# DATASHEET AND OPERATING GUIDE

# QCL Series

## Low-Noise Quantum Cascade Laser Driver


## FEATURES AND BENEFITS

- Off-the-shelf models at 500 mA, 1 A, 1.5 A, 2 A
- Can be delivered in other current ranges up to 2 A
- Compliance voltage 16 V (standard), Compliance up to 20 V with factory modification
- Safety features protect your QCL investment
  - » Adjustable clamping current limit
  - » Brown-out, reverse-voltage, & over-voltage protection
  - » Driver over-temperature protection circuit
  - » Relay shorts output when current is disabled
- Local and Remote Power-On and Enable control, TTL-compatible

## LOWEST-NOISE DRIVER AVAILABLE

These Low Noise QCL Drivers use patented[1] circuitry to produce the lowest current noise density of any commercially available driver. Powering your QCL with this patented driver will enable better performance—at lower cost and in less time—than otherwise possible.

This is the right driver for lasers that require a high-precision and ultra-low noise current source. The 500 mA QCL driver exhibits noise performance of 0.4 µA RMS to 100 kHz, and an average current noise density of 1 nA / √Hz—the lowest available today.

1. Covered by U.S. Patents 6,696,887; 6,867,644 and 7,176,755. Licensed from Battelle Memorial Institute.

## ULTRA-NARROW QCL LINEWIDTH

In order to maintain their characteristically tight center linewidths and minimize jitter, quantum cascade lasers must be powered by drivers with exceptionally low current noise density. Our customers have reported achieving narrower linewidths with these drivers than any other they've used.

## PROTECT YOUR QCL INVESTMENT

All the essential control and monitor functions you expect in a Wavelength laser driver are incorporated into this driver, along with protection circuitry to safeguard your QCL from minor power source faults, over-temperature conditions, and electrical faults.

## CONTENTS



## ORDERING INFORMATION

| PART NO | DESCRIPTION |
|---|---|
| QCL500 | 500 mA Low Noise QCL Driver |
| QCL1000 | 1 A Low Noise QCL Driver |
| QCL1500 | 1.5 A Low Noise QCL Driver |
| QCL2000 | 2.0 A Low Noise QCL Driver |
| PWRPAK-24V | 24 VDC switching power supply (2x required) |
| NOISESCAN | Noise characterization scan |
| 55-110014 | SMA-BNC low noise cable |
| WCB310 | SMA-SMA low noise cable |
| WCB311 | 20-pin connector with cables |
| WCB312 | Dual power supply wiring kit |
| QCL TEST LOAD | Kit with test load components |

LASER TYPES QCL SUPPORTED

Pb RoHS Compliant


406-587-4910
www.teamWavelength.com



QCL1500-00400-I



WAVELENGTH ELECTRONICS

# QUICK CONNECT GUIDE

To ensure safe operation of the QCL driver, it is imperative that you determine that the unit will be operating within the internal heat dissipation Safe Operating Area (SOA).

Visit the Wavelength Electronics website for the most accurate, up-to-date, and easy to use SOA calculator:

http://www.teamwavelength.com/support/calculator/soa/soald.php

**Figure 1** shows the front panel of the QCL driver and the locations of the Power and Enable switches, Analog In and QCL SMA connectors, and SET and LIMIT trimpots.

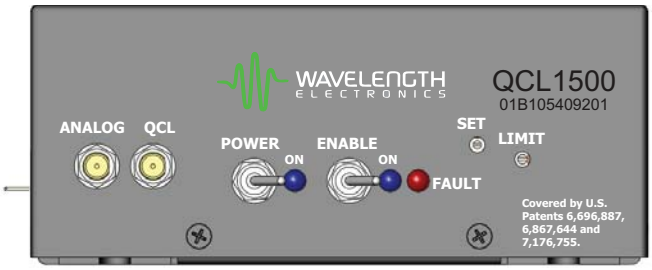



**Figure 1. QCL Driver Front Panel**

**Figure 2** shows the wiring diagram for the QCL driver and external electronics. If you are using the Remote Power On and Remote Enable functions, refer to **page 9** for switch configuration instructions.

For setup and configuration, we recommend using a test load in place of the laser (**Figure 3**). Recommended test load for 0 to 1.5 A operation, $R_{LOAD}$ = 10 Ω, 50 W, metal film resistor:

- Wavelength part number QCL TEST LOAD (available for < 1 A and 1.5 A current ranges)
- Caddock MP850-10-1% (Digikey MP850-10.0-F-ND)
- Ohmite TCH35P10R0JE (Digikey TCH35P10R0JE-ND)

Recommended test load for 1.5 A to 2 A operation, $R_{LOAD}$ = 5 Ω, 50 W, metal film resistor:

- Wavelength part number QCL TEST LOAD (available for 1.5 A, and 2 A current ranges)
- Caddock MP850-5.00-1% (Digikey MP850-5.00-F-ND)

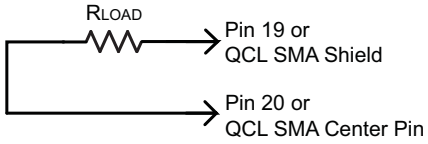
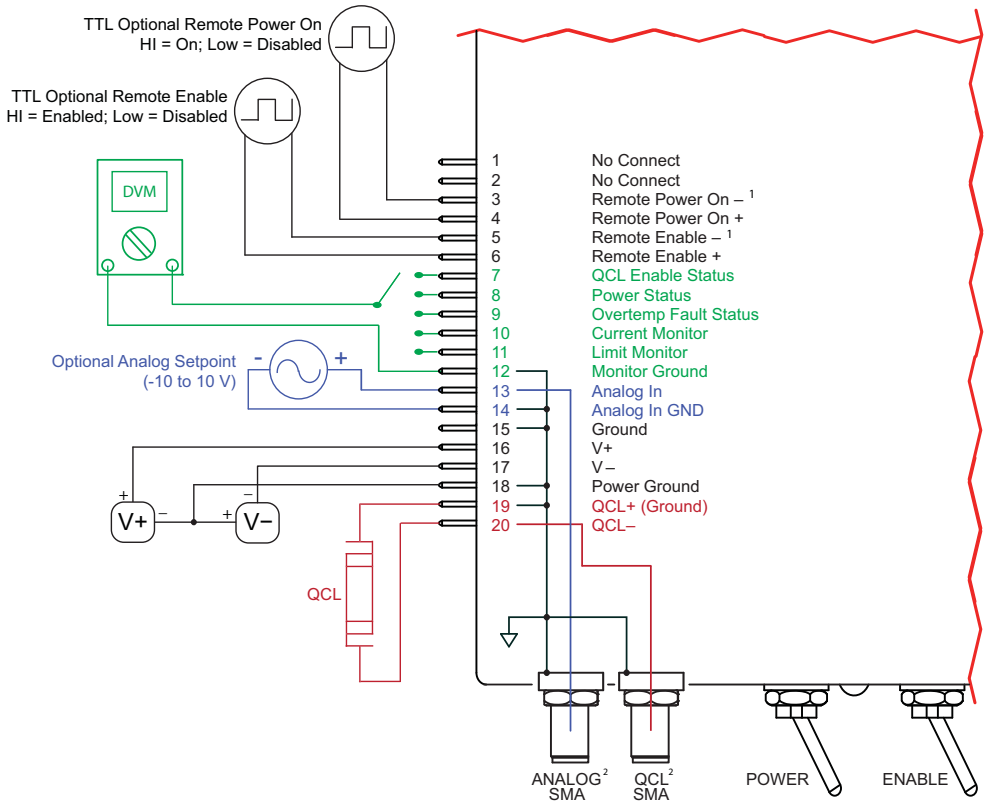



**Figure 3. Test Load**




1. The **Remote Power On –** and **Remote Enable –** inputs can be optically isolated from ground.
2. The SMA connectors are electrically isolated from the QCL chassis.

**Figure 2. QCL Wiring Diagram**

# PIN DESCRIPTIONS

**Table 1. Pin Descriptions, WCB311 Cable Description**

| PIN | NAME | COLOR | BUNDLE | PIN DESCRIPTION |
|---|---|---|---|---|
| 1 | No Connect | | | Reserved. |
| 2 | No Connect | | | Not used. |
| 3 | Remote Power On – | Black | 4 cond, 18” | Return for Remote Power On signal. Can be optically isolated from the instrument ground; see **page 9.** |
| 4 | Remote Power On + | White | | Remote Power On signal. TTL-compatible. OFF = LO (< 5 V), ON = HI (5 to 12 V). Toggle to reset a protection circuit error. |
| 5 | Remote Enable – | Green | | Return for Remote Enable signal. Can be optically isolated from the instrument ground; see **page 9**. |
| 6 | Remote Enable + | Red | | Remote Output Enable signal. TTL-compatible. DISABLE = LO (< 5 V), ENABLE = HI (5 to 12 V). Toggle to reset a protection circuit fault. |
| 7 | Output Enable Status | Blue | 6-cond, 18” | Output Enabled = HI. Can be used to drive an indicator LED, sourcing up to 25 mA at 12 V. |
| 8 | Power Status | Green | | Power On = HI. Can drive an indicator LED, sourcing up to 25 mA at 12 V. |
| 9 | Overtemp Fault Status | Orange | | Overtemp Fault = HI. Indicating internal components are above safe operating temperature and the output has switched off. Can drive an indicator LED, sourcing up to 25 mA at 12 V. |
| 10 | Current Output Monitor[1] | White | | Output current monitor. Transfer function varies by model—refer to **Table 2**. Range 0 to 5 V on Revision C models. Range was 0 to 2.5 V for Revision A and B models. Refer to note 1. |
| 11 | Current Limit Monitor | Red | | Limit current monitor. Transfer function varies by model—refer to **Table 2**. Range 0 to 5 V. |
| 12 | Monitor Ground | Black | | Low current ground used with pins 10 and 11. **This pin is not rated for high current return.** |
| 13 | Analog In | Red | 2-cond, 18” | Analog setpoint input. The voltage input on this pin sums with the onboard setpoint trimpot. Input impedance 1 kΩ. Transfer function varies by model—refer to **Table 2**. |
| 14 | Analog In GND | Black | | Ground for analog setpoint input. **Pin is not rated for high current return.** |
| 15 | Ground | Black | 1-cond, 12” | Ground pin. Can be connected to the chassis. |
| 16 | V+ | Red | 3-cond, 18” | Positive DC power supply input. Typically 24 VDC. Other input voltage ranges can be used with product variations—contact Sales for information. |
| 17 | V– | White | | Negative DC power supply input. Typically –24 VDC. Other input voltage ranges can be used with product variations—contact Sales for information. |
| 18 | Power Ground | Black | | High current return connected to power supplies. |
| 19 | QCL + (Ground) | Black | 2-cond, 18” | Ground connection. QCL current sources from this pin. Refer to **Figure 2**. |
| 20 | QCL – | Red | | Current from the QCL sinks to this pin. Refer to **Figure 2**. |
| **FRONT-PANEL SMA CONNECTORS** | | | | |
| Left Center | | Analog In | | Analog setpoint input. The voltage input on this pin sums with the onboard setpoint trimpot. Input impedance 1 kΩ. Transfer function varies by model—refer to **Table 2**. The analog input voltage can be negative. |
| Left Shield | | Analog In GND | | Ground for analog setpoint input. **Pin is not rated for high current return.** |
| Right Center | | QCL – | | Current from the QCL sinks to this pin. Refer to **Figure 2**. |
| Right Shield | | QCL + (Ground) | | Ground connection. QCL current sources from this pin. Refer to **Figure 2**. |

1. Product revision is indicated by the third digit of the serial number engraved on the front panel. Refer to **page 13 f**or transfer function for Revisions A and B.

**Table 2. Current Limit Monitor and Setpoint Transfer Functions—Revision C**

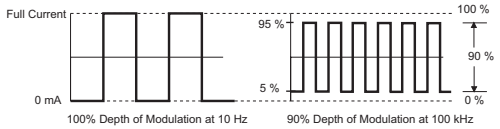
| FUNCTION | QCL500 | QCL1000 | QCL1500 | QCL2000 |
|---|---|---|---|---|
| Current Output Monitor | 0.1 A / V | 0.2 A / V | 0.3 A / V | 0.4 A / V |
| Current Limit Monitor | 0.09 A / V | 0.19 A / V | 0.28 A / V | 0.39 A / V |
| Analog Input | 0.1 A / V | 0.2 A / V | 0.3 A / V | 0.4 A / V |

# ELECTRICAL SPECIFICATIONS

| PARAMETER | SYMBOL | MIN | TYP | MAX | UNIT | NOTE |
|---|---|---|---|---|---|---|
| **ABSOLUTE MAXIMUM RATINGS** | | | | | | |
| Positive Supply Voltage[1] | V+ | | 25 | | VDC | |
| Negative Supply Voltage[1] | V– | | -25 | | VDC | |
| Internal Power Dissipation[2] | $P_{MAX}$ | | | 16 | W | @ 25ºC, no air movement. Reference SOA charts |
| Operating Temperature Range[2] | $T_{OPR}$ | | -40 to 50 | | ºC | 35ºC max for QCL2000 |
| Storage Temperature Range | $T_{STG}$ | | -55 to 125 | | ºC | |
| Weight | | | 2 | | lbs | |
| Size | | | 5.5 x 6.55 x 2.3 | | inches | 139.7 x 166.4 x 58.4 mm |

| PARAMETER | SYMBOL | MIN | TYP | MAX | UNIT | NOTE |
|---|---|---|---|---|---|---|
| **OUTPUT CURRENT** | | | | | | |
| Max Output Current | $I_{MAX}$ | | 0.5, 1.0, 1.5, 2.0 | | A | |
| Compliance Voltage[3] | $V_{COMP}$ | | 16 | | V | |
| Short Term Stability, 1 hr | | 5 | 10 | 15 | ppm | 25ºC |
| Long Term Stability, 24 hr | | 5 | 10 | 15 | ppm | 25ºC |
| Temperature Coefficient | | 5 | 10 | 18 | ppm / ºC | |
| Delayed Start | | | 1.25 | | sec | |
| Slow Start Ramp | | | 100 | | msec | to full scale |
| Leakage Current | | 0.75 | 2 | 3 | mA | |
| **MODULATION** | | | | | | |
| Rise / Fall Time | | | 250 / 200 | | nsec | to full scale |
| Slew Rate | | | 30 | | V / µsec | |
| Depth of Modulation[4] | | | 90% | | | at 500 kHz |
| Bandwidth, 3 dB | | | 2 | 3 | MHz | |
| **NOISE** | | | | | | |
| RMS Noise Current[5]<br>QCL500<br>QCL1000<br>QCL1500<br>QCL2000 | | | <br>0.4<br>0.7<br>1.0<br>1.3 | | µA RMS | 100 kHz bandwidth<br>$I_{OUT}$ = 500 mA |
| Average Noise Current Density[5]<br>QCL500<br>QCL1000<br>QCL1500<br>QCL2000 | | | <br>1.0<br>2.0<br>3.0<br>4.0 | | nA / √Hz | $R_{LOAD}$ = 10 Ω<br>$I_{OUT}$ = 500 mA |
| **POWER SUPPLY** | | | | | | |
| Positive Supply Voltage[1] | V+ | 22 | 24 | 25 | VDC | |
| Negative Supply Voltage[1] | V– | -22 | -24 | -25 | VDC | |
| Quiescent Current, V+ Supply | | | 250 | | mA | |
| Quiescent Current, V– Supply | | | 100 | | mA | |
| Inrush Current Requirement[6] | | | 450 | | mA | |

1. Supply voltage can be changed; contact Sales for information about the product variation.
2. Derating begins at 25ºC. QCL2000 maximum operating temperature is 35ºC.
3. Compliance voltage can be increased to 20 V; contact Sales for information about Product Variation PV055.
4. Peak-to-Peak output amplitude decreases as frequency increases; see figure at right. Also see **page 13**.
5. See Wavelength Electronics technical note TN-LD02: "How is Current Noise Measured at Wavelength Electronics?"
6. Negative power supply must source at least 450 mA. If current to QCL exceeds 450 mA, DC power supply capacity must be (QCL Current) + (Quiescent Current).



# ELECTRICAL SPECIFICATIONS, CONTINUED

| PARAMETER | SYMBOL | MIN | TYP | MAX | UNIT | NOTE |
|---|---|---|---|---|---|---|
| **INPUTS** | | | | | | |
| Analog Input Range | | | 0 to 5 | | V | |
| Input Pin Impedance | | | 1000 | | Ω | |
| Analog Input Damage Threshold | | -10 | | 10 | V | |
| Remote Enable and Remote Power ON | | | TTL Input; must supply min of 5 mA. LO = < 5 V, HI = 5 to 12 V | | | HI = ON, LO = DISABLED / OFF |
| **MONITOR OUTPUT** | | | | | | |
| Current Monitor Range | | 0 | | 5 | V | |
| Current Monitor Bandwidth, 3 dB[1] | | | 1.8 | | MHz | |
| Current Monitor Stability | | | 25 | | ppm | |
| Accuracy, Monitor to Actual Current | | | 0.5 | 1 | % | above 10% full scale |
| Limit Monitor Range | | 0 | | 5.75 | V | |
| Accuracy, Limit Monitor to Actual Limit | | | 1 | 4 | % | limit > 20% above setpoint |
| Status Outputs | | | 12 V output, source up to 25 mA | | | |
| **THERMAL** | | | | | | |
| Pin Solderability | | | Solder Temp at 260ºC for 10 sec | | | |

1. Monitor bandwidth is less than the bandwidth of the current source. To monitor high frequency performance at full compliance, monitor output across a test load only. Do not place measurement equipment across an actual QCL—measurement equipment transients may damage or destroy the laser.

# SAFETY INFORMATION

## SAFE OPERATING AREA – DO NOT EXCEED INTERNAL POWER DISSIPATION LIMITS

Before attempting to operate the QCL driver, it is imperative that you first determine that the unit will operate within the *Safe Operating Area* (SOA). Operating the unit outside of the SOA may damage the driver and the QCL. Operating outside of the SOA will void the warranty.

Go to the Wavelength Electronics website for the most accurate, up-to-date, and easy to use SOA calculator:

http://www.teamwavelength.com/support/calculator/soa/soald.php

To ensure safe operation of the QCL controller, it is imperative that you determine if the unit is going to be operating within the internal heat dissipation Safe Operating Area (SOA).

If you have questions about the Safe Operating Area calculator, call the factory for free and prompt technical assistance.

## USER SERVICEABLE COMPONENTS

The QCL driver is equipped with user-serviceable fuses. Refer to **Replace the Internal Fuses on page 12**.

If you believe your controller needs maintenance or repair, please contact the factory immediately and do not attempt to maintain or repair the unit yourself.

# THEORY OF OPERATION

The QCL Series low noise drivers are designed expressly to drive quantum cascade lasers, and utilize patented[1] circuitry to deliver ultra-low noise current and still maintain a wide modulation bandwidth.

The QCL drivers are controlled current sources, they deliver the current commanded by the setpoint. The current source continually monitors the actual output current, compares it to the setpoint, and adjusts the current if there is a difference between the two signals.

It may be useful to remember that you do not directly set the drive current setpoint. Instead, you adjust a voltage signal that represents the output current; the voltage is set either with the onboard trimpots or by an external input. The voltage and output current are related by a transfer function, described in **Table 2**. The current limit is set in a similar manner.

As current is driven through the load, there is a voltage drop across the load. As the current increases the voltage drop may increase to the point that it reaches the Compliance Voltage limit of the current source. Once that occurs the current source is no longer able to increase the current driven to the load even if you increase the setpoint

The QCL driver includes features that help protect your laser, and also make the driver more versatile in a wide array of applications. These features are explained in detail in the **Operating Instructions**.

- The user-adjustable clamping current limit prevents overdriving the laser even if the analog input signal setpoint is above the maximum drive current for the laser.
- Over- and Under-voltage protection circuits protect the driver and QCL if the power supply voltages fall outside of the acceptable operating range.
- Over-temperature protection circuits safely shut down the output if the internal temperature of the QCL driver rises to an unsafe level.
- Output slow-start ramps the current to setpoint over 100 msec.
- A mechanical relay shorts the output connections when the output is disabled, and when the QCL driver is powered off.

1. Covered by U.S. Patents 6,696,887; 6,867,644 and 7,176,755. Licensed from Battelle Memorial Institute.

# OPERATING INSTRUCTIONS

These instructions are written for the most common operating mode of the QCL driver.

The controller is first configured for local control in order to set the drive current limit. Then the controller is reconfigured according to the actual application. We recommend using a test load until you are familiar with operation of the driver.

## NECESSARY EQUIPMENT

- QCL Driver and QCL
- Digital multimeter (DMM), 4-½ digit resolution recommended
- Low-noise power supplies, 24 VDC; two required for bipolar power supply input
- Connector and cables for remote inputs and QCL output
- Connecting wires
- Test Load; recommended for driver setup

We recommend using the following equipment available from Wavelength Electronics:

- PWRPAK-24V – 24 V switching power supply; two required
- WCB312 – power supply wiring kit
- WCB311 – 20-pin connector and cable
- QCL TEST LOAD – resistive test load for setting up and configuring the driver

## SAFE OPERATING AREA—DO NOT EXCEED INTERNAL POWER DISSIPATION LIMITS

The QCL driver is equipped with a heatsink that is sufficient for most operating environments. In high current applications, or when operating temperatures are elevated, forced airflow over the heatsink may be required.

Refer to the online SOA calculator to determine whether or not a fan will be necessary in your application.

It is imperative that you verify the unit will operate within the internal heat dissipation Safe Operating Area (SOA).

Operating the driver outside the SOA may damage or destroy the driver and/or laser.

## PREVENT DAMAGE FROM ELECTROSTATIC DISCHARGE

Before proceeding, it is critical that you take precautions to prevent electrostatic discharge (ESD) damage to the driver and your laser. ESD damage can result from improper handling of sensitive electronics, and is easily preventable with simple precautions.

Enter the search phrase “ESD Precautions for Handling Electronics” in an internet search engine to find information on ESD-safe handling practices.

We recommend that you always observe ESD precautions when handing the QCL driver and your QCL.

## THERMAL MOUNTING CONSIDERATIONS

The QCL driver is equipped with internal over-temperature protection circuitry. The FAULT LED on the front panel will illuminate, and the output will switch off if the protection circuitry detects an internal over-temperature condition.

To prevent over-temperature faults, the QCL driver should be mounted so that the heatsink receives adequate airflow. If the driver is installed in a case, the enclosure must be ventilated.

## WIRE THE POWER SUPPLIES

Wire the QCL driver to the dual power supplies as shown in **Figure 4**. If you are using the PWRPAK-24V power supplies from Wavelength, we recommend you also use the wiring kit, part number WCB312. The wires included in WCB312 are indicated with an asterisk in **Figure 4**.

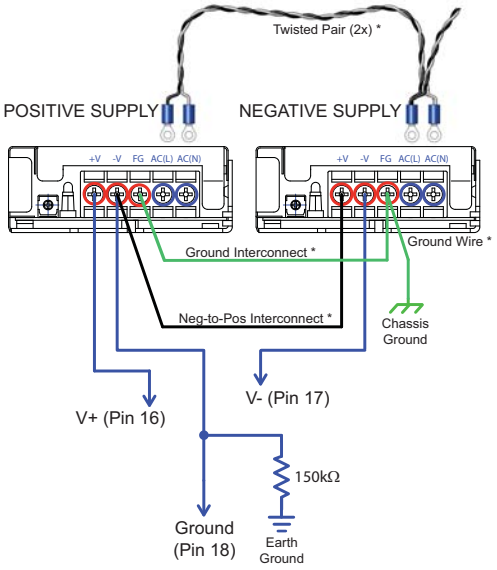



**Figure 4. QCL Power Supply Wiring**

Follow these instructions to wire the power supplies using the WCB312 kit. The same method applies to connect other power supplies to the QCL driver.

- AC Safety Ground #1: 24 AWG green wire, 10” with ring lugs on each end; connect to the Frame Ground terminals on the power supplies.
- AC Safety Ground #2: 24 AWG green wire; 10” with one ring lug; connect to the Frame Ground terminal on one power supply; connect the other end to AC Chassis Ground.
- Common Ground: 24 AWG black wire; 10” with ring lugs on each end; connect between V- of Positive Supply and V+ of Negative Supply.
- Use the remaining ring lugs to connect the power supply cord (not included) to the V+, Power Ground, and V- terminals of the power supplies.

**Figure 4** indicates a 150 kΩ resistor connecting the power supplies to ground; this resistor is necessary if the electronics ground is tied to earth ground at some point within your system, such as at a DAQ card, computer, or USB cable connection.

This resistor provides a lossy connection from system ground to earth ground, and will prevent the ground potential of isolated power supplies from drifting. Note that if this resistor is necessary the remote POWER and ENABLE inputs **must** be optically isolated in order to function properly.

If you are unsure whether to include this resistor in your system, contact Wavelength Electronics for technical assistance.

## CONNECT THE TEST LOAD

It is very important to configure the QCL driver using a test load rather than the actual quantum cascade laser. Refer to **page 2** for test load specifications and wiring instructions. Connect the test load now.

## SET THE CURRENT LIMIT

Prior to switching on the QCL driver, zero the SET and LIMIT currents by turning the trimpots counter-clockwise; 21 turns for the SET trimpot and 12 turns for the LIMIT trimpot.

Next switch on the power supplies, then switch on the QCL driver by setting the POWER switch to ON (right); the blue POWER LED on the front panel will illuminate. Do not enable the output at this time.

The current limit is set using the LIMIT trimpot on the front panel:

- Refer to the datasheet for your QCL to find the maximum current, then calculate the Current Limit Monitor voltage, referencing **Table 2** for the transfer function:

  $V_{LIMIT} = I_{LIMIT}$ / Transfer Function

- Connect the voltmeter to the Current Limit Monitor, pins 11 (positive) and 12 (negative/gnd).
- Adjust the LIMIT trimpot until the Current Limit Monitor voltage matches the calculated $V_{LIMIT}$ value.

## ADJUST THE OUTPUT CURRENT

The DC current setpoint is set by adjusting the SET trimpot on the front panel:

- Refer to the datasheet for your QCL to find the operating current, then calculate the Current Output Monitor voltage using this equation and referencing **Table 2 on page 3** for the transfer function:

  $V_{SETPOINT} = I_{SETPOINT}$ / Transfer Function

- Connect the voltmeter to the Current Output Monitor, pins 10 (positive) and 12 (negative/gnd).
- Switch on the driver output using the ENABLE switch.
- Adjust the SET trimpot until the Current Output Monitor voltage on the voltmeter matches the calculated $V_{SETPOINT}$ value.
- To further protect the QCL, the current limit can be decreased to just above the setpoint value by adjusting the LIMIT trimpot until the voltage just begins to decrease. Then increase the limit until the voltmeter reads the correct $V_{SETPOINT}$ value again.

Once the driver is configured, disable the output then switch off the driver. Finally, switch off the power supplies.

## CONFIGURE LOCAL VS. REMOTE CONTROL

The factory default configuration is with onboard Power and Enable switches active, and the remote signals are inactive. Changing the configuration requires opening the QCL driver case.

In an ESD-safe environment, remove the eight Phillips screws located around the perimeter of the base of the unit; there are two screws on each side. Next remove the baseplate; the fit is intentionally tight and it will take some effort to remove the baseplate. Be careful to avoid bending the pins.

The DIP switches are located on the bottom of the circuit board, as illustrated in **Figure 5**.

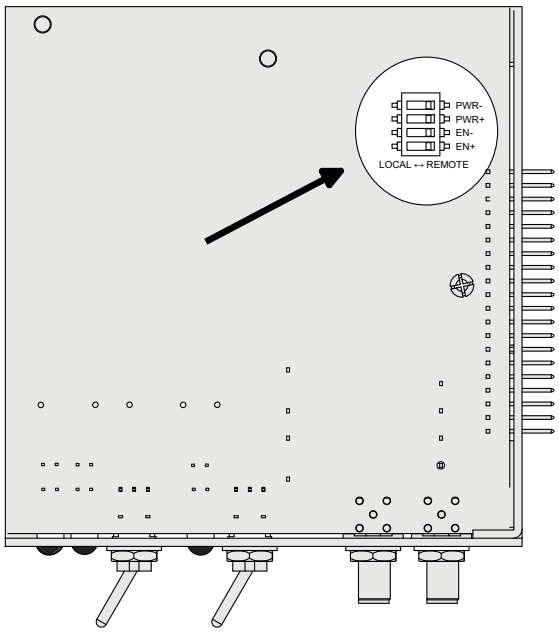
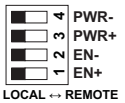



**Figure 5. Bottom View of QCL Driver Showing the Internal Remote / Local Switch Location**

**Table 3** details the switch settings for Local vs. Remote control. The Remote input signals can be optically isolated, or they can be tied to the instrument ground. Choosing whether or not to isolate the remote Power and Enable functions depends on the control system configuration.

**Table 3. Local vs. Remote Switch Settings**

| SWITCH | NO. | ON (LEFT) | OFF (RIGHT) |
|---|---|---|---|
|  | 4 | Remote Signal Tied to Driver Ground | Remote Signal Optically Isolated |
| | 3 | Local Power Switch | Remote Power Signal |
| | 2 | Remote Signal Tied to Driver Ground | Remote Signal Optically Isolated |
| | 1 | Local Output Enable Switch | Remote Output Enable Signal |
| Note: If Switch 1 is ON, Switch 2 must also be ON<br>If Switch 3 is ON ,Switch 4 must also be ON | | | |



- Isolate the inputs when using a computer or DAQ card to generate the control signals. Computers and DAQ cards are typically very noisy, and optically isolating these inputs will prevent that noise from conducting to the QCL driver and laser.

- Isolating the remote inputs requires two I/O lines per function, one for the signal and one for the return. If there is not a sufficient number of I/O lines on the DAQ card, the functions can't be isolated.

- If the ground potential resistor is installed (see **Wire The Power Supplies on page 8**) then the Remote inputs **must** be optically isolated in order to function properly.

Once the switches are configured reassemble the chassis and tighten the screws.

## COMPLETE ADDITIONAL WIRING

If the remote power and enable functions of the QCL driver are being used, connect them to the control electronics. Also connect external electronics for status monitoring. Refer to **Table 1** for specifications on each connection.

## ANALOG SETPOINT INPUT

The external analog setpoint signal sums with the onboard SET trimpot. To calculate the analog input signal voltage, reference **Table 2** for the transfer function, and use the following equation:

$$V_{ANALOG} = I_{SETPOINT} / \text{Transfer Function}$$

The $V_{ANALOG}$ signal can be positive or negative with respect to ground, so the current output can be modulated around a DC setpoint set with the onboard trimpot.

If the analog setpoint input causes the driver to reach the current limit, the output signal will be clamped at the limit level but will not switch off. Refer to **page 13** for information on current limit circuit response to modulated analog setpoint input signals.

The bandwidth of the Current Monitor is lower than the bandwidth of the output. To monitor the actual output waveform at high frequencies, connect an oscilloscope across the output pins 10 (positive) and 12 (negative/gnd) while using the resistor test load.

CONNECT THE OSCILLOSCOPE ACROSS THE TEST LOAD ONLY—NEVER CONNECT THE OSCILLOSCOPE ACROSS A QUANTUM CASCADE LASER.

## CONNECT THE QUANTUM CASCADE LASER

Once you are comfortable with operating the QCL driver, disable the output, switch off all power to the driver, disconnect the test load, and connect the laser. Refer to **Figure 6** for proper wiring polarity.

Note that the Positive Terminal of the QC Laser is connected to ground, and the Negative Terminal is connected to the Driver. The QCL driver acts as a *current sink*.

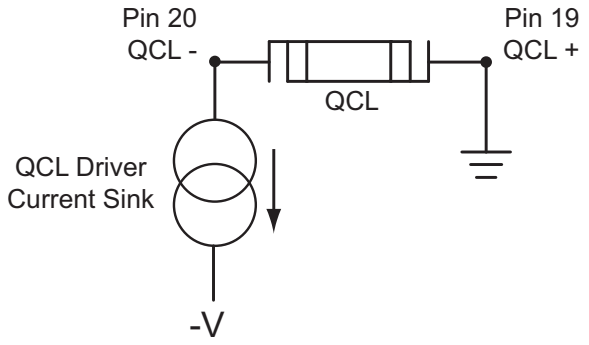



**Figure 6. QCL Wiring and Polarity**

## ENABLE THE QCL DRIVER OUTPUT

Enable the output current by setting the ENABLE switch to ON (right). The blue ENABLE LED on the front panel will illuminate. The output is disabled by setting the switch to the OFF position (left).

## RECOVER FROM A POWER SUPPLY PROTECTION CIRCUIT FAULT

If the voltage from the dual power supplies is over or under voltage limits, the protection circuits will disable the output and latch the driver in a FAULT state. If a fault is indicated, switch off the QCL driver and power supplies.

After correcting the cause of the power supply error, the driver must be reset. Toggle the Power OFF then ON using either the remote signal or front panel switch. After switching on the power, wait one second to re-enable current.

If supply voltage to the QCL driver is reversed, protection circuits activate and the current from the power supplies is shunted through a protection diode. The internal fuses may blow, and the QCL driver will not operate under this condition. Switch off all power, correct the error, and re-enable the driver.

## RECOVER FROM AN INTERNAL OVER-TEMPERATURE FAULT

The QCL driver is equiped with a protection circuit to switch off the output if the internal temperature exceeds a safe operating value. If an overtemperature fault is detected the FAULT LED will illuminate red, and the signal on Pin 9 will go HI. Switch off the output using the onboard switch or the remote output enable signal. The QCL will not allow the output to be enabled until the internal temperature is within the safe operating range.

# TROUBLESHOOTING

| PROBLEM | POTENTIAL CAUSES | SOLUTIONS |
|---|---|---|
| Driver will not switch on | Improperly configured power supplies | Carefully check the wiring diagram in **Figure 2 on page 2**. Make sure the power supply polarity is not reversed. The FAULT LED will illuminate red if the driver is switched on with reversed power supply polarity. |
| | Internal fuses are blown | In an ESD-safe environment, open the QCL driver chassis and verify the fuses are not blown. Replace the fuses if necessary. Refer to **Replace the Internal Fuses on page 12**. |
| Output will not enable | Improperly configured Remote switches on the QCL unit | Make sure that the Remote switches in the QCL driver are set to the correct position for your application. Refer to **Configure Local vs. Remote Control on page 9**. |
| | Remote Enable signal is not correct | If the driver is configured to reference the Remote inputs, make sure the signals are correct. Disconnect the remote input lines and check them independently of the driver. Refer to **Table 1 on page 3**. |
| | The QCL driver detected a power supply Fault | If the red FAULT LED is illuminated, the protection circuitry has detected a fault condition on the power supply inputs. Refer to **Recover from a Power Supply Protection Circuit FAULT on page 10**. |
| | The QCL driver detected an over-temperature condition | If the red FAULT LED is illuminated and the signal on Pin 9 is HI, the protection circuitry has detected an overtemperature fault condition. Refer to **page 10.** |
| Noise current is higher than expected | There may be ground loops in the system; some system components may be higher noise than expected; cabling and shielding may be inadequate | Refer to Wavelength Electronics Application Note AN-LD08, Manage Grounding to Minimize Noise with the QCL Drivers: http://www.teamwavelength.com/downloads/notes/an-ld08.pdf<br><br>Also reference AN-LD09, Troubleshooting Low Noise Systems: http://www.teamwavelength.com/downloads/notes/an-ld09.pdf |
| | Switching power supplies may be noisy | Use the best quality switching power supplies you can find. We test our QCL drivers using our stock PWRPAK-24V power supplies. |
| The output switched off unexpectedly | The QCL driver detected a power supply Fault | If the red FAULT LED is illuminated the protection circuitry has detected a fault condition on the power supply inputs. Refer to **Recover from a Power Supply Protection Circuit FAULT on page 10**. |
| | The QCL driver detected an overtemperature condition | If the red FAULT LED is illuminated and the signal on Pin 9 is HI, the protection circuitry has detected an overtemperature fault condition. Refer to **Recover from a Power Supply Protection Circuit FAULT on page 10.** |
| Laser output power lower than expected | Current limit set too low | Using a test load (see **Figure 3 on page 2**) follow the procedure to set the current limit (**page 8**). Verify that the current limit is suitable for your laser by connecting the voltmeter across $R_{LOAD}$; calculate the drive current using Ohm's Law (V = I * R). |

# TECHNICAL SUPPORT INFORMATION

This section includes useful technical information on these topics:

- **Replace the Internal Fuses**
- **Set the Current Limit More Accurately**
- **Drive LEDs With the Status Outputs**
- **Cable Adapter**
- **Revision A & B Transfer Functions**
- **Square Wave Response**
- **Current Limit Response - Applicable to Product Revision C and Prior**
- **Product Variations**
- **Optimizing the System for Low Noise**
- **Safe Operating Area Calculation**

## REPLACE THE INTERNAL FUSES

The QCL driver is equipped with two internal fuses. If the QCL driver will not power on and you have verified that the power supplies are wired and working properly, check and replace these two fuses. See **Figure 7** for the fuse location. The fuses are 5 A, 5 x 20 mm, SLO-BLO fuses.

In an ESD-safe environment, remove the eight Phillips screws around the base of the unit. Then remove the baseplate—the fit is intentionally tight and will require some effort. Be careful to avoid bending the pins.

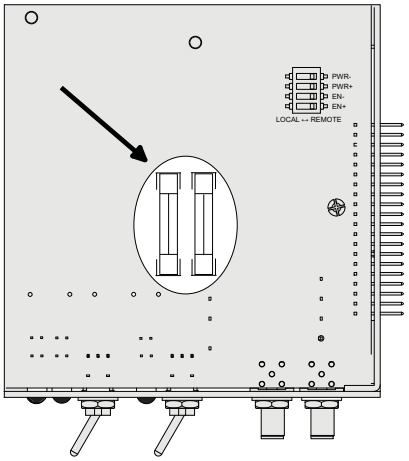



**Figure 7. Location of Internal Fuses**

Replace the fuses, then reinstall the chassis cover and tighten the eight screws.

## SET THE CURRENT LIMIT MORE ACCURATELY

The drive current limit can be more accurately set using a 4½-digit digital multimeter to measure the voltage drop across the test load while adjusting the LIMIT trimpot. For best results use a high-precision resistor with a low temperature coefficient.

NEVER CONNECT A MULTIMETER ACROSS THE ACTUAL QUANTUM CASCADE LASER—MEASUREMENT TRANSIENTS MAY DAMAGE THE LASER.

## DRIVE LEDS WITH THE STATUS OUTPUTS

In the ON state the Status pins output a 12 V signal, sourcing up to 25 mA, and can be used to drive indicator LEDs. Assuming $V_F$ = 2 V and a drive current requirement of 10 mA, LEDs can be connected per **Figure 8**.

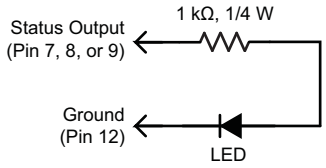
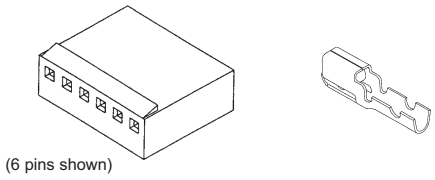



**Figure 8. Wiring Status LEDs**

## CABLE ADAPTER

Use the Wavelength Electronics cable PN WCB311 to connect to the twenty pins on the side of the QCL driver.

If you wish to make your own cable to connect to the QCL driver, use the Molex high pressure housing 7880-family (**Figure 9**).




20-pin Connector, Molex Part Number: 10-11-2203
5-pin Connector, Molex Part Number: 10-11-2053

Crimp, Molex Part Number: 08-50-0005 (20 req'd)

**Figure 9. Molex Connector Part Numbers**

## REVISION A & B TRANSFER FUNCTIONS

The transfer functions for production revisions A & B are different than for revision C; refer to **Table 4**.

**Table 4. Current Limit Monitor and Setpoint Transfer Functions—Revisions A & B**

| FUNCTION | QCL500 | QCL1000 | QCL1500 | QCL2000 |
|---|---|---|---|---|
| Current Output Monitor | 0.2 A / V | 0.4 A / V | 0.6 A / V | 0.8 A / V |
| Current Limit Monitor | 0.09 A / V | 0.19 A / V | 0.28A / V | 0.39 A / V |
| Analog Input | 0.1 A / V | 0.2 A / V | 0.3 A / V | 0.4 A / V |

## SQUARE WAVE RESPONSE

**Figure 10** and **Figure 11** illustrate the modulation response of the QCL1000 driven at 1.15 A into a 10 Ω test load.

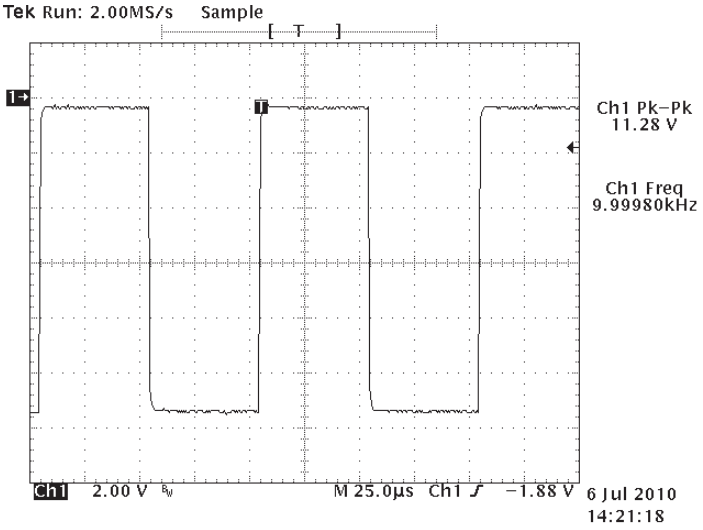



**Figure 10. 10 kHz Output Plot; QCL1000 at 1.15 A 10 Ω Test Load**

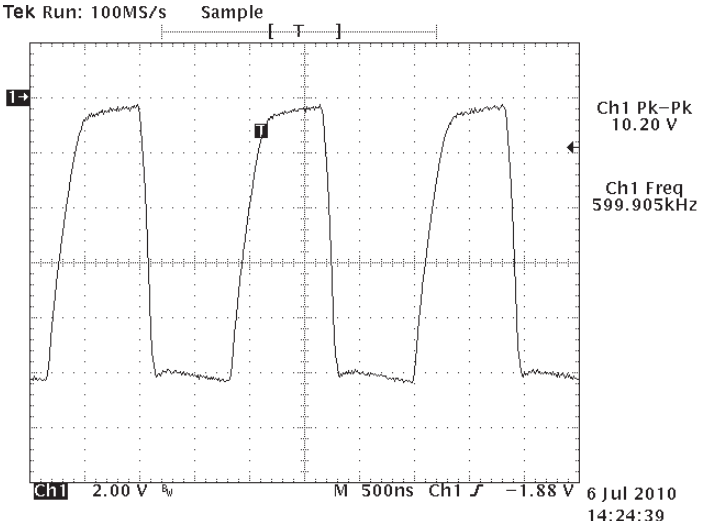



**Figure 11. 600 kHz Output Plot; QCL1000 at 1.15 A 10 Ω Test Load**

## CURRENT LIMIT RESPONSE - APPLICABLE TO PRODUCT REVISION C AND PRIOR

The output current overshoots the current limit by approximately 2% if the setpoint significantly exceeds the limit setting. Refer to **Figure 12**. To avoid overshooting the current limit we recommend operating the QCL driver with the limit set above the setpoint.

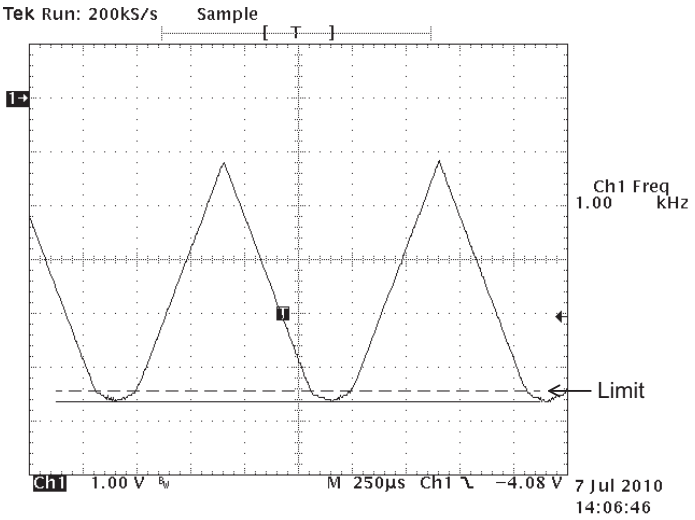



**Figure 12. Limit Circuit Response**

## PRODUCT VARIATIONS

We design and manufacture our products in-house, and that gives us the unique ability to modify our drivers and controllers to suit exactly your application. Our Product Variation service allows us to quickly and cost-effectively address your design requests, from prototype quantities to long-term high-volume manufacturing.

Examples of past Product Variations include:

- Increasing the compliance voltage limit.
- Replacing current limit trimpots with fixed-value resistors to maximize stabilty in an OEM laser controller.
- Optimizing heatsink size and configuration to fit within the space constraints of your electronics chassis.
- Increasing the maximum output current.
- Changing the controller input voltage.

## OPTIMIZING THE SYSTEM FOR LOW NOISE

The QCL driver is designed to deliver extremely low noise drive current to the quantum cascade laser, but other factors must also be considered for optimum system performance.

Wavelength Electronics provides a number of resources on our website that will help you understand noise sources and how to eliminate them. Visit this link:
http://www.teamwavelength.com/support/reference.php

One of the most important components affecting noise performance is the power supply used to power the QCL driver. Wavelength has extensively tested the TDK/Lambda switching power supply, and recommends this power supply for most QCL applications (available as our PN PWRPAK-24V, two required per driver).

Proper grounding technique is also critical. Always ensure there are no ground loops within the system. Grounding the chassis of the QCL driver will help reduce 50/60 Hz noise.

**Figure 13** through **Figure 15** illustrate the benefits of using high-quality switching power supplies and grounding the chassis.

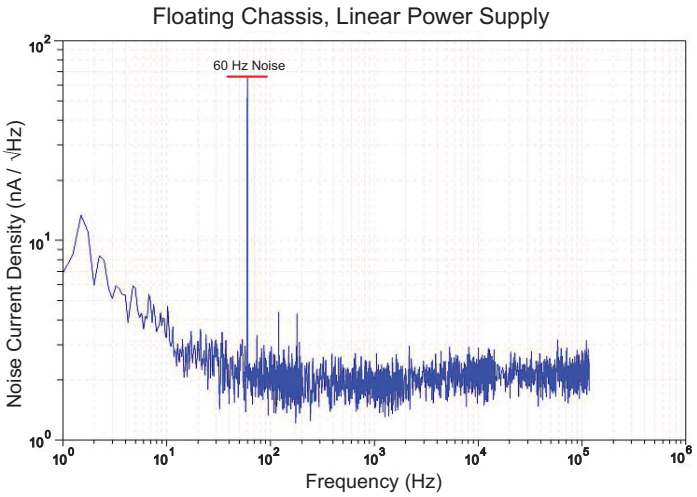



**Figure 13. Noise Plot with Floating Chassis and Linear Power Supplies**

Leaving the chassis ungrounded and using a low-quality linear power supply introduces a very strong 60 Hz noise signature on the output. In most applications this strong 60 Hz signature will negatively impact QCL performance, so it is critical to ground the chassis to achieve the best system performance.

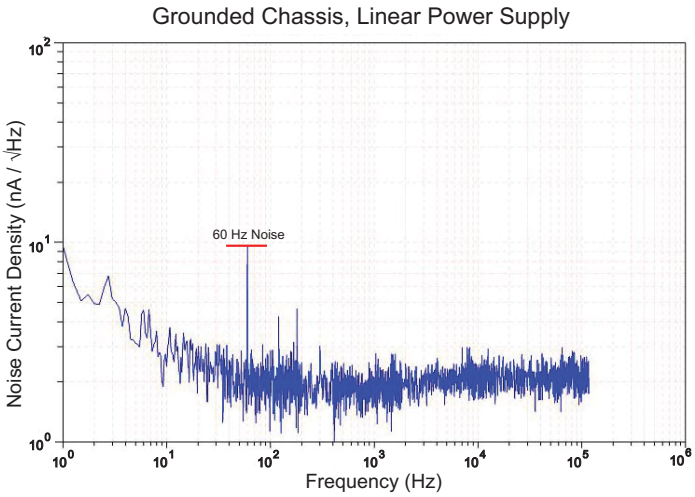



**Figure 14. Noise Plot with Grounded Chassis and Linear Power Supplies**

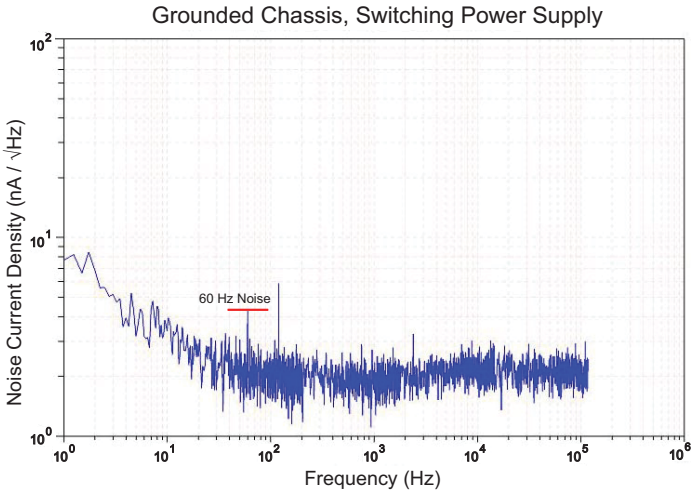



**Figure 15. Noise Plot with Grounded Chassis and High Quality Switching Power Supplies**

Additional recommendations to minimize noise:

- Use high quality power supplies, and test the power supplies independent from the laser driver system in order to ensure they are performing at a level that will not introduce unacceptable noise.
- Use filters on the power supplies; off-the-shelf EMI filters such as the TDK/Lambda MAW Series will provide a noticeable benefit.
- Use low-noise analog input signal generators. Even “low noise” function generators have a significant noise signature that may negatively impact system performance.
- If a fan is required to help keep the driver cool, do not wire the fan to the same power supplies used to power the driver. Fans are notoriously noisy.
- Use the shortest possible power, control, and laser leads. Use twisted pairs, shielded cables, and shielded connectors.

## SAFE OPERATING AREA CALCULATION

The Safe Operating Area of the QCL is determined by the amount of power that can be dissipated within the output stage of driver. If that power limit is exceeded permanent damage can result.

DO NOT OPERATE THE QCL DRIVER OUTSIDE OF THE SAFE OPERATING AREA CURVE.

OPERATING THE QCL DRIVER OUTSIDE OF THE SOA VOIDS THE WARRANTY.

Refer to the Wavelength Electronics website for the most up-to-date SOA calculator for our products. The on-line tool is fast and easy to use, and also takes into consideration operating temperature.

http://www.teamwavelength.com/support/calculator/soa/soald.php

SOA charts are included in this datasheet for quick reference. We recommend you use the on-line tools instead.

Follow these steps to determine if the driver will be operating within the SOA.

- Refer to the QCL laser datasheet to find the maximum voltage ($V_{QCL}$) and current ($I_{MAX}$) specifications.
- Calculate the voltage drop across the controller:

  $V_{DROP}$ = |V-| - $V_{QCL}$ (V- is the negative power supply voltage)

- Mark $V_{DROP}$ on the X-axis, and extend a line upward.
- Mark $I_{MAX}$ on the Y-axis, and extend a line to the right until it intersects the $V_{DROP}$ line.
- On the X-axis, mark value of the negative supply voltage.
- Extend a diagonal line from V- to the intersection of the other two lines; this is the Load Line.
- If the Load Line crosses the Safe Operating Area line at any point, the configuration is not safe.

If the SOA calculator indicates the QCL will be outside of the safe operating area, the system must be changed so that less power is dissipated within the driver. See Wavelength Electronics Application Note AN-LDTC01 for information on shifting the load-line.

After changing any of the parameters, recalculate the SOA to make sure the controller will operate safely. If you have questions, or run into difficulties calculating the SOA, contact Wavelength Electronics for assistance.

## QCL500 SAFE OPERATING AREA

The QCL500 will safely operate at 25ºC under any drive condition and no additional airflow is required over the heatsink. For operating temperatures above 25ºC, refer to the on-line SOA calculator.

Depending on the results of the SOA calculation, the QCL1000, QCL1500, and QCL2000 may require airflow over the heatsink in order to safely operate.

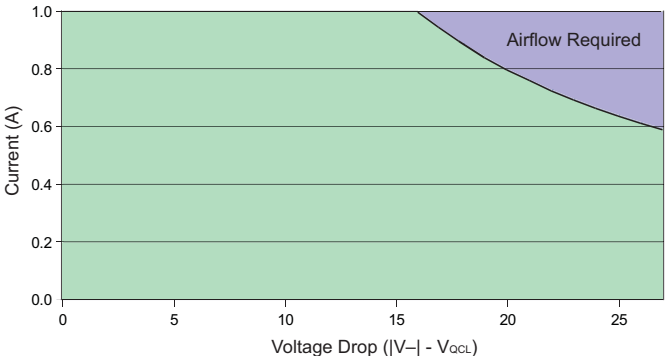



**Figure 16. QCL1000 SOA Chart, at 25ºC**

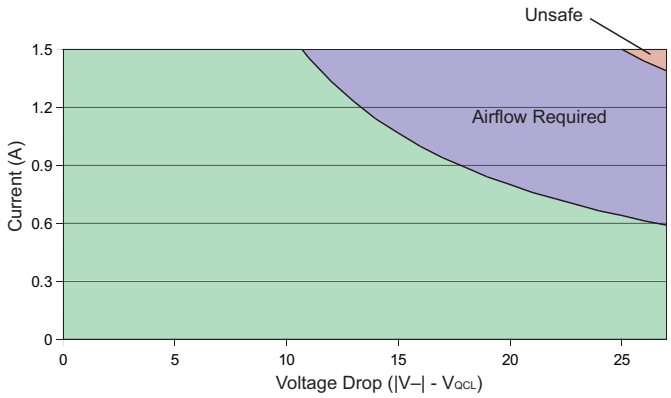



**Figure 17. QCL1500 SOA Chart, at 25ºC**

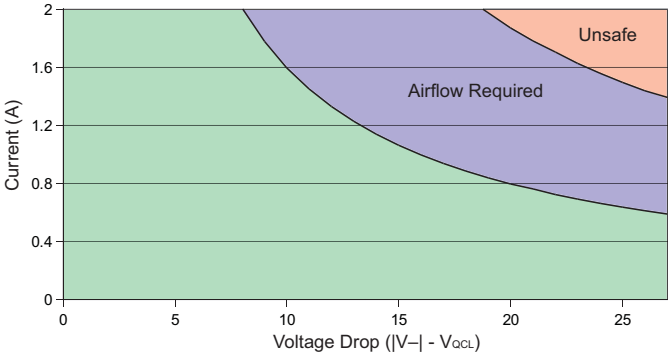
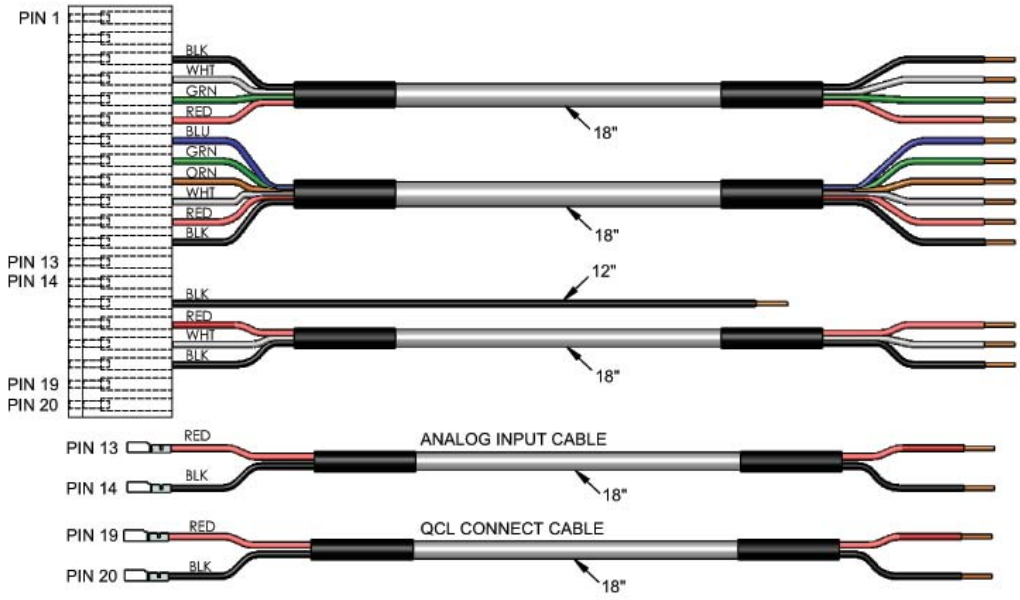



**Figure 18. QCL2000 SOA Chart, at 25ºC**

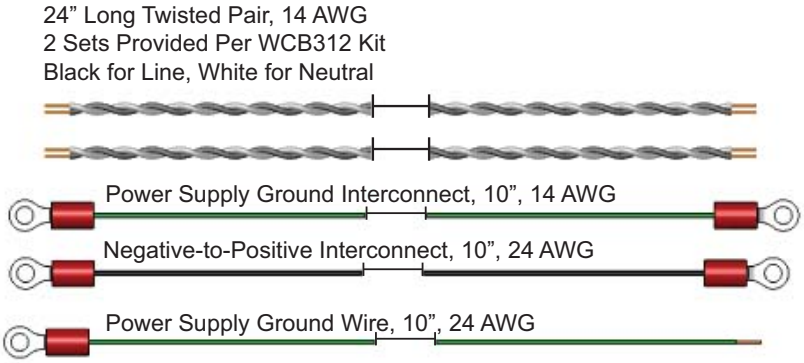
## CABLE SPECIFICATIONS

### WCB311 -- 20-PIN CABLE




The ANALOG INPUT CABLE and QCL CONNECT CABLE are not installed in the connector when the cable ships from the factory. If the SMA connectors on the QCL driver front panel are not used, insert these cables into the 20-pin connector.

### WCB312 -- POWER SUPPLY WIRING KIT



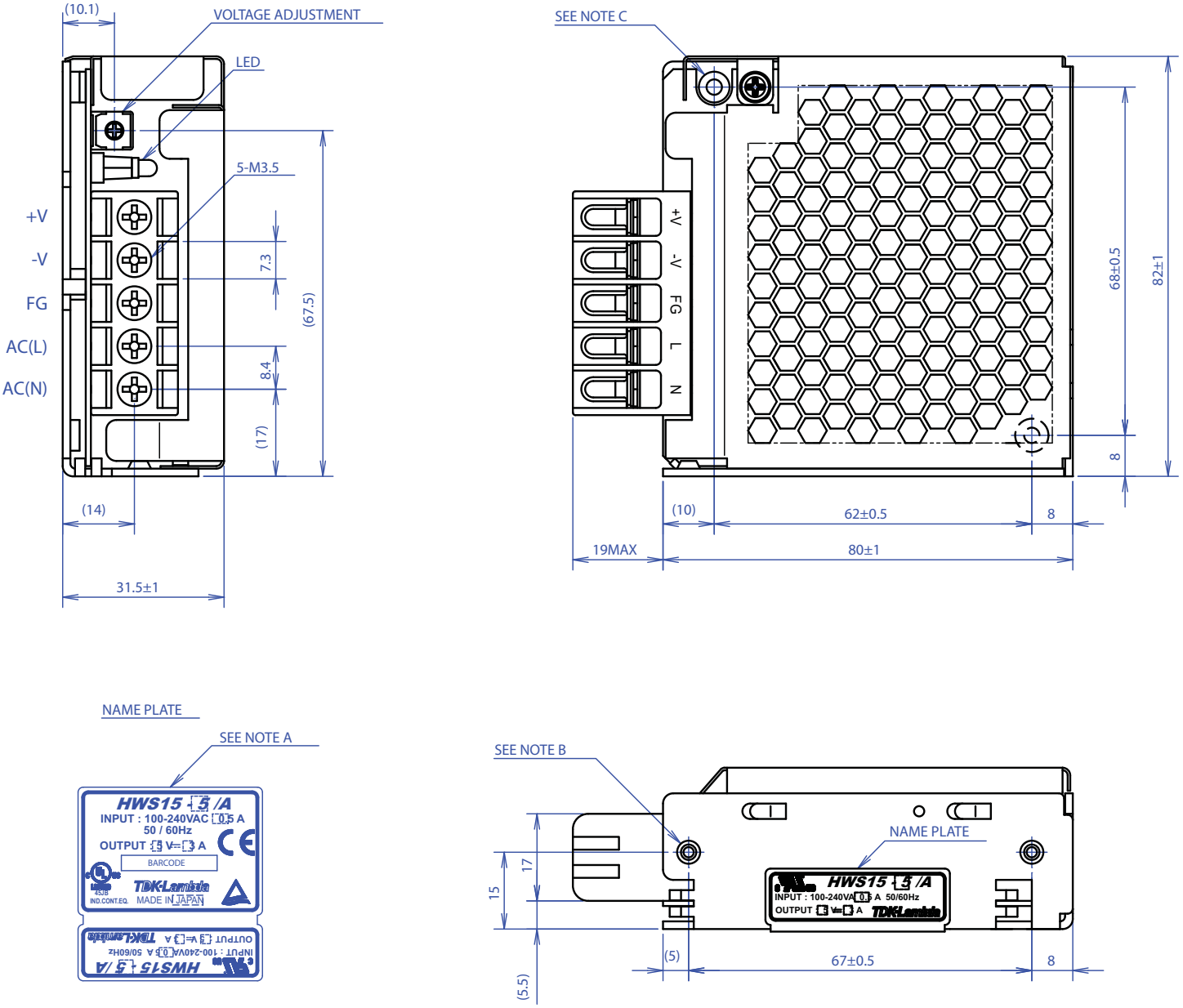

The WCB312 Power Supply Wiring Kit includes the wires illustrated above, and also includes crimp-type ring lugs:

- (6) blue lugs for 14 AWG wire
- (3) red lugs for 24 AWG wire.

If using the PWRPAK-24 power supplies available from Wavelength, connect the cables as shown in **Figure 4 on page 8**. If different power supplies are used, the connection and wiring principles are the same.

- AC Safety Ground #1: 24 AWG green wire, 10" with ring lugs on each end; connect to the Frame Ground terminals on the power supplies.
- AC Safety Ground #2: 24 AWG green wire; 10" with one ring lug; connect to the Frame Ground terminal on one power supply; connect the other end to AC Chassis Ground.
- Common Ground: 24 AWG black wire; 10" with ring lugs on each end; connect between V- of Positive Supply and V+ of Negative Supply.
- Use the remaining ring lugs to connect the wires from WCB311 to the V+, V-, and Power Ground terminals of the power supplies. The wires on the WCB311 are pins 16, 17, and 18, respectively.

## MECHANICAL SPECIFICATIONS - PWRPAK-24V POWER SUPPLY




NOTES

A : MODEL NAME, INPUT VOLTAGE RANGE, NOMINAL OUTPUT VOLTAGE, MAXIMUM OUTPUT CURRENT AND COUNTRY OF MANUFACTURE ARE SHOWN HERE IN ACCORDANCE WITH THE SPECIFICATIONS.

B : M3 EMBOSSED, TAPPED AND COUNTERSUNK HOLES (2) FOR CUSTOMER CHASSIS MOUNTING. SCREWS MUST NOT PROTRUDE INTO POWER SUPPLY BY MORE THAN 6m/m.

C : M3 TAPPED HOLES (2) FOR CUSTOMER CHASSIS MOUNTING. SCREWS MUST NOT PROTRUDE INTO POWER SUPPLY BY MORE THAN 6m/m.

(unit : mm)

| MODEL | HWS15/A |
|---|---|
| DENSEI-LAMBDA | |

A224-02-01/A-A

**Figure 19. Power Supply Mechanical Specifications**

**Diagram courtest TDK-Lambda.**
**Specifications subject to change.**

# MECHANICAL SPECIFICATIONS

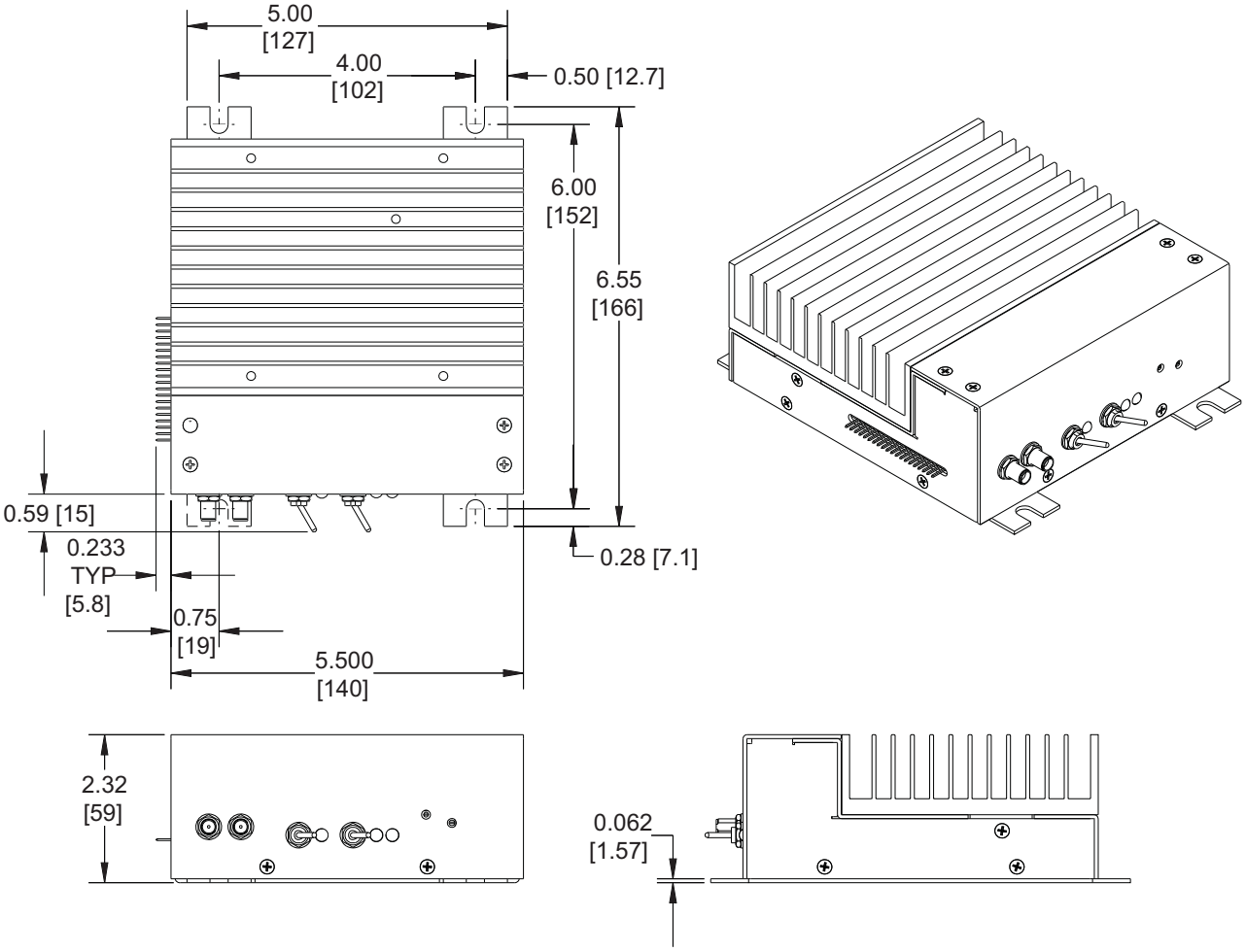



**Figure 20. QCL Driver Mechanical Dimensions**

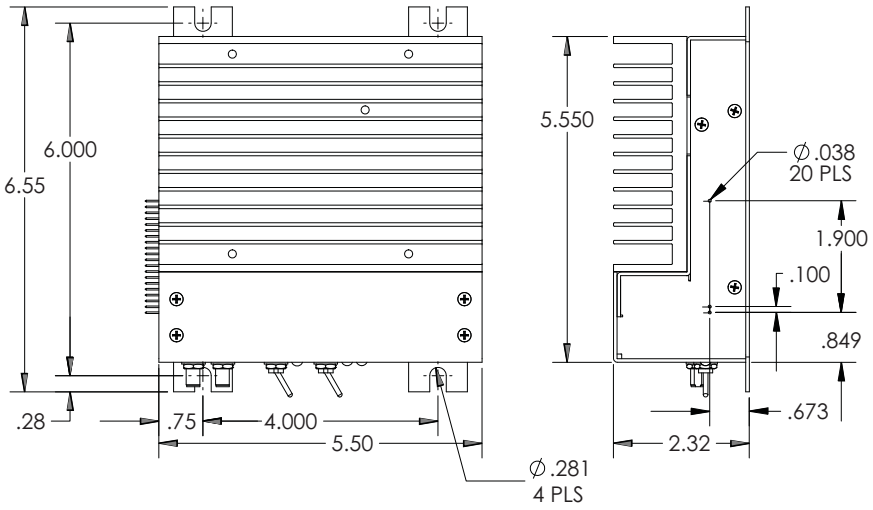



**Figure 21. QCL Driver PCB Mounting Dimensions**

The QCL Driver must be firmly secured by the baseplate mounting tabs, and not supported by the solder joints. Use either 1/4-20 screws for mounting (4 places), or #8 screws with a shoulder washer (4 places).

All Dims in inches [mm]; Tolerance ±5%

# CERTIFICATION AND WARRANTY

## CERTIFICATION

Wavelength Electronics, Inc. (Wavelength) certifies that this product met its published specifications at the time of shipment. Wavelength further certifies that its calibration measurements are traceable to the United States National Institute of Standards and Technology, to the extent allowed by that organization's calibration facilities, and to the calibration facilities of other International Standards Organization members.

## WARRANTY

This Wavelength product is warranted against defects in materials and workmanship for a period of 1 year from date of shipment. During the warranty period, Wavelength will, at its option, either repair or replace products which prove to be defective.

## WARRANTY SERVICE

For warranty service or repair, this product must be returned to the factory. An RMA is required for products returned to Wavelength for warranty service. The Buyer shall prepay shipping charges to Wavelength and Wavelength shall pay shipping charges to return the product to the Buyer upon determination of defective materials or workmanship. However, the Buyer shall pay all shipping charges, duties, and taxes for products returned to Wavelength from another country.

## LIMITATIONS OF WARRANTY

The warranty shall not apply to defects resulting from improper use or misuse of the product or operation outside published specifications. No other warranty is expressed or implied. Wavelength specifically disclaims the implied warranties of merchantability and fitness for a particular purpose.

## EXCLUSIVE REMEDIES

The remedies provided herein are the Buyer's sole and exclusive remedies. Wavelength shall not be liable for any direct, indirect, special, incidental, or consequential damages, whether based on contract, tort, or any other legal theory.

## REVERSE ENGINEERING PROHIBITED

Buyer, End-User, or Third-Party Reseller are expressly prohibited from reverse engineering, decompiling, or disassembling this product.

## NOTICE

The information contained in this document is subject to change without notice. Wavelength will not be liable for errors contained herein or for incidental or consequential damages in connection with the furnishing, performance, or use of this material. No part of this document may be translated to another language without the prior written consent of Wavelength.

## SAFETY

There are two fuses within the chassis that are user-serviceable. There are no other user-serviceable parts inside this product. Return the product to Wavelength Electronics for service and repair to ensure that safety features are maintained.

## LIFE SUPPORT POLICY

This important safety information applies to all Wavelength electrical and electronic products and accessories:

As a general policy, Wavelength Electronics, Inc. does not recommend the use of any of its products in life support applications where the failure or malfunction of the Wavelength product can be reasonably expected to cause failure of the life support device or to significantly affect its safety or effectiveness. Wavelength will not knowingly sell its products for use in such applications unless it receives written assurances satisfactory to Wavelength that the risks of injury or damage have been minimized, the customer assumes all such risks, and there is no product liability for Wavelength. Examples of devices considered to be life support devices are neonatal oxygen analyzers, nerve stimulators (for any use), auto-transfusion devices, blood pumps, defibrillators, arrhythmia detectors and alarms, pacemakers, hemodialysis systems, peritoneal dialysis systems, ventilators of all types, and infusion pumps as well as other devices designated as "critical" by the FDA. The above are representative examples only and are not intended to be conclusive or exclusive of any other life support device.

## PATENTED TECHNOLOGY

Covered by U.S. Patents 6,696,887; 6,867,644; and 7,176,755. Licensed from Battelle Memorial Institute.

## REVISION HISTORY

| REV. | DATE | CHANGE |
|---|---|---|
| I | 1 June 2012 | Release in new format |

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