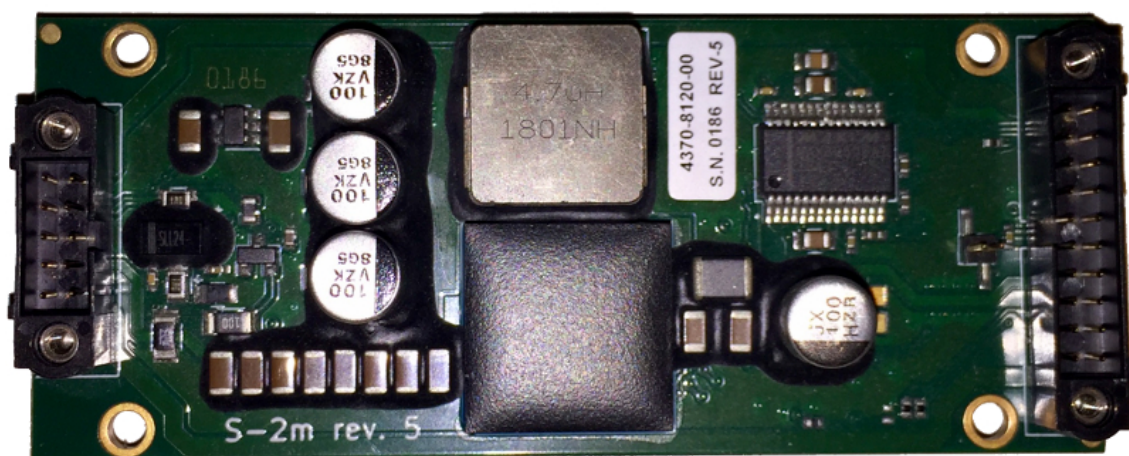




S-2M DRIVER USER MANUAL



Version number 1.0.2
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DOCUMENT VERSION

This is Version 1.0.2 of the S-2m manual, published on 2024/01/11, superseding version 1.0.1 of the manual, published on February 17th, 2023. The following modifications have been applied since the publication of version 1.0.0:

| Publication date | Version number | Changes |
|------------------|----------------|--|
| 2022/06/30 | 1.0.0 | Original release |
| 2023/02/17 | 1.0.1 | § 6.2 modified to clarify maximum 50 ms pulse length and parameter definition. |
| 2024/01/11 | 1.0.2 | § 7 modified to add warning that internal and external clocks are not synced. |

Preface

This manual serves is intended for personnel using the S-2m pulser to drive ALPES LASERS QCLs. Its purpose is to serve as a reference for the mechanical and electronic configuration and provide the customer with sufficient information to carry out normal operation. The specifications provided herein refer to the output of the electronic driver, not to a detected optical signal of a QCL. This manual should be used in conjunction with the QCL datasheet and the separate QCL operation manual. It is not intended to replace or supersede any local directive. Table 1 summarizes the content of each section.



CAUTION:

All personnel must read and understand this manual before attempting to operate ALPES LASERS QCLs and the associated electronic devices. Failure to follow safety instructions could result in death or serious injury.

| Chapter | Content |
|--|---|
| 1. Introduction | General description |
| 2. Specifications | Table of values |
| 3. Mechanical Interface | Drawings and mounting instructions |
| 4. Electrical Interface | Pinout and system assembly |
| 5. Graphical User Interface | Software instructions |
| 6. Safety interlocks, external modulation and security | Description of interlocks with schematics |
| 7. Modes of Operation | Descriptions and graphs of the internal pulsing modes |
| 8. Non-volatile Memory | Information stored on the S-2m card |
| 9. Built-in Test | Information retrieved in the BIT |
| 10. Communication Protocol | Overview and data packet structure |
| 11. Environmental Specifications | Description of ESS testing |

Table 1: Structure of the S-2m User Manual.

Typesetting conventions

- Table 2 gives a list of the acronyms used in this manual.
- A *boxed item* indicates a button to push (hw) or click (sw)

| Acronym | Full name |
|---------|--|
| BIT | Built-In Test |
| GUI | Graphical User Interface |
| HHL | High Heat Load (QCL package) |
| MCU | Microcontroller unit |
| PCB | Printed Circuit Board |
| QCL | Quantum Cascade Laser |
| S-2m | ALPES LASERS QCL pulser driver |
| TC-3 | Temperature Controller |
| TEC | ThermoElectric Cooler (Peltier junction) |

Table 2: Acronyms used in this manual.

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1. Introduction

The S-2m pulser driver is designed to provide fast, high impedance electrical current pulses to non-linear current-driven devices. It is a ruggedized version of the ALPES LASERS S-2 pulser driver, and was designed for use with high-power HHL-packaged QCLs. The general driver capabilities are:

- Producing power for the QCL
- Producing modulation to the QCL
- Transfer TEC current from the main system to the internal QCL TEC
- Transfer thermistor signal to the main system
- Provide safety interlocks to prevent inadvertent laser activation
- Communication with the main system or maintenance software

The S-2m driver can be directly controlled by a computer, with drivers available for Linux, Windows, and OSX.

To provide maximum flexibility for integrating into the customer device, the S-2m pulser is provided as a connectorized PCB, as shown in Fig. 1.1. A conformal parylene coating is applied for electronic protection.

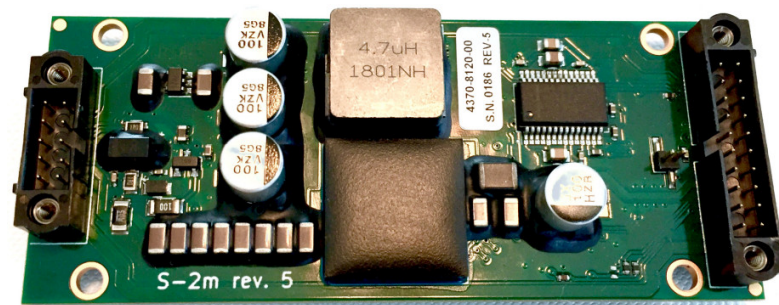


Figure 1.1: S-2m pulser PCB card.

2. Specifications

| Specification | Value |
|-------------------------------------|-------------|
| Max. peak current output | ≥ 8 A |
| Max. avg. current output | ≥ 3 A |
| Max. output voltage | 25 V |
| Pulse width minimum | 10 ns |
| Pulse width min. increment | 10 ns |
| Pulse repetition period resolution | 10 ns |
| Max. pulse repetition frequency | 1 MHz |
| Current measurement resolution | 1 mA |
| Voltage setting resolution | 10 mV |
| Output voltage modulation bandwidth | 1 kHz |
| Rise time | 5-15 ns |
| Fall time | 5-15 ns |
| Input voltage range | 9-28 V |
| Power supply (included) | 18 V / 40 W |

Table 2.1: S-2m specifications. Note that the electronic rise and fall times specified here will vary from driver to driver.

In standard pulsing mode, also referred to "internal" mode, the S-2m pulser can generate a maximum peak current ≥ 8 A and a maximum average current ≥ 3.0 A. The maximum values can vary between S-2m cards, and in general depend on the duty cycle as well as on the selected operation mode when the output mode is not "internal." The maximum peak current as function of duty cycle is depicted in Fig. 2.1. These values represent the maximum allowable user input for the "Peak current limit" in the GUI, with higher attempted input values automatically reduced to the corresponding value from the figure for the selected mode and duty cycle combination.

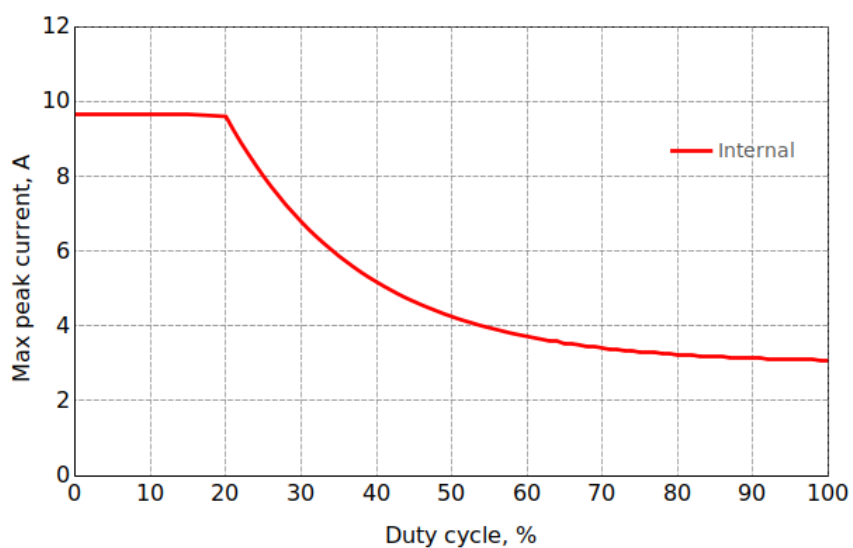


Figure 2.1: ALPES LASERS S-2m pulser maximum peak current as a function of duty cycle.

3. Mechanical interface

3.1 Drawings

All dimensions in the drawings provided are in mm.

3.1.1 S-2m driver PCB

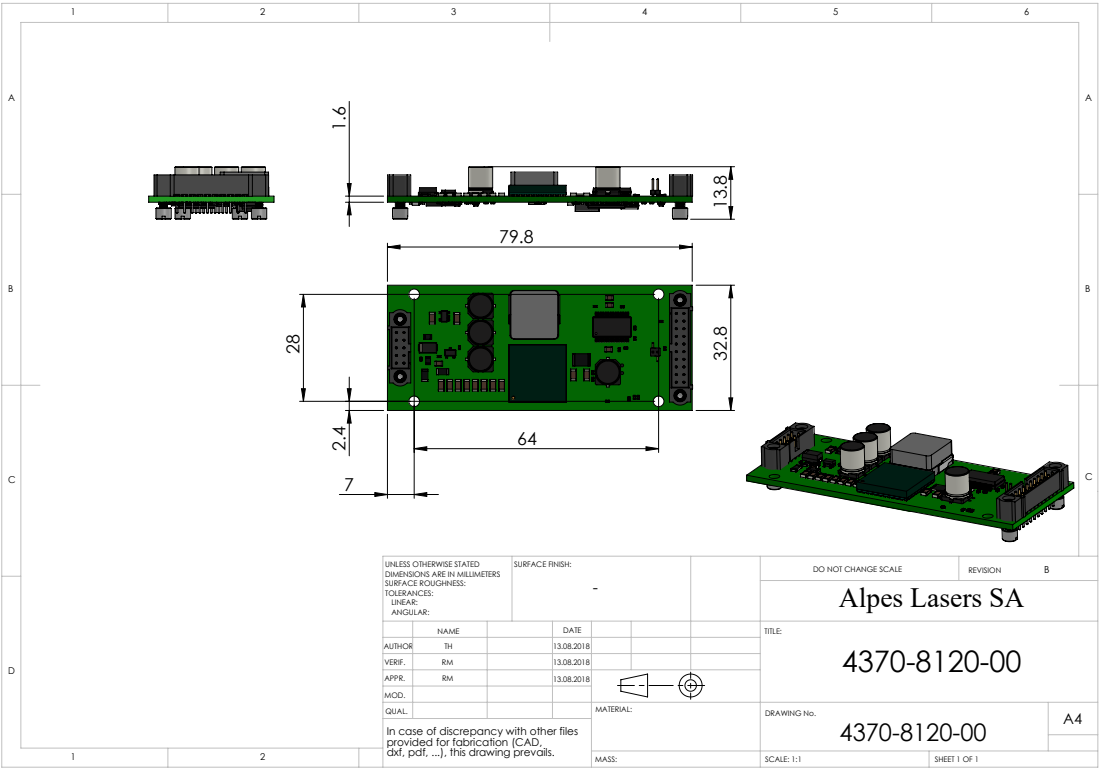


Figure 3.1: S-2m driver PCB. Through-hole spacing 64 mm.

3.1.2 S2m-HHL interface

C-S2m-HHL flex cable

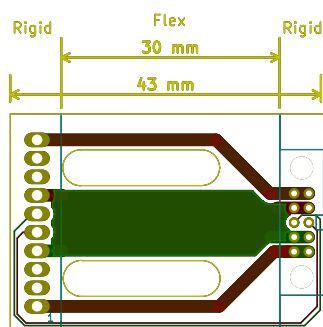


Figure 3.2: C-S2m-HHL flex cable for attaching the HHL package to the S-2m PCB

HHL package with C-S2m-HHL flex cable

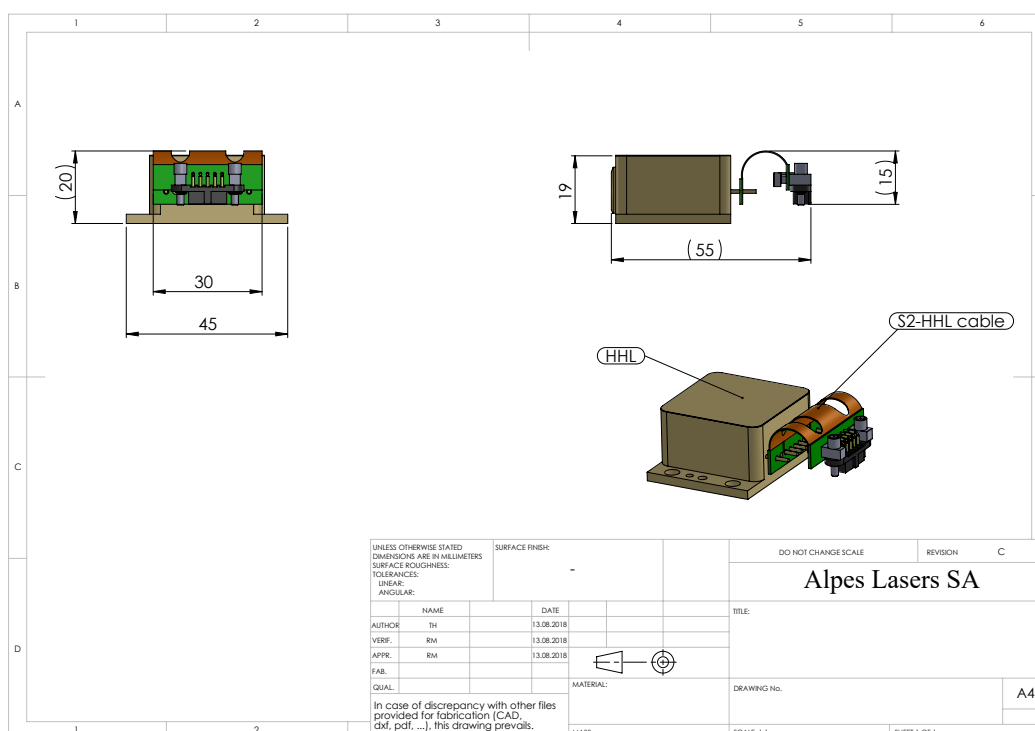


Figure 3.3: HHL-packaged QCL with flex cable for attachment to the S-2m

3.1.3 HHL - S-2m assembly

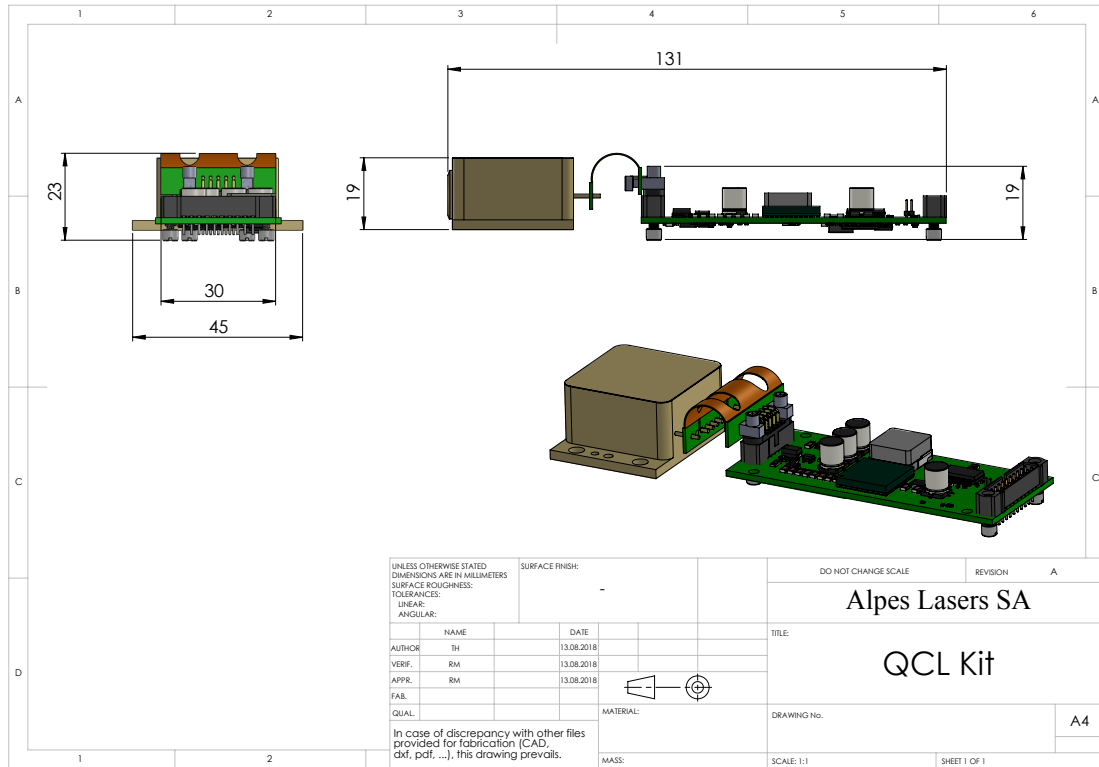


Figure 3.4: HHL-packaged QCL attached to the S-2m driver with a C-S2m-HHL cable

3.2 Mounting instructions

The S-2m PCB does not explicitly require water cooling as the HHL itself does. For optimized temperature performance, a thermal pad may nonetheless be used for the area of the PCB closest to the HHL-S2m flex cable attachment, as depicted in Fig. 3.5.

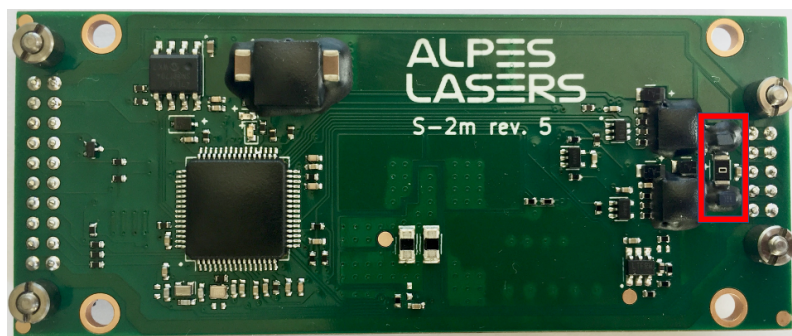


Figure 3.5: Area on S-2m to cool for optimal thermal performance

4. Electrical interface

This chapter describes the electrical pinouts and cable connections for the ALPES LASERS S-2m laser driver. For reference, the "back" or "input" end refers to the 20-pin end of the S-2m PCB connecting to external instruments such as the temperature controller and computer, whereas "front" or "output" end refers to the 10-pin end connecting to the laser. The general system components are depicted in Fig. 4.1.



CAUTION:

Do not apply more than 3.3 V on any external input other than the power supply. There is a risk of damaging the S-2m pulser.

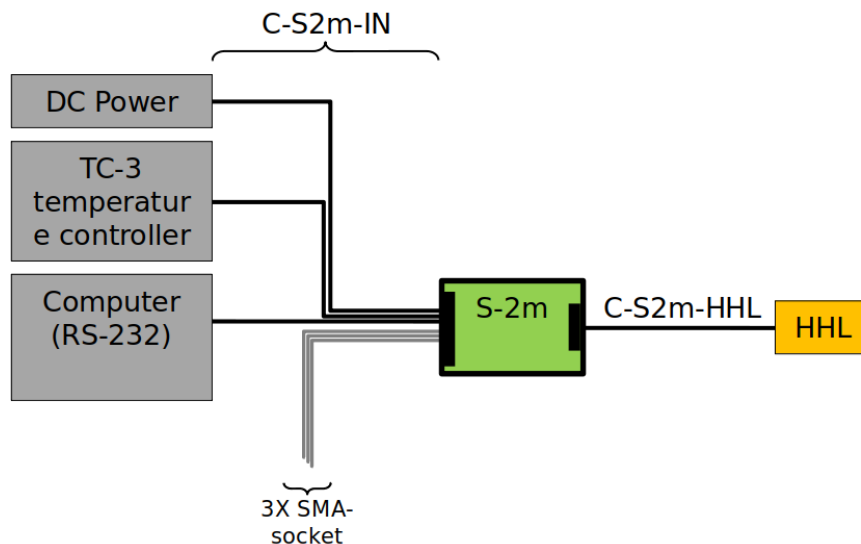


Figure 4.1: Block diagram of system components: power supply, temperature controller TC-3, computer, C-S2m-IN cable, S2-m driver, C-S2-m-HHL cable, and the HHL-packaged QCL. The C-S2m-IN cable splits into 6 outputs from the S2-m PCB, 3 of which are terminated with SMA-Socket plugs. See Sec. 4.3 for details.

4.1 S-2m Input Pinout

The back pinout of the S-2m is shown in Table 4.1 and Fig. 4.2.

| Pin | Name | Description |
|-----|-------------------|--|
| 1 | TEC+ | Power + of the TEC |
| 2 | RS-232 Ground* | Communication Ground |
| 3 | Ground | Ground |
| 4 | Ground | Short to pin 3 |
| 5 | T_SENSOR-EXT | Temp. sensor negative line |
| 6 | T_SENSOR+EXT | Temp. sensor positive line |
| 7 | IN_V_SUPPLY+ | Short to pin 8 |
| 8 | IN_V_SUPPLY+ | DC power + |
| 9 | IN_MOD_DIRECT | External modulation input |
| 10 | TEC- | Power - of the TEC |
| 11 | TEC+ | Short to pin 1 |
| 12 | OUT_RS232_TX | Communication transmit line |
| 13 | IN_RS232_RX | Communication receive line |
| 14 | MCU_OUT_STATUS | Microcontroller output status |
| 15 | OUT_LASER_ON | Output status: 3.3 V when output is enabled, 0 V when output is OFF |
| 16 | IN_VREG_INTERLOCK | Laser voltage interlock |
| 17 | MCU_OUT_INTERLOCK | Microcontroller output interlock |
| 18 | IN_SAFETY | Interlock |
| 19 | IN_ARM | Interlock |
| 20 | TEC- | Short to pin 10 |

Table 4.1: S-2m input (instrument end) pinout.

*Pin 2 is by default connected to Pin 3 by the zero-ohm resistor R43, so that the whole PCB by default has a single ground. R43 may be desoldered from the PCB to float the communication ground. See Fig. 4.3 for the board location.

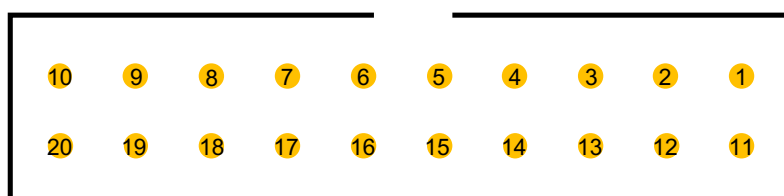


Figure 4.2: S-2m input end pin numbering. Refer to Table 4.1 for pin descriptions.

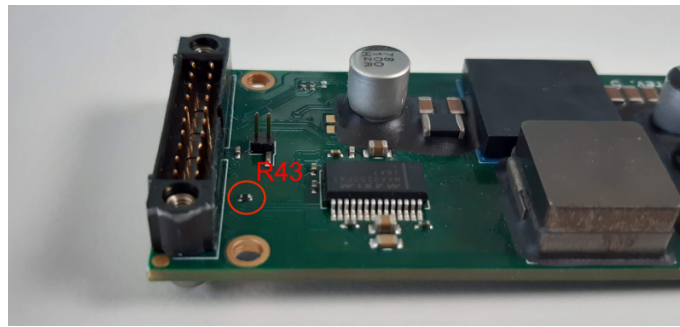


Figure 4.3: Zero-ohm link R43 may be desoldered from the PCB if an isolated communication ground is desired.

4.2 S-2m Output Pinout

The front pinout of the S-2m is shown in Table 4.2 and Fig. 4.4.

| Pin | Name | Description |
|-----|-----------|----------------------------|
| 1 | TEC- | Power - of the TEC |
| 2 | Laser+ | Laser voltage + |
| 3 | T_SENSOR- | Temp. sensor negative line |
| 4 | Laser- | Laser voltage - |
| 5 | TEC+ | Power + of the TEC |
| 6 | TEC- | Short to pin 1 |
| 7 | Laser+ | Short to pin 2 |
| 8 | T_SENSOR+ | Temp. sensor positive line |
| 9 | Laser- | Short to pin 4 |
| 10 | TEC+ | Short to pin 5 |

Table 4.2: S-2m output (laser end) pinout

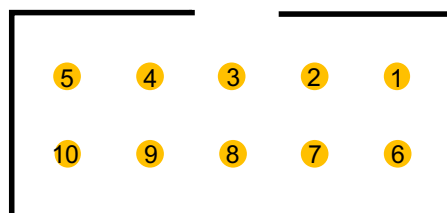


Figure 4.4: S-2m output (laser end) pin numbering

4.3 C-S2m-IN cable

The C-S2m-IN cable provides the connections from the power supply and external instruments to the 20-pin input connector on the S2-m PCB. Unless otherwise indicated

in the pinout of Table 4.3.1 below, the pairs are not shielded.

4.3.1 Instrument end of cable

Temperature controller

Connector: DB-15 Male
Cable type: 4 wires 24AWG
Length: 1.4 m (55 in.)
Label: TEC

| DB-15 pin | Descr. | S-2m pin |
|--------------|-------------------------|-------------|
| 1 | TEC+ | 1 |
| 2 | n/c | - |
| 3 | TEC- | 10 |
| 4 | n/c | - |
| 5 | Earth gnd (shielded) | - |
| 6 | Earth gnd (shielded) | - |
| 7 | T Sensor+ | 6 |
| 8 | T Sensor- | 5 |
| 9 | n/c | - |
| 10 | n/c | - |
| 11 | n/c | - |
| 12 | n/c | - |
| 13 | n/c | - |
| 14 | n/c | - |
| 15 | n/c | - |

Communication

Connector: DB-9 Female
Cable type: 3 wires 24AWG
Length: 1.4 m (55 in.)
Label: RS232

| DB-9 pin | Descr. | S-2m pin |
|-------------|-----------|-------------|
| 1 | n/c | - |
| 2 | RS232 TX | 12 |
| 3 | RS232 RX | 13 |
| 4 | n/c | - |
| 5 | RS232 GND | 2 |
| 6 | n/c | - |
| 7 | n/c | - |
| 8 | n/c | - |
| 9 | n/c | - |

Power supply

Connector: 2.1 mm DC jack
Cable type: 2 wires 24AWG
Length: 0.3 m (12 in.)
Label: POWER

| Pin | Descr. | S-2m pin |
|------|-----------|-------------|
| PIN | DC Power+ | 8 |
| RING | DC Power- | 4 |

4.3.2 S-2m end of cable



Figure 4.5: C-S2m-IN cable connector (female) to the S-2m input (male), Sec. 4.1.

| Pin | S-2m Pin Name | Length | Connection to / Terminal |
|-----|-------------------|--------|------------------------------------|
| 1 | TEC+ | 1.4 m | Temperature controller |
| 2 | RS232_GND | 1.4 m | Computer |
| 3 | GND | | |
| 4 | DC power- | 0.3 m | Power supply, 2.1 mm DC jack |
| 5 | T_SENSOR-EXT | 1.4 m | Temperature controller |
| 6 | T_SENSOR+EXT | 1.4 m | Temperature controller |
| 7 | IN_V_SUPPLY+ | - | No wire |
| 8 | IN_V_SUPPLY+ | 0.3 m | Power supply, 2.1 mm DC jack |
| 9 | IN_MOD_DIRECT | 15 cm | SMA-socket Label: IN MOD DIRECT |
| 10 | TEC- | 1.4 m | Temperature controller |
| 11 | TEC+ | - | No wire |
| 12 | OUT_RS232_TX | 1.4 m | Computer |
| 13 | IN_RS232_RX | 1.4 m | Computer |
| 14 | MCU_OUT_STATUS | 15 cm | SMA-socket Label: MCU OUT |
| 15 | OUT_LASER_ON | 15 cm | SMA-socket Label: OUT LASER ON |
| 16 | IN_VREG_INTERLOCK | 15 cm | No wire |
| 17 | MCU_OUT_INTERLOCK | 15 cm | No wire |
| 18 | IN_SAFETY | 15 cm | No wire |
| 19 | IN_ARM | 15 cm | No wire |
| 20 | TEC- | - | No wire |

Table 4.3: C-S2m-IN cable with connector to the S-2m input

4.4 C-S2m-HHL cable

The C-S2m-HHL cable provides a 30 mm flexible bridge between the S-2m PCB output and the HHL pins, as depicted in 3.1.2.

| HHL Pin | Name | S-2m Output Pin |
|---------|------------|-----------------|
| 1 | TEC - | 1, 6 |
| 2 | (No pin) | |
| 3 | nc | |
| 4 | Laser + | 2, 7 |
| 5 | T sensor - | 3 |
| 6 | T sensor + | 8 |
| 7 | Laser - | 4, 9 |
| 8 | nc | |
| 9 | nc | |
| 10 | TEC + | 5, 10 |

Table 4.4: C-S2m-HHL pin connections

5. Graphical User Interface

This section describes how to program the S-2m pulser with the provided GUI.

With the S-2m powered on and connected to the computer via the C-S2m-IN cable, open the S-2m control software: a dialog similar to the one shown in figure 5.1 will appear. The top line of the dialog box shows a drop-down menu for the port connection. Click `scan` to search for connected ports if necessary, then tick the box next to "connect" to start communication with the S-2m card. An active connection is indicated by "ok" appearing to the right of "connect." If no ports appear after the scan, ensure all drivers are installed, e.g. for the RS232-USB serial adapter.

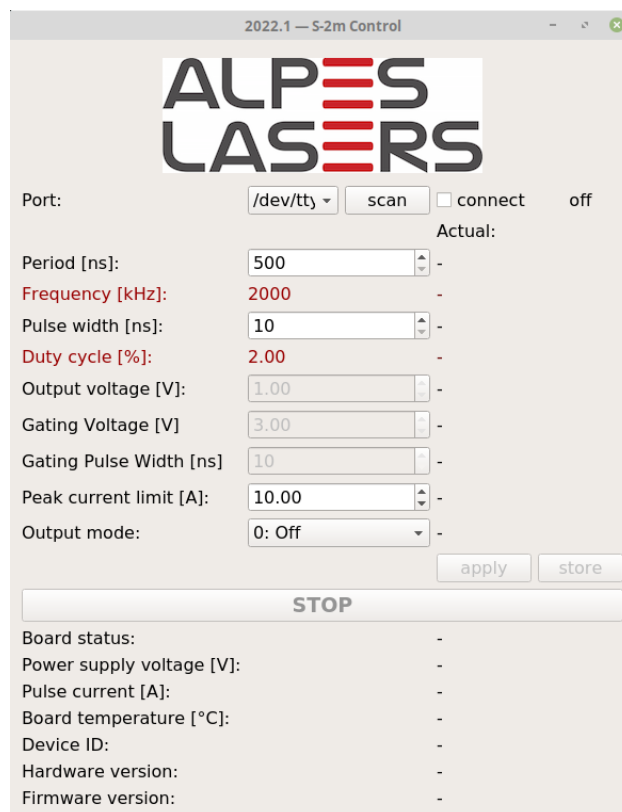


Figure 5.1: Dialog Box for internal control.

5.1 General operation

- Enter the desired repetition period, pulse width, and peak current limit using the dialog box. The corresponding frequency and duty cycle are calculated automatically.
 - These parameters are adjustable even if the output is off
 - Pulse width and repetition period can be adjusted in 10 ns increments
 - Note:* If the pulse width is set to a value larger than the repetition period, the current will be on continuously.
 - Note:* The **Peak current limit [A]** line displays the maximum allowed peak current for the current duty cycle and repetition rate. If this value is exceeded during operation, the driver will shut down in order to protect the laser.
- Click **apply** to set the values. The values displayed on the right will update accordingly under **Actual:** to the right of the input box, as shown in Fig. 5.2.

| Left Panel (Initial State) | | Right Panel (After Clicking 'apply') | |
|---|-----------|---|-----------|
| Port: | \\\\.COM4 | Port: | \\\\.COM4 |
| scan <input checked="" type="checkbox"/> connect ok | | scan <input checked="" type="checkbox"/> connect ok | |
| | Actual: | | Actual: |
| Period [ns]: | 5000 | Period [ns]: | 5000 |
| Frequency [kHz]: | 200 | Frequency [kHz]: | 200 |
| Pulse width [ns]: | 300 | Pulse width [ns]: | 300 |
| Duty cycle [%]: | 6.00 | Duty cycle [%]: | 6.00 |
| Output voltage [V]: | 0.01 | Output voltage [V]: | 0.01 |

Figure 5.2: The set value appears under **Actual**, which changes upon clicking **apply**, as shown here for changing the pulse repetition period.

- Select an output mode from the dropdown box to enter the mode-specific pulse width(s) and amplitude(s). Refer to the laser datasheet for the voltage setpoints. Details of the various output modes are given in Ch. 7 *Modes of operation*.
 - Output voltage can be adjusted in 10 mV increments
 - Two voltage values separated by a / appear under "Actual." These indicate the Set value / Real-time measured value.
- Click on **apply** to start the selected operating mode with the defined settings, or on **store** to simultaneously start pulsing and save the current settings permanently in the driver.

IMPORTANT:

By default, the S-2m pulser is powered up with the settings stored during the last session, including automatic pulse generation at power up if the stored output mode is other than OFF. The S-2m driver should only be used with its paired HHL-QCL to avoid the card's stored parameters exceeding the setpoints of another laser.

Below the `apply` and `store` buttons, several informational values are displayed. Values like the Power supply voltage and Device ID are static, while others like the Board temperature [°C] are measured. *When pulsing*, the measured value of the **Pulse current [A]** is displayed at the bottom of the GUI screen, indicating the current measured in the output ON state. This measured Pulse current value is indicative only, accurate for pulse widths >300 ns and above the minimum measurable value, which can be as high as 0.15 A in some conditions.

5.2 Direct Software Commands

The S-2m pulser can also be driven using a pure Python driver which can be integrated into another software at the user's convenience. The python driver containing the functions to perform all the capabilities of the GUI can be downloaded from the The Python Package Index: <https://pypi.org/project/sdeux/>.

Note: ALPES LASERS offers this Python driver for convenience only. Software support will not be provided.

Example of Python communication

The Python library of the S-2m may be used to write applications. A basic example is provided here:

```
import time
from sdeux.auto_detect import init_driver
from sdeux.serial_handler import S2SerialHandler

if __name__ == '__main__':
    th = S2SerialHandler('/dev/ttyUSB0')
    th.open()
    s2 = init_driver(th)
    s2.set_up()
    print(s2.info)
    print(s2.settings)
    s2.set_settings(pulsing_mode='internal',
                   voltage=5.0,          # applied voltage
                   pulse_period=1000,    # in nanoseconds
                   pulse_width=500,      # in nanoseconds
                   current_limit=3.0)    # amps
    time.sleep(1.0) # wait a bit for measure averaging
    s2.reload_info()
    s2.reload_settings()
    print(s2.info)
    print(s2.settings)
    th.close()
```

The sdeux library is available from The Python Package Index.

6. Safety interlocks, external modulation and security

6.1 Interlocks

The safety interlocks built into the S-2m driver card are implemented as part of the hardware, and thus are not defeatable by software settings. The safety interlocks are not accessible from the C-S2M-IN cable (as described in Ch. 4): the C-S2M-IN cable already provides a build-in connection for the interlocks.

For an advanced direct operation of the S-2m card without the C-S2M-IN cable, the GND pin must be grounded, and the 3 interlocks held at +3.3 V:

| | |
|-------------------|---|
| IN_VREG_INTERLOCK | Gates the main voltage regulator chip on the driver card, effectively the DC power supply. Schematized in Fig. 6.1. |
| IN_ARM | Interlock for the main gate driver. Schematized in Fig. 6.3 |
| IN_SAFETY | Interlock for the safety gate driver. Schematized in Fig. 6.3 |

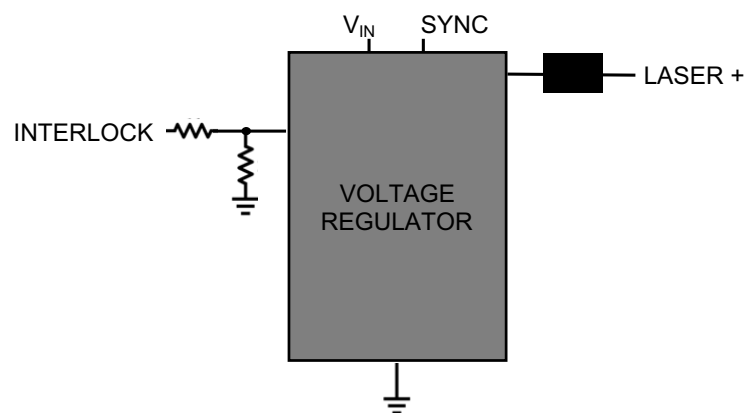


Figure 6.1: Simplified INTERLOCK connection schematic

Note: the MCU_OUT_INTERLOCK output provides +3.3V and can be used to enable the interlocks. This is how the C-S2M-IN cable enables all interlocks.

Note: It is also possible to short the MCU_OUT_INTERLOCK with IN_VREG_INTERLOCK by connecting the jumper "JP2" directly on the driver PCB. The two pins are located near the input end of the PCB, as shown in Fig. 6.2.

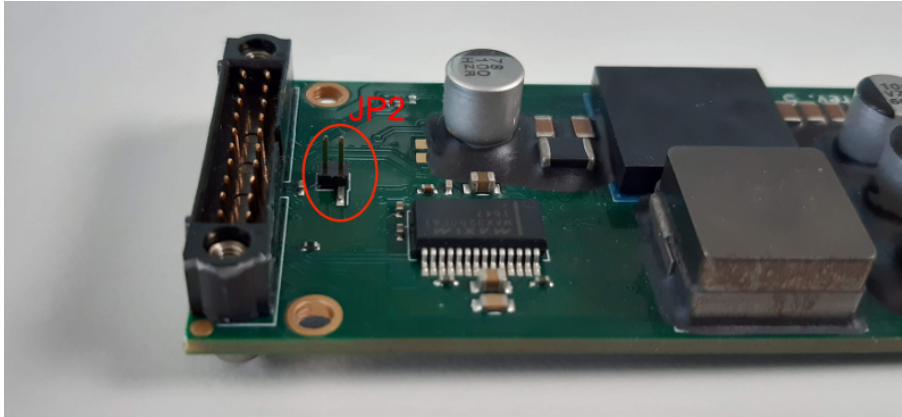


Figure 6.2: Jumper to short INTERLOCK with MCU_OUT_INTERLOCK

The pulse settings defined in the GUI are output from the microcontroller and input to the driver. The driver itself consists of two identical arms, referred to as SAFETY and ARM, both of which must be enabled for laser output. When this is the case, the OUT_LASER_ON pin effectively provides a TTL signal with the modulation input to the transistor drivers. Fig. 6.3 depicts the parallel driver chips, OUT_LASER_ON signal, as well as the optional external modulation input IN_MOD_DIRECT as described in Sec. 6.2 below.

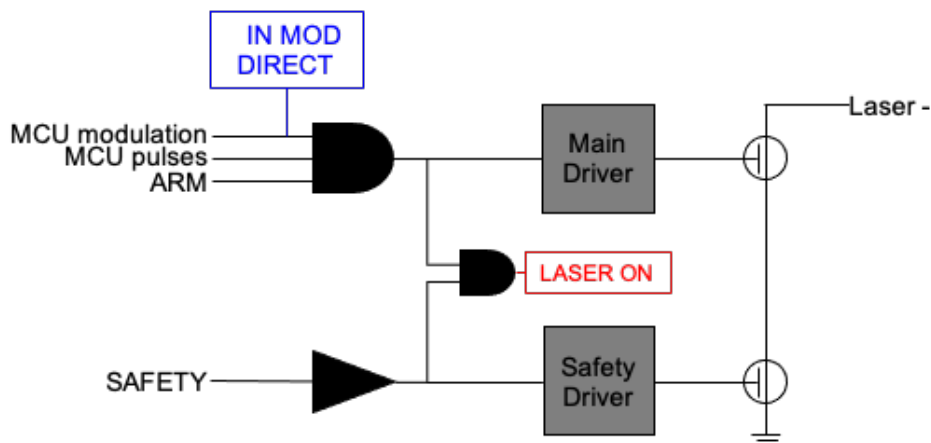


Figure 6.3: Simplified driver connection schematic

Figs. 6.4 and 6.5 depict the OFF/ON switching time measured for the ARM and SAFETY arms of the driver circuit.

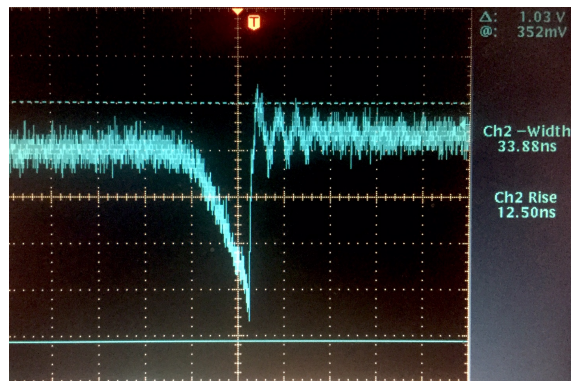


Figure 6.4: ARM interlock response time: ON 13 ns, OFF 34 ns

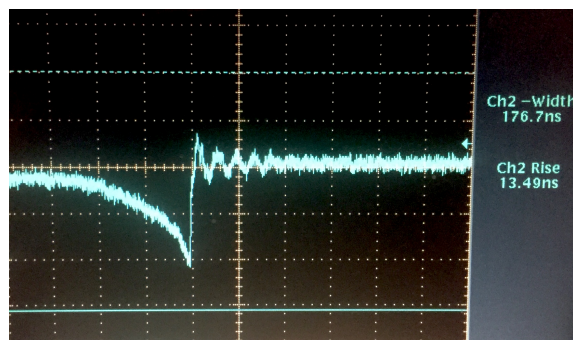


Figure 6.5: SAFETY interlock response time: ON 13 ns, OFF 177 ns

6.2 External Modulation

For an external modulation source, pulses are provided via a TTL signal delivered into the C-S2M-IN cable's IN_MOD_DIRECT SMA-socket connector. TTL generators are not supplied by ALPES LASERS.

With an external modulation source, mode "External Gating" must be selected in the provided GUI. Pulses will be emitted only when the TTL signal on IN_MOD_DIRECT is in the "high" state (+3.3V). When IN_MOD_DIRECT is off or disconnected, no output is produced. For all other mode selections, IN_MOD_DIRECT must be disconnected.

In this mode "Voltage" in the GUI is the voltage that the driver will output when active and the "pulse_width" and "period" are internal pulsing parameters. The TTL external signal gives an envelope and pulses will be emitted according to the internal pulsing parameters when the TTL external signal is high. As such if you specify a CW operation¹, the output signal on the laser will have the same shape as the TTL external signal.

Note: In External Modulation the maximum pulse length is 50 ms. This is a safety

¹with the pulse length equal or longer than the period

feature to ensure the laser is not inadvertently set to CW mode; the S-2m is not meant for true CW usage. If a longer TTL pulse is used the driver will be set to 0 voltage after 50 ms until the TTL signal is dropped.



CAUTION:

Overcurrent protection in "External Gating" is controlled only by the GUI input value of "Peak current limit." This limit is solely user-defined, and not subject to an internal ceiling as the other mode options as depicted in Fig. 2.1.



WARNING:

Internal pulses must be disabled during external control and vice-versa. Enabling internal and external pulses simultaneously might result in damages to the laser and the pulser.

6.3 Security Features

An LED indicator on the back side of the PCB turns from green (ready) to red in normal operation when the S-2m is running. The LED also turns red in case of status errors: a power supply outside the specified range, triggering an Overvoltage or Undervoltage status, or Overcurrent as defined by the current limit set in the GUI. In these cases, the microcontroller no longer outputs to the driver circuit, and the voltage on the green MCU OUT cable which serves as a status indicator switches from 0 V (normal operation) to +3.3 V (status error/no MCU output). The status must be reset via the RESET_STATUS_FLAG before operation can resume.

As an additional security feature, the S-2m will shut down if the pulse length is longer than 50 ms to avoid overheating the QCL.

7. Modes of operation

The S-2m's pulsing schemes are described here.

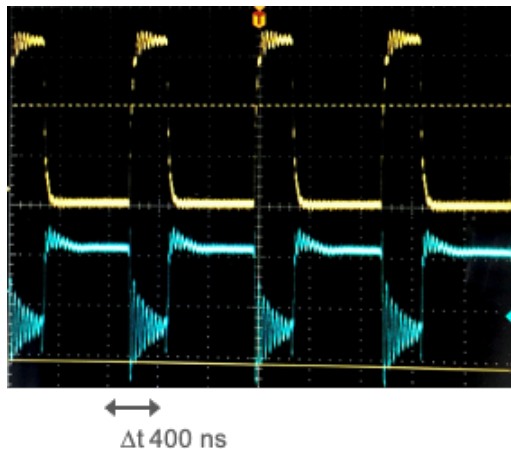
The IN_MOD_DIRECT SMA-socket cable must be disconnected for all other modes other than "External Gating".

0. Off

No pulsing.

1. Pulsing

Standard internal pulsing mode with pulse width and duty cycle configurable in the GUI. Minimum pulse width 300 ns.



Pulsing with 30% duty cycle: 300 ns ON / 1 ms period. Timescale blocks 400 ns. The yellow trace shows the MCU output to the current drivers, as measured from the red OUT LASER ON cable. The blue trace shows the S-2m's "Laser -" output to the HHL, with the polarity reversal compared to the MCU output (yellow) indicative of the QCL bias polarity.

2. External Gating

The internal modulation (typically fast) is modulated by an external signal (typically slower) provided by a TTL signal from an external modulation source using the C-S2M-IN cable's IN_MOD_DIRECT SMA-socket connector. If the external signal pulse width is longer than 50 ms, the output is stopped.



Note that the fast internal modulation is not synced with the external modulation. For example the two images on the left both show the external gating signal in green and the S-2m output in yellow for identical parameters. While the pulse length and the repetition rate of the yellow signal are fixed, the time delay between the onset of the external modulation signal and the rise of the first pulse can vary randomly due to variation between internal and external clocks. The S-2m external gating mode does not allow for syncing that would allow this time delay to be fixed.

8. Non-volatile Memory

The following information is stored in the S-2m's non-volatile memory. The **NAME** refers to the data packet type where the value occurs. See Ch.10 for further details.

INFO

| | |
|-----------------------|---|
| device_id | Unique ID of the board |
| sw_version | Installed firmware version |
| hw_version | Hardware version |
| pulse_clock_frequency | Indicates the pulse timer resolution (Hz) |
| API_version | Incremental number that indicates which version of the communication protocol is used |
| laser_id | ID number of the QCL emitter |

SETTINGS

| | |
|----------------------|---|
| pulse_period | Pulse period given as a multiple of the period $1/\text{pulse_clock_frequency}$ |
| pulse_width | Pulse width of the output pulses given as a multiple of the period $1/\text{pulse_clock_frequency}$ |
| output_voltage_set | Output voltage setting, range from 1 to 25 V (V) |
| output_current_limit | Output current protection limit (A) |
| pulsing_mode | Output pulsing mode, see Ch. 7 |
| bias_t | DC current bias (mA) |
| burst_ON | Number of periods with pulsing enabled, given as multiple of 10 pulse_period |
| burst_OFF | Number of periods with pulsing disabled, given as multiple of 10 pulse_period |
| output_voltage_set_A | Voltage A (see pulsing mode MODE_AB (V) |
| output_voltage_set_B | Voltage B (see pulsing mode MODE_AB (V) |
| pulse_width_A | Pulse width A |
| pulse_width_B | Pulse width B |

UPTIME

| | |
|------------------|--|
| uptime | Time elapsed since the last power on of the S-2m (s) |
| total_uptime | Total time the S-2m was powered on (s) |
| lasing_uptime | Total lasing time (output current >0.1A) (s) |
| operation_uptime | Total operation time (output voltage >5V) |

QUERY_BIT

| | |
|--------------------|--|
| overcurrent_first | Time (total S-2m uptime) at the first occurrence of overcurrent (s) |
| overcurrent_last | Time (total S-2m uptime) at the last occurrence of overcurrent (s) |
| overcurrent_count | Count of overcurrent status events |
| undervoltage_first | Time (total S-2m uptime) at the first occurrence of undervoltage (s) |
| undervoltage_last | Time (total S-2m uptime) at the last occurrence of undervoltage (s) |
| undervoltage_count | Count of undervoltage status events |
| overvoltage_first | Time (total S-2m uptime) at the first occurrence of overvoltage (s) |
| overvoltage_last | Time (total S-2m uptime) at the last occurrence of overvoltage (s) |
| overvoltage_count | Count of overvoltage status events |
| overtemp_first | Time (total S-2m uptime) at the first occurrence of overtemp (s) |
| overtemp_last | Time (total S-2m uptime) at the last occurrence of overtemp (s) |
| overtemp_count | Count of overtemp status events |

9. Built-in Test

Built-in test (BIT) information of the S-2m can be queried as described in the communication protocol in Sec. 10.2.2. In particular, the BIT provides a log of the time and status fault count for the S-2m card, stored in its non-volatile memory and updated upon triggering of a status error. These are tabulated in Table 9.1.

| Error | Unit | Description |
|--------------------|------|--|
| overcurrent_first | s | Time (total S-2m uptime) at the first occurrence of overcurrent |
| overcurrent_last | s | Time (total S-2m uptime) at the last occurrence of overcurrent |
| overcurrent_count | - | Count of overcurrent status events |
| undervoltage_first | s | Time (total S-2m uptime) at the first occurrence of undervoltage |
| undervoltage_last | s | Time (total S-2m uptime) at the last occurrence of undervoltage |
| undervoltage_count | - | Count of undervoltage status events |
| overvoltage_first | s | Time (total S-2m uptime) at the first occurrence of overvoltage |
| overvoltage_last | s | Time (total S-2m uptime) at the last occurrence of overvoltage |
| overvoltage_count | - | Count of overvoltage status events |
| overtemp_first | s | Time (total S-2m uptime) at the first occurrence of overtemp |
| overtemp_last | s | Time (total S-2m uptime) at the last occurrence of overtemp |
| overtemp_count | - | Count of overtemp status events |

Table 9.1: Status errors logged in the S-2m non-volatile memory.

10. Communication Protocol

The present chapter describes the communication protocol between a host and an S-2m rev. 2005 device, otherwise called simply S-2 in the remainder of this text, with API version 2018102501.

10.1 Communication Overview

10.1.1 Data format

The host computer initiates the communication by sending fixed-size binary data packets to the S-2m. The S-2m then always replies with a fixed-size binary packet to each valid packet it receives. However, the S-2m does not reply to any invalid or corrupted packets it receives.

10.1.2 Data framing

The packets are encapsulated into frames according to the serial line over IP (SLIP) RFC 1055. A delimiting character, called END, decimal 192, is appended to the beginning and the end of the packet. An additional escape character, called ESC, decimal 219, is used to escape any END or ESC byte that occurs in the data itself. The escape sequences of the END and ESC characters are called ESC_END and ESC_ESC given by 219,220 and 219,221 respectively in decimal form.

10.1.3 Data transmission

The frames are exchanged over a serial line with a baudrate of 38400. The serial port settings are 8 data bits, no parity, 1 stop bit, no handshaking.

Because the S-2 ignores corrupted packets, it is a good practice to set a small read timeout of the order of 0.1s on the host. If no response comes within this time, it means that the S-2 will not reply at all. The only exception to this rule is for operations that store settings in the flash memory of the S-2 which can take a few seconds.

10.2 Data Packet Structure

Before SLIP framing, the packets consist of a type header of 2 bytes and a payload of 60 bytes. Both are in binary, little-endian format. A control checksum of 2 bytes is appended to the end of the packet to verify the data integrity. The checksum is calculated with the Fletcher-16 algorithm.

An example of a valid packet with an empty payload and a correct checksum is given by:

$1,0,$
 $0,1,62$

where the first two bytes 1,0 are the type header (decimal value 1), the next 60 null bytes are the empty payload, and the last two bytes 1,62 are the two bytes as calculated by the Fletcher-16 algorithm applied to all the previous 62 bytes.

10.2.1 Packet types

The S-2 recognizes seven different packet types. The table below summarizes all the valid packet types with their corresponding header bytes, payload format, header of the S-2 response, and the format of the response payload.

| Packet type | Header bytes | Payload | Response header | Response payload |
|-------------------------|--------------|-------------|-----------------|------------------|
| INFO | 0, 0 | - | 0, 0 | INFO |
| QUERY_SETTINGS | 1, 0 | - | 1, 0 | SETTINGS |
| SET_SETTINGS | 2, 0 | SETTINGS | 1, 0 | SETTINGS |
| SET_PERSISTENT_SETTINGS | 4, 0 | SETTINGS | 1, 0 | SETTINGS |
| RESET_STATUS_FLAG | 5, 0 | STATUS_FLAG | 5, 0 | STATUS_FLAG |
| ADVANCED_INFO | 11, 0 | - | 11, 0 | ADV_INFO |
| QUERY_BIT | 20, 0 | - | 20, 0 | QUERY_BIT |

Table 10.1: S-2m packet types

An empty payload (indicated by a dash) means that the payload is ignored but must still be present in the packet, for instance filled with null bytes. Moreover, all the payload bytes are used to compute the checksum, regardless if the bytes are actually used or not.

The S-2 does not change its status or operation mode in response to any of the five packet types: INFO, QUERY_SETTINGS, UPTIME, ADVANCED_INFO, and QUERY_BIT. The host sends these packet types only to query the information returned by the payload of the response packet. See the next section for a detailed description of the data contained in those payloads.

On the other hand, the three packet types SET_SETTINGS, SET_PERSISTENT_SETTINGS and RESET_STATUS_FLAG change the S-2m operation.

The SET_SETTINGS packet is the principal packet sent to operate the S-2m. It allows the host to change the pulse settings (pulsing mode, pulse width, pulse period, pulse voltage) and to set the current protection limit. See the table in 10.2.2 for a detailed account.

The SET_PERSISTENT_SETTINGS does the same, moreover it also saves the settings to the flash memory, so that the applied settings will persist after a power cycle of the device. Note that this should not be used very frequently because it is rather slow and the flash memory will wear out eventually.

The RESET_STATUS_FLAG is used to reset the S-2m into normal operation after it has triggered a safety protection (e.g. output current over the protection limit).

10.2.2 Payload formats

The payloads consist of a list of fields transmitted in binary, little-endian, format. The tables of this section describe the structure of all the payloads as an ordered list of fields with their associated data types and byte sizes in the payload. Float values are packed according to the IEEE 754 binary32 representation.

Structure of the INFO payload

| Name | Type | Size (Bytes) | Description | Units |
|--------------------------------------|---------|--------------|---|-------|
| device_id | UINT32 | 4 | Unique ID of the board | - |
| sw_version | UINT16 | 2 | Installed firmware version | - |
| hw_version | UINT16 | 2 | Hardware version | - |
| input_voltage_measured | FLOAT | 4 | Measured input (power supply) voltage | V |
| output_voltage_measured | FLOAT | 4 | Measured output (pulse amplitude) voltage | V |
| output_current_measured | FLOAT | 4 | Measured pulse current | A |
| MCU_temperature | FLOAT | 4 | Temperature of the micro-controller | °C |
| laser_temperature | FLOAT | 4 | Voltage measured across the laser temperature sensor (if connected) | V |
| output_current_measured_out_of_pulse | FLOAT | 4 | Measured out-of-pulse current | A |
| status | UINT16 | 2 | Status flag byte: 0=OK, 1=UNDERVOLTAGE, 2=OVERCURRENT, 4=OVERVOLTAGE, 8=OVERTEMP | - |
| pulse_clock_frequency | UINT32 | 4 | Indicates the pulse timer resolution | Hz |
| API_version | UINT32 | 4 | Incremental number that indicates which version of the communication protocol is used | - |
| laser_id | Char[8] | 8 | ID number of the QCL emitter | - |
| TOTAL USED bytes | | 50/60 | | |

Table 10.2: S-2m INFO payload

Structure of the SETTINGS payload

| Name | Type | Size (Bytes) | Description | Units |
|-------------------------|--------|--------------|---|-------|
| pulse_period | UINT32 | 4 | Pulse period given as a multiple of the period $1/\text{pulse_clock_frequency}$ (see 10.1 structure) | - |
| pulse_width | UINT32 | 4 | Pulse width of the output pulses given as a multiple of the period $1/\text{pulse_clock_frequency}$; CW output for $\text{pulse_width} \geq \text{pulse_period}$ | - |
| output_voltage_set | FLOAT | 4 | Output voltage setting, range from 1 to 25 V | V |
| output_current_limit | FLOAT | 4 | Output current protection limit | A |
| pulsing_mode | UINT16 | 2 | Output pulsing mode (see below) | - |
| bias_t | FLOAT | 4 | Approximate bias T current; range from 0 to 35 mA | A |
| burst_ON | UINT32 | 4 | Number of periods with pulsing enabled, given in multiple of 10 pulse_periods | - |
| burst_OFF | UINT32 | 4 | Number of periods with pulsing disabled, given in multiple of 10 pulse_periods | - |
| output_voltage_set_A | FLOAT | 4 | Voltage A (see pulsing mode MODE_AB) | V |
| output_voltage_set_B | FLOAT | 4 | Voltage B (see pulsing mode MODE_AB) | V |
| pulse_width_A | UINT32 | 4 | Pulse width A | |
| pulse_width_B | UINT32 | 4 | Pulse width B | |
| TOTAL used bytes | | 46/60 | | |

Table 10.3: S-2m SETTINGS payload

The *pulsing_mode* controls the type output produced by the S-2.

| Pulsing mode | Value | Description |
|--------------|-------|--|
| OFF | 0 | No pulses are produced, the output is switched off |
| INTERNAL | 1 | The S-2 is producing pulses continuously according to the pulse settings |
| MODE_A | 4 | Special pulsing scheme |
| MODE_B | 5 | Special pulsing scheme |
| BURST | 3 | Pulses are regularly produced in bursts as controlled by the burst_ON and burst_OFF settings |
| MODE_AB | 8 | The output switches between mode A and mode B depending on the duty cycle of the external signal over 450 μ s (mode A: < 25%, mode B: > 30%) |
| MODE_CSS | 12 | Special pulsing scheme (mode C, Steady-State) |
| MODE_CST | 13 | Special pulsing scheme (mode C, Short-Time) |

Table 10.4: S-2m pulsing mode options

Structure of the STATUS_FLAG payload

| Name | Type | Size (Bytes) | Description | Units |
|-------------|--------|--------------|--|-------|
| status_flag | UINT16 | 2 | Which status flag (see INFO structure field status) to reset | - |

Table 10.5: S-2m STATUS_FLAG payload

For instance, if the S-2 is in the OVERCURRENT state, the host can send a RESET_STATUS_FLAG packet with the *status_flag* of the payload set to 1 (corresponds to the OVERCURRENT *status* value of the INFO structure).

Structure of the UPTIME payload

| Name | Type | Size (Bytes) | Description | Units |
|------------------|--------|--------------|---|-------|
| uptime | UINT64 | 8 | Time elapsed since the last power on of the S-2 | s |
| total_uptime | UINT64 | 8 | Total time the S-2 was powered on | s |
| lasing_uptime | UINT64 | 8 | Total lasing time (output current >0.1A) | s |
| operation_uptime | UINT64 | 8 | Total operation time (output voltage >5V) | |

Table 10.6: S-2m UPTIME payload

Structure of the ADV_INFO payload

| Name | Type | Size (Bytes) | Description | Units |
|-----------------------------|-------|--------------|---|-------|
| input_voltage_measured_raw | FLOAT | 4 | Uncalibrated ADC value of the input voltage | - |
| output_voltage_measured_raw | FLOAT | 4 | Uncalibrated ADC value of the input voltage | - |
| output_current_measured_raw | FLOAT | 4 | Uncalibrated ADC value of the in-pulse output current) | - |
| current_out_of_pulse_raw | FLOAT | 4 | Uncalibrated ADC value of the out-of-pulse output current | - |

Table 10.7: S-2m ADV_INFO payload

Structure of the QUERY_BIT payload

| Name | Type | Size (Bytes) | Description | Units |
|--------------------|-------------|-------------------------|---|--------------|
| overcurrent_first | UINT32 | 4 | Time (total S-2 uptime) at the first occurrence of overcurrent | s |
| overcurrent_last | UINT32 | 4 | Time (total S-2 uptime) at the last occurrence of overcurrent | s |
| overcurrent_count | UINT32 | 4 | Count of overcurrent status events | - |
| undervoltage_first | UINT32 | 4 | Time (total S-2 uptime) at the first occurrence of undervoltage | s |
| undervoltage_last | UINT32 | 4 | Time (total S-2 uptime) at the last occurrence of undervoltage | s |
| undervoltage_count | UINT32 | 4 | Count of undervoltage status events | - |
| overvoltage_first | UINT32 | 4 | Time (total S-2 uptime) at the first occurrence of overvoltage | s |
| overvoltage_last | UINT32 | 4 | Time (total S-2 uptime) at the last occurrence of overvoltage | s |
| overvoltage_count | UINT32 | 4 | Count of overvoltage status events | - |
| overtemp_first | UINT32 | 4 | Time (total S-2 uptime) at the first occurrence of overtemp | s |
| overtemp_last | UINT32 | 4 | Time (total S-2 uptime) at the last occurrence of overtemp | s |
| overtemp_count | UINT32 | 4 | Count of overtemp status events | - |

Table 10.8: S-2m QUERY_BIT payload

10.2.3 Examples

To query the S-2 information structure, the host sends

192,0,
0,
0,0,192

where the opening and closing 192 byte are *END* characters of the SLIP framing protocol.

The S-2 replies:

192,0,0,37,0,29,0,185,11,5,0,241,81,144,65,244,86,36,60,0,0,0,
0,143,160,8,66,34,13,116,63,32,52,90,57,0,0,0,225,245,5,65,138,
58,120,85,116,84,63,0,0,0,0,0,0,0,0,0,0,0,0,0,0,202,81,192

where we see again the SLIP framing bytes. The response header is *0,0*, indicating an INFO payload. The next four bytes correspond to the first field of the INFO payload *device_id*. The bytes *37,0,29,0* translate to the integer value 1900581. The next two bytes correspond to *sw_version*, and so on.

As an other example, the host sends an UPTIME query packet to the S-2:

[illegible]

And the S-2 replies:

[illegible]

here we see the SLIP escaping where the fourth and fifth bytes `219,221` correspond to the escape sequence of the `ESC` character with decimal value 219. In that case, the `uptime` value is given by the bytes `219,4,0,0,0,0,0,0` after unescaping, which correspond to 1243 seconds.

11. Environmental Specifications

The S-2m has been rigorously tested to the following specifications:

- Non-operating temperature: -20 to +71 °C
- Operating temperature: 0 to 85 °C
- Vibrations: 1 hour per axis of the vibration profile depicted in Fig. 11.1
- Mechanical shock: 3-Axis total of 18 shocks 85 g, 5 ms half-sine
- Temperature shock: non-operational thermal shock at a rate of 11 °C/min during warm-up from -20 °C to 35 °C or cool-down from 55 °C to 0 °C
- Outgassing: TML less than 1%, CVCM less than 0.1%, as defined in test method ASTM-E-595

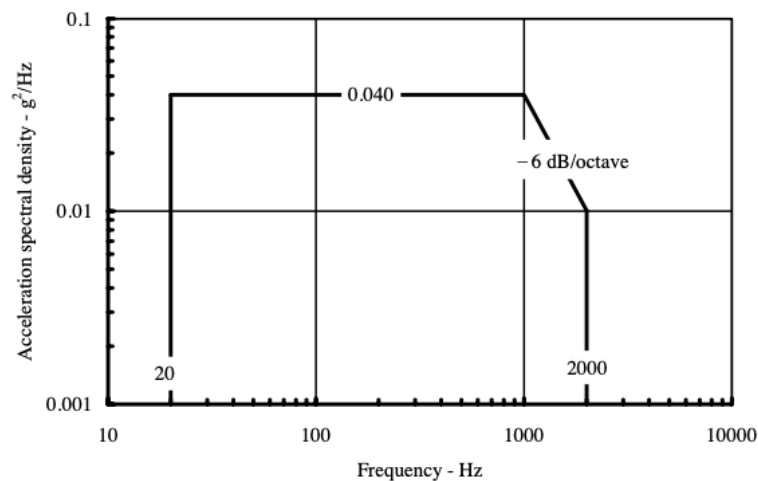


Figure 11.1: General minimum integrity exposure profile for vibration testing, ref. MIL-STD-810F Fig. 514.5C-17