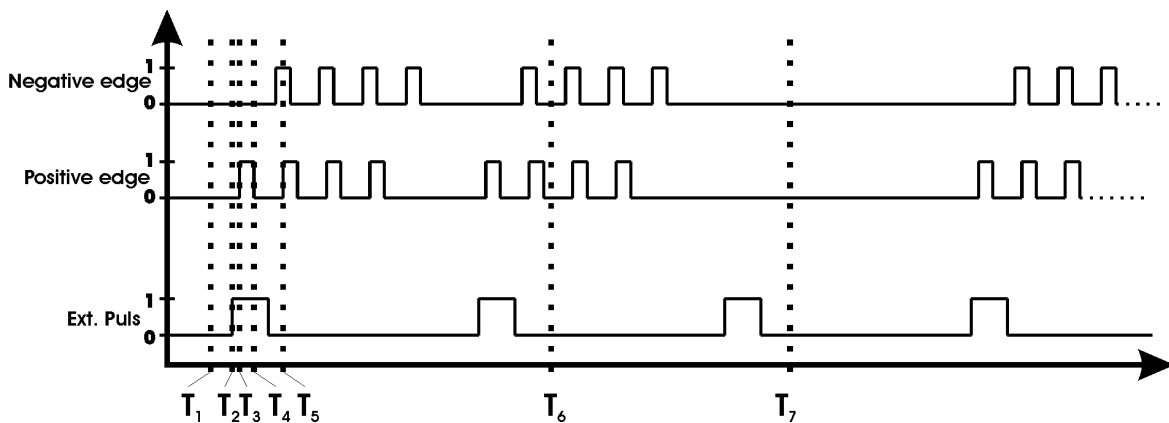| Symbol	Meaning
T_1	Enabling of the output.
T_2-T_3	Pulse rise time. It depends on the load inductance.
T_4-T_5	Pulse fall time. It depends on the load inductance.
T_6	Disabling of the output.
T_7	Re-enabling of the output.

Software (trgmode = 3)

This trigger mode works exactly like the external controlled mode. The only difference is that the trigger is given using a software command.

Capacitor Voltage

The capacitor bank is charged by an internal DC-DC converter. It transforms the supply voltage of 48 V into a configurable capacitor voltage. The converter is equipped with an active input current limiter, which limits the maximum input current consumption of the driver to a configurable value. The SETCURIN is used to set the value, the GETCURIN, GETCURINMIN and GETCURINMAX commands are used to read the actual value as well as the minimum and maximum values.

The power conversion is controlled by the interlock input. Setting the interlock to "1" while the enable signal is "0" will start the capacitor loading procedure. If the enable signal is given before the interlock, the driver will enter an error condition and no power is transferred into the capacitors.

The capacitor voltage is controlled by the SETVCAP command. It must be set by the operator to a value that depends on the chosen pulse width, repetition rate and compliance voltage. If his value is too low the current will drop during the pulse or not even reach the setpoint, if it is too high the output stage will heat up fast and lead to an overtemperature shutdown.

The following equation can be used to calculate the capacitor voltage V_{cap} in dependence of the output current, compliance voltage and pulse width:

$$V_{cap} = 5 + U_{LD} + (I_{LD}(0.011 + \frac{T_{pulse}}{0.22 + Ccap\_ext}))$$

where

U_{LD} Compliance voltage in V
I_{LD} Current setpoint in A
T_{pulse} Pulse width in s
C_{cap_Ext} Capacity of the external bank in F

This equation does not use the repetition rate. Hence, this value must be increased if a current drop is measured during operation.

⚠️ If the capacitor voltage is way too high, the output stage can get damaged. It is safe to start with a lower than required voltage and raise it slowly during operation until the pulse shape is rectangular.

If the determined voltage is more than ~ 20 V above the connected compliance voltage the operator can add an external capacitor bank to increase the energy storage of the driver and therefore decreasing the voltage drop during a current pulse. The Cap+ and Cap- connectors on the back side of the driver are used to connect the external capacitors.

⚠️ The capacitors must be at least rated for 160 V DC and 85 °C. Using lower voltages might result in an explosion of the capacitor and serious risk of injuries and / or fire.

⚠️ The connectors are not touch protected and provide the full capacitor voltage. Touching them might result to an electrical shock.

⚠️ The storage capacitors provide a high amount of energy. Creating a short cut over the output clamps is not recommended and might result in an electrical spark and / or fire.

⚠️ The capacitors are charged up to 160 V. Touching the clamps may result in an electrical shock and serious injury.

Output Enable

The output stage of the driver is controlled by the interlock and the enable signal. Setting the eFnable to "1" while the interlock is given, the driver will start to produce output current pulses according to the selected trigger mode. The driver will produce output current as long as the trigger condition is matched and the enable and interlock signals are given. Setting the enable signal to "0" will disable the output.

Setting the interlock signal to "0" while the enable signal is given will disable the output stage, discharge the capacitor bank and put the driver into an error condition. This is reset by setting the enable signal to "0".

Monitoring

The driver is equipped with several monitoring features that records data of the last performed current pulse as well as several operation parameters.

Pulse Data

The driver samples during each current pulse several internal data values in intervals of approx. 20 µs. These include:

- Load current
- Load voltage
- Capacitor voltage
- I-Control VP
- I-Control HP

The number of available data sets can be read using the GETPULSNUM command. Each data set can be read out using the GETPULSUDIODE, GETPULSUIODE, GETPULSVCAP, GETPULSIVP and GETPULSIHP commands.

Please note that at the beginning of each pulse the data fields are deleted as the driver can only hold the data of one pulse.

Operation Parameters

The driver monitors the supply voltage as well as several temperature sensors. This data can be read using the GETUIN and GETTEMP1 … GETTEMP8 commands.

Output disable

The drivers output is disabled by setting the enable signal to "0". This will disable the internal pulse generator and therefore the current output.

Exchange Dummy Load for Laser Diode

Before removing the dummy load it is recommended to set the interlock signal to "0" as well. This will discharge the capacitor bank and put the driver into a safe condition.

> ⚠️ After setting interlock to "0", the capacitors require a certain amount of time to discharge. Before working on the capacitor or output clamps make sure that there is no residual voltage.

Timing Diagram

The following diagram shows the effect of the MEN (Master Enable), ENABLE and trigger input signals to the external current flow:
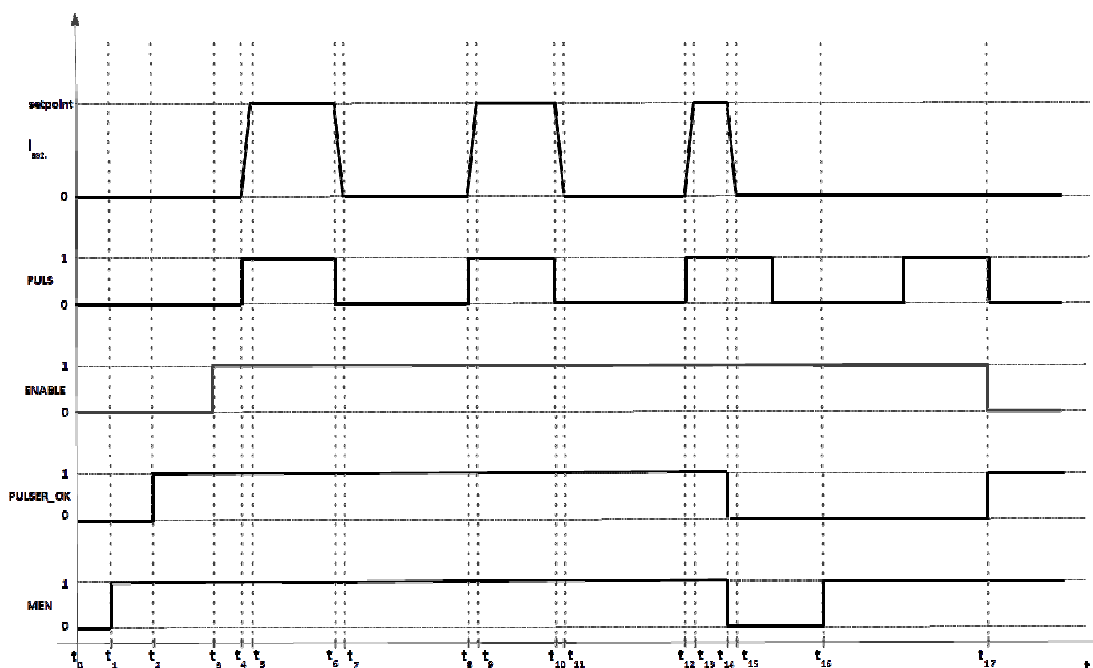
Symbol	Meaning	Min.	Max.	Avg.	Description
t_1	MEN given				
$t_0 - t_2$	Power on self test	2.5 s	14 s	4 s	
t_3	ENABLE given				
$t_4 - t_5$ $t_8 - t_9$ $t_{12} - t_{13}$	Rise time	1 µs			Depends on the inductance of the connected load.
$t_6 - t_7$ $t_{10} - t_{11}$ $t_{14} - t_{15}$	Fall time				Depends on the inductance of the connected load.
t_{14}	MEN released				Output current drops to zero, driver in error state.
t_{17}	MEN state reset				Driver is operational again.

Dos and Don'ts

<u>Never</u> ground any output connector.
<u>Never</u> use any grounded probes at the output.
<u>Do not</u> connect your oscilloscope to the output!
This will immediately destroy the driver and the probe!
For measuring current and voltage you connect the scope to pin 9 or pin 4 of the BOB connector respectively.
<u>Never</u> create a short over the capacitor clamps while the capacitors contain energy!

Keep connecting cables between power supply and driver as well as the connection between driver and laser diode as short as possible.

Mount the driver on an appropriate heat sink!

Please be aware that there might be hot surfaces, be careful not to touch them!

Do never connect the oscilloscope to the output connectors!!!!
(Please note: above picture shows another but similar PicoLAS driver)

Overtemperature Shutdown

To protect the laser diode and the driver itself, the LDP-QCW automatically disables itself if its temperature rises above the maximum allowed operating temperature. This condition is latched and the LDP-QCW will not start working until temperature drops five degrees and the ENABLE signal is toggled.

Absolute maximum Ratings

Output current	Combined mode: 50 .. 600 A Independent mode: 20 .. 220 A pre pulse 50 .. 600 A main pulse
Max. compliance voltage	50 V / 120 V
Min. pulse duration	< 100 µs
Max. pulse duration	500 ms
Max. repetition rate	> 1 kHz
Max. duty cycle	10 %
Max. rise time	< 25 µs
Current overshoot	< 5 % (depending on regulator settings)
Pulse trigger input	Analog Interface: TTL
Connectivity	Interlock, Trigger in, Trigger out, Enable, RS-232
Supply voltage	52 V DC (destroying limit)
Max. input current limitation	1 .. 80 A
Max. power dissipation	TBD
Dimensions in mm	295 x 150 x 160
Weight	~ 5.6 Kg
Operating temperature	0 to +55 °C

If an Error Occurs

If an error occurs during operation the pulse output is switched off. All error conditions are latched and cleared by disabling the driver (either using the switch or the software control).

Mechanical Dimensions

The following dimensions are in millimetres (mm). Please note that the picture is horizontally compressed.
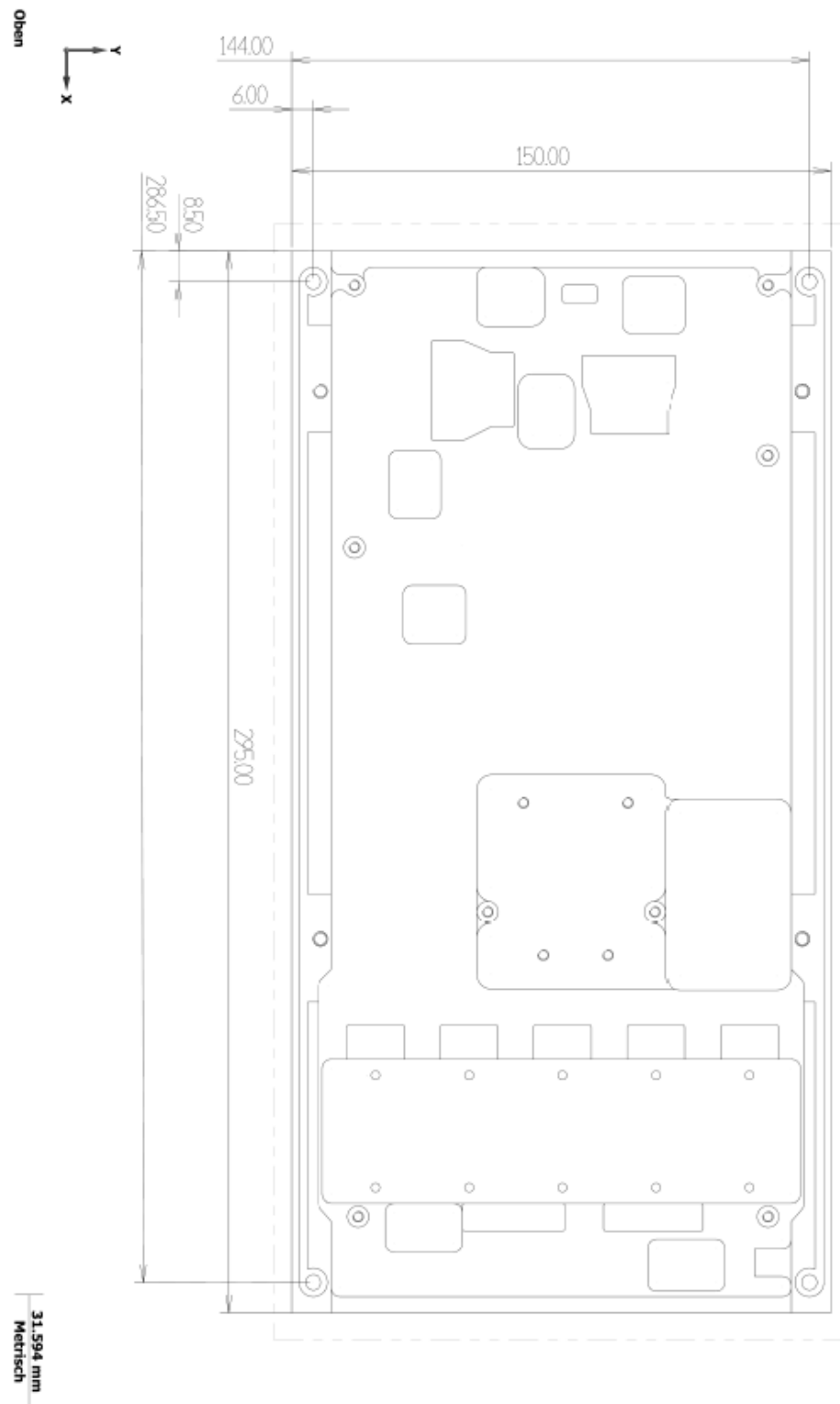
Controlling the LDP-QCW via RS-232

Introduction

The RS-232 interface allows communications over a serial text interface as well as using the PicoLAS protocol. While the text interface is designed for communication with a terminal program, the PicoLAS protocol is designed as a system interact protocol.

The switching between the two protocols occurs automatically as soon as the LDP-QCW receives a certain sequence. The corresponding commands are:

- **PING** for the PicoLAS protocol
- "**init**" followed by <Enter> for the text interface

The connection settings are:

Baud rate	115200
Data bits	8
Stop bits	1
Parity	even

The Serial Text Interface

The following section describes the structure and commands of the text interface.

Structure

Every command that is sent to the LDP-QCW must be completed with a CR (Enter). It consists of a command word followed by one ore more a parameters. If the command was successfully executed a "00" is sent, otherwise a "01". If there is an error pending, the response will be "10", otherwise "11". If the command requires an answer parameter, this parameter is sent before the confirmation is given.

Example:

The user would like to read out the actual setpoint current:

User input:	gcur <Enter>
Output of the LDP-CW:	2500<CR><LF>
	00<CR><LF>

Example 2:

The user would like to set a new setpoint current:

User input:	scur 2700<Enter>
Output of the LDP-CW:	2700<CR><LF>
	00<CR><LF>

Input is done in ASCII code and is case sensitive. Every terminal can be used that supports this standard.

Commands for the LDP-QCW

The following table contains a command reference for the LDP-QCW.

Command	Parameter	Description
ghwver	-	returns the hardware version number
gswverst	-	returns the software version number of the control board
gswverlt	-	returns the software version number of the power board
gswverif	-	returns the software version number of the interface board
gserial	-	returns the serial number
gname	-	returns the device name
ps	-	prints out all settings
loaddef	-	load default values
savedef	-	save all settings as default values
enautodef	-	enables the automatic loading of default settings on power on
disautodef	-	disables the automatic loading of default settings on power on
gerrtxt	-	returns the error register in text form
gerr1	-	returns the error register 1 as a 32 bit number
gerr2	-	returns the error register 2 as a 32 bit number
clrerr	-	clears the error register
glstat	-	returns the laser status register
slstat	32 bit number	sets the laser status register to the given value
gtrgedge	-	returns "0" for negative edge or "1" for positive edge
strgedge	0 or 1	sets the trigger edge for external trigger "0" = negative, "1" = positive
gmode	-	returns the current regulator mode Mode 0: manual Mode 1: semi-automatic Mode 2: manual + VCAP tracking Mode 3: semi-automatic + VCAP tracking See section "Current Regulator" for more information
smode	0 … 1	sets the current regulator mode to the given value Mode 0: manual Mode 1: semi-automatic Mode 2: manual + VCAP tracking Mode 3: semi-automatic + VCAP tracking See section "Current Regulator" for more information
lockch	-	combines both current regulators (only one output pulse)
unlockch	-	separates both current regulators (pre- and mainpulse)

Command	Parameter	Description
gcur	-	returns the actual setpoint current in [A]. Only used in locked mode.
gcurmin	-	returns the minimum setpoint current. Only used in locked mode.
gcurmax	-	returns the maximum setpoint current. Only used in locked mode.
scur	<current>	sets the internal setpoint current to the given value. This value must be within the minimum/maximum borders (see above). One position after decimal point is used (e.g. 80.5). The return value is the new setpoint. Only used in locked mode.
gcurlimit	-	returns the actual current limit value in [A]. Only used in locked mode.
gcurlimitmin	-	returns the minimum current limit value in [A]. Only used in locked mode.
gcurlimitmax	-	returns the maximum current limit value in [A]. Only used in locked mode.
scurlimit	<current>	sets the internal setpoint current limit to the given value. This value must be within the minimum/maximum borders (see above). One position after decimal point is used (e.g. 80.5). The return value is the new setpoint. Only used in locked mode.
gcurvp	-	returns the actual setpoint of the pre pulse current in [A]. Only used in unlocked mode.
gcurvpmin	-	returns the minimum setpoint of the pre pulse current. Only used in unlocked mode.
gcurvpmax	-	returns the maximum setpoint of the pre pulse current. Only used in unlocked mode.
scurvp	<current>	sets the internal setpoint current of the pre pulse to the given value. This value must be within the minimum/maximum borders (see above). One position after decimal point is used (e.g. 80.5). The return value is the new setpoint. Only used in unlocked mode.
gcurvplimit	-	returns the actual setpoint of the pre pulse current limit in [0.1 A]. Only used in unlocked mode.
gcurvplimitmin	-	returns the minimum setpoint of the pre pulse current limit. Only used in unlocked mode.
gcurvplimitmax	-	returns the maximum setpoint of the pre pulse current limit. Only used in unlocked mode.
scurvplimit	<current>	sets the internal setpoint current limit of the pre pulse to the given value. This value must be within the minimum/maximum borders (see above). One position after decimal point is used (e.g. 80.5). The return value is the new setpoint. Only used in unlocked mode.

Command	Parameter	Description
gcurhp	-	returns the actual setpoint of the main pulse current in [A]. Only used in unlocked mode.
gcurhpmin	-	returns the minimum setpoint of the main pulse current. Only used in unlocked mode.
gcurhpmax	-	returns the maximum setpoint of the main pulse current. Only used in unlocked mode.
scurhp	<current>	sets the internal setpoint current of the main pulse to the given value. This value must be within the minimum/maximum borders (see above). One position after decimal point is used (e.g. 80.5). The return value is the new setpoint. Only used in unlocked mode.
gcurhplimit	-	returns the actual setpoint of the main pulse current limit in [0.1 A]. Only used in unlocked mode.
gcurhplimitmin	-	returns the minimum setpoint of the main pulse current limit. Only used in unlocked mode.
gcurhplimitmax	-	returns the maximum setpoint of the main pulse current limit. Only used in unlocked mode.
scurhplimit	<current>	sets the internal setpoint current limit of the main pulse to the given value. This value must be within the minimum/maximum borders (see above). One position after decimal point is used (e.g. 80.5). The return value is the new setpoint. Only used in unlocked mode.
gwidth	-	returns the actual pulse width in [us]. Only used in locked mode.
gwidthmin	-	returns the minimum possible pulse width in [us]. Only used in locked mode.
gwidthmax	-	returns the maximum possible pulse width in [us]. Only used in locked mode.
swidth	<width>	sets the pulse width for the pulse. Please note that any change in this register affects the maximum possible repetition rate. The return value is the new pulse width. Only used in locked mode.
gwidthlimit	-	returns the actual pulse width limit in [us]. Only used in locked mode.
gwidthlimitmin	-	returns the minimum possible pulse width limit in [us]. Only used in locked mode.
gwidthlimitmax	-	returns the maximum possible pulse width limit in [us]. Only used in locked mode.
swidthlimit	<width>	sets the pulse width limit for the pulse. Please note that any change in this register affects the maximum possible repetition rate. The return value is the new pulse width. Only used in locked mode.

Command	Parameter	Description
gwidthvp	-	returns the actual pulse width of the pre pulse in [us]. Only used in unlocked mode.
gwidthvpmin	-	returns the minimum possible pulse width of the pre pulse in [us]. Only used in unlocked mode.
gwidthvpmax	-	returns the maximum possible pulse width of the pre pulse in [us]. Only used in unlocked mode.
swidthvp	<width>	sets the pulse width for the pulse of the pre pulse. Please note that any change in this register affects the maximum possible repetition rate. The return value is the new pulse width. Only used in unlocked mode.
gwidthvplimit	-	returns the actual pulse width limit of the pre pulse in [us]. Only used in unlocked mode.
gwidthvplimitmin	-	returns the minimum possible pulse width limit of the pre pulse in [us]. Only used in locked mode.
gwidthvplimitmax	-	returns the maximum possible pulse width limit of the pre pulse in [us]. Only used in unlocked mode.
swidthvplimit	<width>	sets the pulse width limit for the pulse of the pre pulse. Please note that any change in this register affects the maximum possible repetition rate. The return value is the new pulse width. Only used in unlocked mode.
gwidthhp	-	returns the actual pulse width of the main pulse in [us]. Only used in unlocked mode.
gwidthhpmin	-	returns the minimum possible pulse width of the main pulse in [us]. Only used in unlocked mode.
gwidthhpmax	-	returns the maximum possible pulse width of the main pulse in [us]. Only used in unlocked mode.
swidthhp	<width>	sets the pulse width for the pulse of the main pulse. Please note that any change in this register affects the maximum possible repetition rate. The return value is the new pulse width. Only used in unlocked mode.
gwidthhplimit	-	returns the actual pulse width limit of the main pulse in [us]. Only used in unlocked mode.
gwidthhplimitmin	-	returns the minimum possible pulse width limit of the main pulse in [us]. Only used in locked mode.
gwidthhplimitmax	-	returns the maximum possible pulse width limit of the main pulse in [us]. Only used in unlocked mode.
swidthhplimit	<width>	sets the pulse width limit for the pulse of the main pulse. Please note that any change in this register affects the maximum possible repetition rate. The return value is the new pulse width. Only used in unlocked mode.

Command	Parameter	Description
greprate	-	returns the actual repetition rate in [Hz]
grepratemin		returns the minimal possible repetition rate in [Hz]
grepratemax		returns the maximal possible repetition rate in [Hz]
sreprate	reprate in [Hz]	sets the pulse repetition rate to the given value. The return value is the new repetition rate.
grepratelimit	-	returns the actual repetition rate limit in [Hz]
grepratelimitmin		returns the minimal possible repetition rate limit in [Hz]
grepratelimitmax		returns the maximal possible repetition rate limit in [Hz]
srepratelimit	reprate in [Hz]	sets the pulse repetition rate limit to the given value. The return value is the new repetition rate.
gcurin	-	returns the actual input current limit value in [A]
gcurinmin	-	returns the minimum current limit value in [A]
gcurinmax	-	returns the maximum input current limit value in [A]
scurinmax	current in [A]	sets the input current limit to the given value. This value must be within the minimum/maximum borders (see above). One position after decimal point is used (e.g. 80.5). The return value is the new setpoint.
gvcap	-	returns the actual pre charge voltage of the internal capacitor bank in [V]
gvcapmin	-	returns the minimum pre charge voltage of the internal capacitor bank in [V]
gvcapmax	-	returns the maximum pre charge voltage of the internal capacitor bank in [V]
svcap	voltage in [V]	sets the pre charge voltage of the internal capacitor bank to the given value in [V]
gidelay	<channel>	returns the delay value of the given channel at witch the output current of the pulse must rise before the integral part of the current regulator is switched on. This value is measured in percent of the setpoint current.
sidelay	<channel> <delay>	sets the delay value of the given channel at witch the output current of the pulse must rise before the integral part of the current regulator is switched on to the given value. This value is measured in percent of the setpoint current.
gidelaymin	<channel>	returns the minimum i-delay value of the selected channel
gidelaymax	<channel>	returns the maximum i-delay value of the selected channel

Command	Parameter	Description
gi	<channel>	returns the actual strength of the integral part of the selected channel.
si	value	sets the strength of the integral part of the current regulator for the selected channel to the given value.
gimin	-	returns the minimum strength of the integral part of the current regulator.
gimax	-	returns the maximum strength of the integral part of the current regulator.
gffwd	<channel>	returns the actual voltage of the feed forward part of the current regulator of the selected channel in [V]. See section "Current Regulator" for more information.
sffwd	<channel> <voltage>	sets the feed forward voltage of the selected channel to the given value. Two positions after decimal point are used (e.g. 3.45). It must be within the borders of gffwdmin / gffwdmax.
gffwdmin	-	returns the minimum possible value of the feed forward voltage in [V]
gffwdmax	-	returns the maximum possible value of the feed forward voltage in [V]
gtemp	-	returns the actual device temperature in °C. This is the maximum of the single temperature sensors.
gtemp1	-	returns the value of temp. sensor number 1 in [°C]
gtemp2	-	returns the value of temp. sensor number 2 in [°C]
gtemp3	-	returns the value of temp. sensor number 3 in [°C]
gtemp4	-	returns the value of temp. sensor number 4 in [°C]
gtemp5	-	returns the value of temp. sensor number 5 in [°C]
gtemp6	-	returns the value of temp. sensor number 6 in [°C]
gtemp7	-	returns the value of temp. sensor number 7 in [°C]
gtemp8	-	returns the value of temp. sensor number 8 in [°C]
gtemp9	-	returns the value of temp. sensor number 9 in [°C]
gtemphys	-	returns the temperature at witch the device switches back on after an overtemperature shutdown in [°C]
gtempwarn	-	returns the temperature at witch the TEMP_WARN bit in the ERROR register is set
gtempoff	-	returns the overtemperature shutdown value in [°C]

Command	Parameter	Description
gadcudiode	-	returns the actual measured pulse current in [A]
gadcidiode	-	returns the actual measured pulse voltage in [V]
gadcvcap	-	returns the actual measured capacitor bank voltage in [V]
gadcuin	-	returns the actual measured input voltage in [V]
gadcpulsidiode	<sample num>	returns the pulse voltage during the given sample number in [A]
gadcpulsvcap	<sample num>	returns the capacitor voltage during the given sample number in [A]
gadcpulshp	<sample num>	returns the strength of the integration part of the regulator for the pre pulse during the given sample number
gadcpulsivp	<sample num>	returns the strength of the integration part of the regulator for the main pulse during the given sample number
gadcnum	-	returns the number of samples that was taken during the last generated pulse
gcount	-	returns the actual configured number of pulses to be generated
gcountmin	-	returns the minimum possible number of pulses to be generated
gcountmax	-	returns the maximum possible number of pulses to be generated
scount	number	sets the number of pulses to be generated
execpuls	--	generates a software trigger
strgmode	0 … 3	sets the pulse generator trigger mode to the given value Mode 0: internal Mode 1: external Mode 3: external controlled Mode 4: software controlled See section "Trigger Modes" for more information
gtrgmode	--	returns the actual used trigger mode
sfanmode	0 or 1	sets the cooling fan to manual (0) or automatic mode (1)
sfan	speed in %	sets the speed of the cooling fan to the given value in %
gfanmin	--	returns the minimum fan speed in %
gfanmax	--	returns the maximum fan speed in %
gfan	--	returns the actual fan speed in %
gfanspd1	--	returns the actual speed of fan 1 in rpm (does not work yet)
gfanspd2	--	returns the actual speed of fan 2 in rpm (does not work yet)

If an Error Occurs

If an error occurs during operation the pulse output is switched off and the return value of a command is no longer "00" or "01" but "10" or "11". Errors have to be acknowledged with a toggle of the ENABLE signal, otherwise switching on again of pulse output is not possible.

To retrieve the error use the **gerror** command for the content of the ERROR register or the **gerrtxt** command for a human readable form.

Description of the LSTAT Register

The following list contains a description of the individual LSTAT bits. These can be read with the GETLSTAT and written with SETLSTAT command.

Bit	Name	Read/Write	Meaning
0	ENABLE_OK	ro	Indicates the state of the ENABLE signal.
1	MASTER_ENABLE_1	ro	Indicates the state of the interlock pin. Internally connected to MASTER_ENABLE_2.
2	MASTER_ENABLE_2	ro	Indicates the state of the interlock pin. Internally connected to MASTER_ENABLE_1.
3	PULSER_OK	ro	When the bit is read "0" an error has occurred
4	DEF_PWRON	r/w	When "1" the device loads its default values on power on.
5	TRG_EDGE	r/w	When "1" the positive edge is used.
6-7	TRG_MODE	r/w	Trigger mode: 0: internal 1: external 2: external controlled 3: software controlled
8-9	REGLER_MODE	r/w	Current regulator mode: 0: manual 1: semi-auto 2: manual + VCAP autotracking 3: semi-auto + VCAP autotracking
10	CALMODE	ro	Indicates that the driver is in calibration mode.
11	ENABLE_LOCK	ro	Indicates, that the Enable pin must be set to "0" in order to continue normal operation.
12	ENABLE_CH0	ro (r/w cal)	Enables the usage of the current channel 0. Only used during calibration.
13	ENABLE_CH1	ro (r/w cal)	Enables the usage of the current channel 1. Only used during calibration.
14	OVERCUR_EN_CH0	ro	Enabled the overcurrent detection of current channel 0. Currently not used.
15	OVERCUR_EN_CH1	ro	Enabled the overcurrent detection of current channel 1. Currently not used.

Bit	Name	Read/Write	Meaning
16	ENABLED	ro	Indicates that the driver is enabled.
17	ENABLE_EXT	ro	Currently not used.
18	EXEC_SW_PULSE	r/w	When "1", the driver will execute a pulse (in trigger mode 3).
19	EXECUTING_PULSES	ro	Indicates that the driver is currently executing a software trigger.
20	ABORT_EXEC_PULSES	r/w	When "1", the driver will abort the current software trigger.
21	MODE_TWO_CHANNEL	ro	Currently not used. May be removed in future designs.
22	FAN_AUTO	r/w	Cooling fan operation mode: 0: fan speed manually controlled 1: fan speed depend on device temperature
23	LT_EXTCTRL	ro	
24	CH_LOCKED	ro	Configures the current regulator mode: 0: channels are separately configurable 1: both channels are combined.
25	DIS_INTEGRAL	ro	Controls the integral part of the current regulator: 0: Enabled (default) 1: Disabled
26-31	reserved	ro	Currently not used.

Description of the ERROR Registers

The device has two 32 bit wide error registers. The following lists contain a description of the individual bits of each register. Unless otherwise noted, a "1" indicates an error or warning condition.

Register 1

Bit	Name	Read/Write	Meaning
0	CRC_DEFAULT_FAIL	ro	A CRC error was detected in the default values. A re-save of the values should correct this.
1	CRC_CONFIG_FAIL	ro	A CRC error was detected in the internal configuration values. Please contact your distributor.
2	CRC_FFWDCAL_0_FAIL	ro	Indicates that the feed forward calibration of channel 0 is faulty.
3	CRC_FFWDCAL_1_FAIL	ro	Indicates that the feed forward calibration of channel 1 is faulty.
4	CRC_ISOLLCAL_0_FAIL	ro	Indicates that the current setpoint calibration of channel 0 is faulty.
5	CRC_ISOLLCAL_0_FAIL	ro	Indicates that the current setpoint calibration of channel 1 is faulty.
6	TEMP_OVERSTEPPED	ro	The internal temperature was beyond safe operating limits.
7	TEMP_WARNING	ro	The internal temperature is 5 °C before shutdown.
8	TEMP_HYSTERESE	ro	Device is cooling down. Temperature needs to drop below (maximum – 10 °C)
9	VCC_FAIL	ro	Internal supply voltage error.
10	FAIL_DEFAULTS	ro	The loading of the default failed. Normally this is because of a pending CRC error.
11	I2C_EEPROM_FAIL	ro	Internal EEProm error. Please contact your distributor.
12	I2C_DAC_1_FAIL	ro	Internal DAC error.
13	I2C_DAC_2_FAIL	ro	Internal DAC error.
14-21	TEMP_SENSOR_FAIL	ro	The individual bits describe the status of each temperature sensor. A "1" indicates an error.
22-31	TEMP_NTC_ERRSRC	ro	A "1" in one of the individual bits describe which sensor has caused the temperature shutdown.

Register 2

Bit	Name	Read/Write	Meaning
0	ENABLE_POWERON	ro	Indicates that the ENABLE signal was given during start-up.
1	VCC_UVLO	ro	Indicates that the supply voltage dropped during operation.
2	PMAX_ERR	ro	Indicates that the maximum power losses were overstepped during the last pulse.
3	MAX_REPRATE	ro	Indicates that the external trigger signal has a too high repetition rate.
4	LT_COM_ERR	ro	Indicates communication errors between the input and output stage.
5	LT_OTEMP	ro	Indicates an overtemperature error in the input stage.
6	LT_PWMMAX	ro	Indicates that the maximum power transfer from the input stage has been reached.
7	LT_ILIMIT	ro	Indicates that the input current limiter is active.
8	SYNC_BOARD_FAIL	ro	Indicates a faulty connection between the power rectifier and the control board.
9	FAN_0_SPEED_ERR	ro	Indicates that the round per minute of cooling fan 0 is below safe limits.
10	FAN_1_SPEED_ERR	ro	Indicates that the round per minute of cooling fan 1 is below safe limits.
11	LT_PULSER_OK	ro	A "0" indicates a general error in the input stage.
12	LT_PARAM_ERR	ro	Indicates a parameter discrepancy between the input and control CPU.
13	I2C_RD_FAIL	ro	Indicates an I²C read error.
14	I2C_WR_FAIL	ro	Indicates an I²C write error.
15	OCUR_DETECTED_CH0	ro	Indicates that an overcurrent on channel 0 has been detected.
16	OCUR_DETECTED_CH1	ro	Indicates that an overcurrent on channel 1 has been detected.
17	I2C_BCL_RD	ro	Indicates an I²C bus error during a read operation.
18	I2C_BCL_WR	ro	Indicates an I²C bus error during a write operation.
19	MEN_1_DROPPED	ro	Indicates that MEN 1 has dropped during operation.
20	MEN_2_DROPPED	ro	Indicates that MEN 2 has dropped during operation.
21-31	reserved	ro	Currently not used