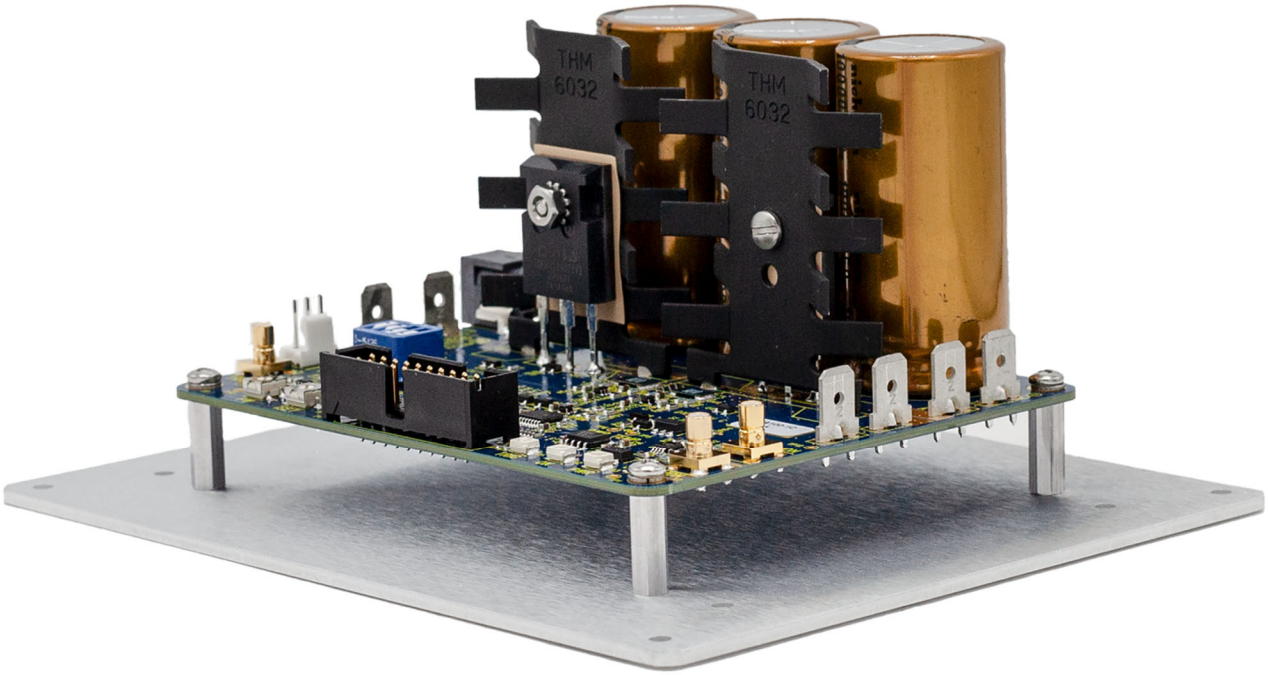
HIGHLAND TECHNOLOGY

MODEL D100

COMPACT 250A LASER DRIVER



Technical Manual

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650 Potrero Avenue San Francisco, CA 94110 www.highlandtechnology.com tel: 415 551-1700 fax: 415 551-5129

650 Potrero Avenue, San Francisco, CA 94110
Phone 415-551-1700 • Fax 415-551-5129
www.highlandtechnology.com

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Table of Contents

1. INTRODUCTION

This is the technical manual for the Highland D100 compact 250A laser driver.

The D100 is a constant-current pulsed bar laser driver available as an unpackaged printed-circuit board.

Features of the D100 include:

- Constant-current pulsed drive up to 250 amps into 30 volt laser load
- Trimpot or external analog programming of current and pulse width
- Trimpots serve as laser current and pulse width limits in external-programming mode
- Thermal and safe-operating-area protections of power drivers
- LED indicators: Power, OK, Trigger
- 4.2 x 3.5 inch printed-circuit board
- Single external power supply 20 to 48 volts; compatible with embedded or wall-wart supplies
- Evaluation kits are available

2. SPECIFICATIONS

Specifications are typical unless otherwise noted.

FUNCTION	High power pulsed laser driver
TRIGGER INPUT	CMOS/TTL PULSE input enables laser current Threshold +1.4 volts typ, protected to ± 20 volts
TIMING MODES	A) Laser drive follows PULSE input B) Laser drive follows PULSE input with trimpot pulse width limit C) PULSE input rising edge triggers trimpot-set pulse width Pulse width/limit adjustable with trimpot from 50 µs to 1000 µs
LASER OUTPUT	Constant-current drive Trimpot or user adjustable 10 to 250 amps Compliance up to 30 volts at 250 amps, 750 µs with 48 volt power supply
RISE/FALL TIMES	10 µs typical
MAX POWER DISSIPATION	12 watts free air 30 watts with 500 LFPM air flow 60 watts with optional customer-supplied heat sink
TEMPERATURE RANGE	Operating, 0 to 60°C; to -40°C with restrictions Non-operating, -40 to 80°C
INTERNAL CONTROLS	DIPswitch: Laser ON/OFF Current setpoint POT / External Timing modes A, B, C ISET: current set / limit trimpot, 10-250 amps PW: pulse width set / limit trimpot, 50-1000 µs
POWER	+20 to +48 volts DC Model J25, 24 volt 65W power supply, furnished Model J40, 48 volt 1 amp power supply, optional Reverse and startup-surge protected HV Present LED and bleeder provided
CONNECTORS	V+, GND, LASER A, LASER K: 0.25" male fastons TRIG : SMB trigger input, CMOS/TTL IMON : SMB current monitor output, 5 volts at 250 amps VLMON : SMB laser anode – cathode voltage output, V_{AK} / 5 ILK : 3-pin laser drive interlock 20-pin ribbon cable connector provides full control and supervision

LED INDICATORS	Orange PWR Green OK Blue TRIG
PACKAGING	3.5" x 4.2" printed circuit board 2" nom height

3. ARCHITECTURE

The following is the basic block diagram of the D100.

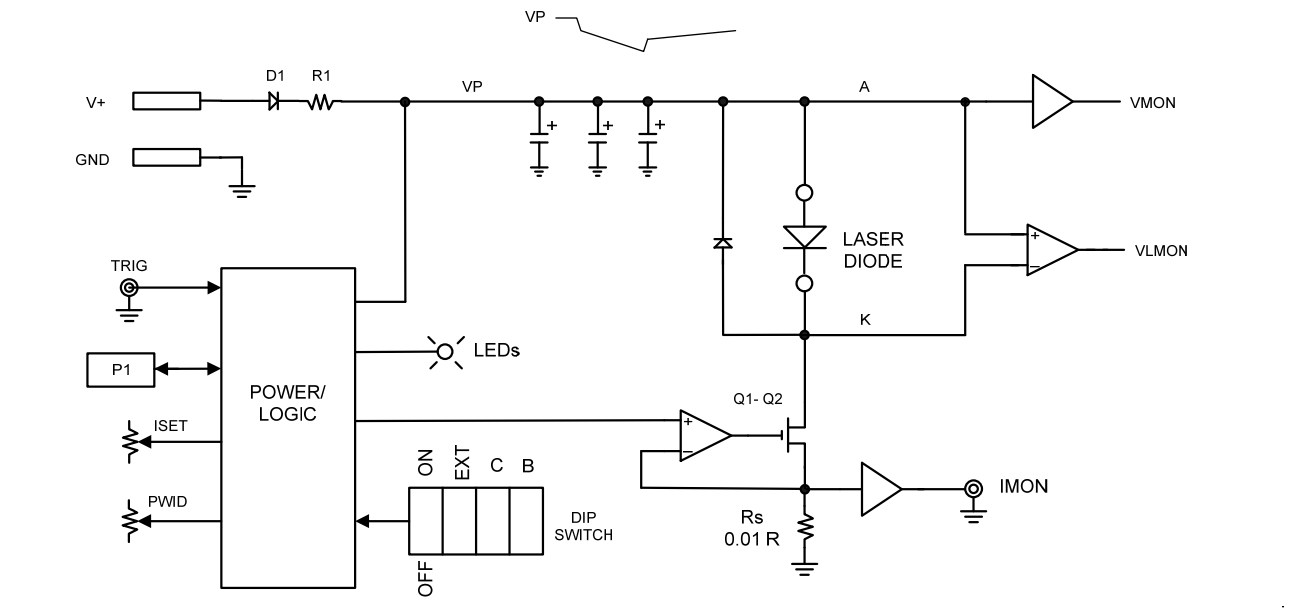


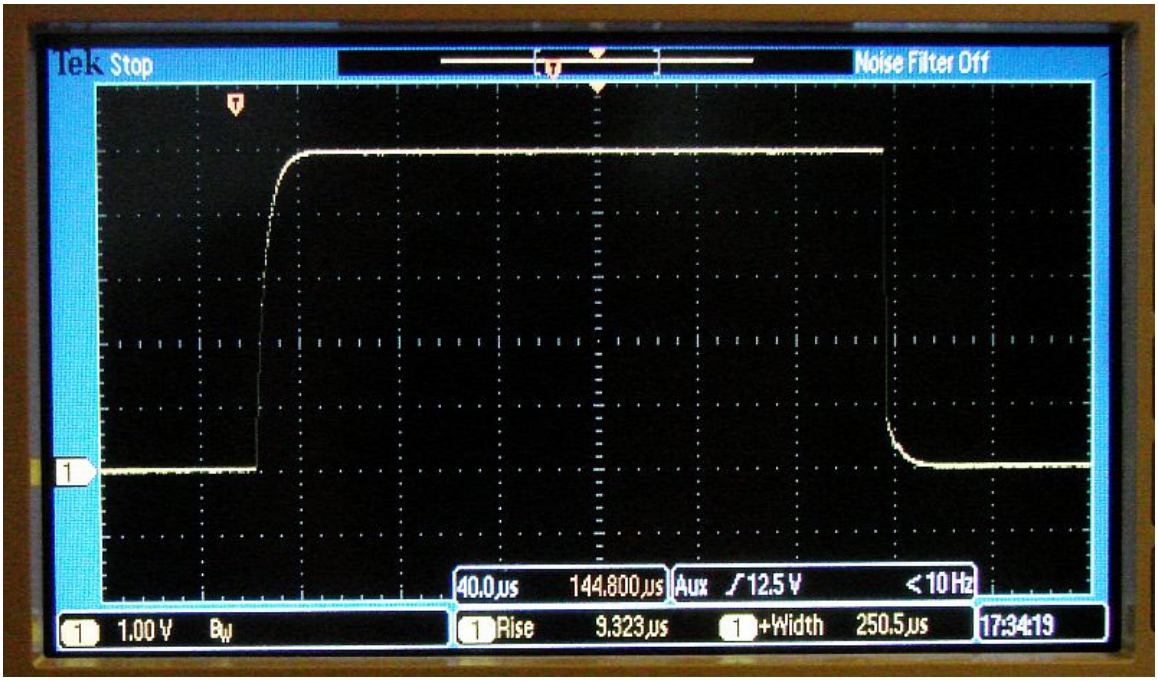
Diagram 1: D100 Block Diagram

User-furnished DC power is applied to the V+ and GND faston terminals, or the wall-wart barrel connector. The capacitor bank charge current flows through D1 and R1. For the standard D100-1 version, R1 is 3Ω and the capacitor bank totals 30,000 microfarads.

V+ is normally in the range of 20 to 48 volts DC. It is applied to the anode of the laser diode. The laser cathode is driven by active current sink Q1-Q2.

In basic operating mode, the P1 ribbon cable connector is not used. The user can set the laser drive current using the ISET trimpot, and program pulse width via the PW pot. The trigger input is applied to the TRIG SMB connector, and laser current can be monitored on the IMON connector.

When the external power supply is removed, an internal bleeder circuit discharges the capacitor bank. Typical discharge time is about 30 seconds, and the PWR LED will remain on until the capacitors are essentially fully discharged.



Waveform 1: 250 amp, 250 microsecond pulse, 25 volt laser drop

4. CONNECTION AND OPERATION

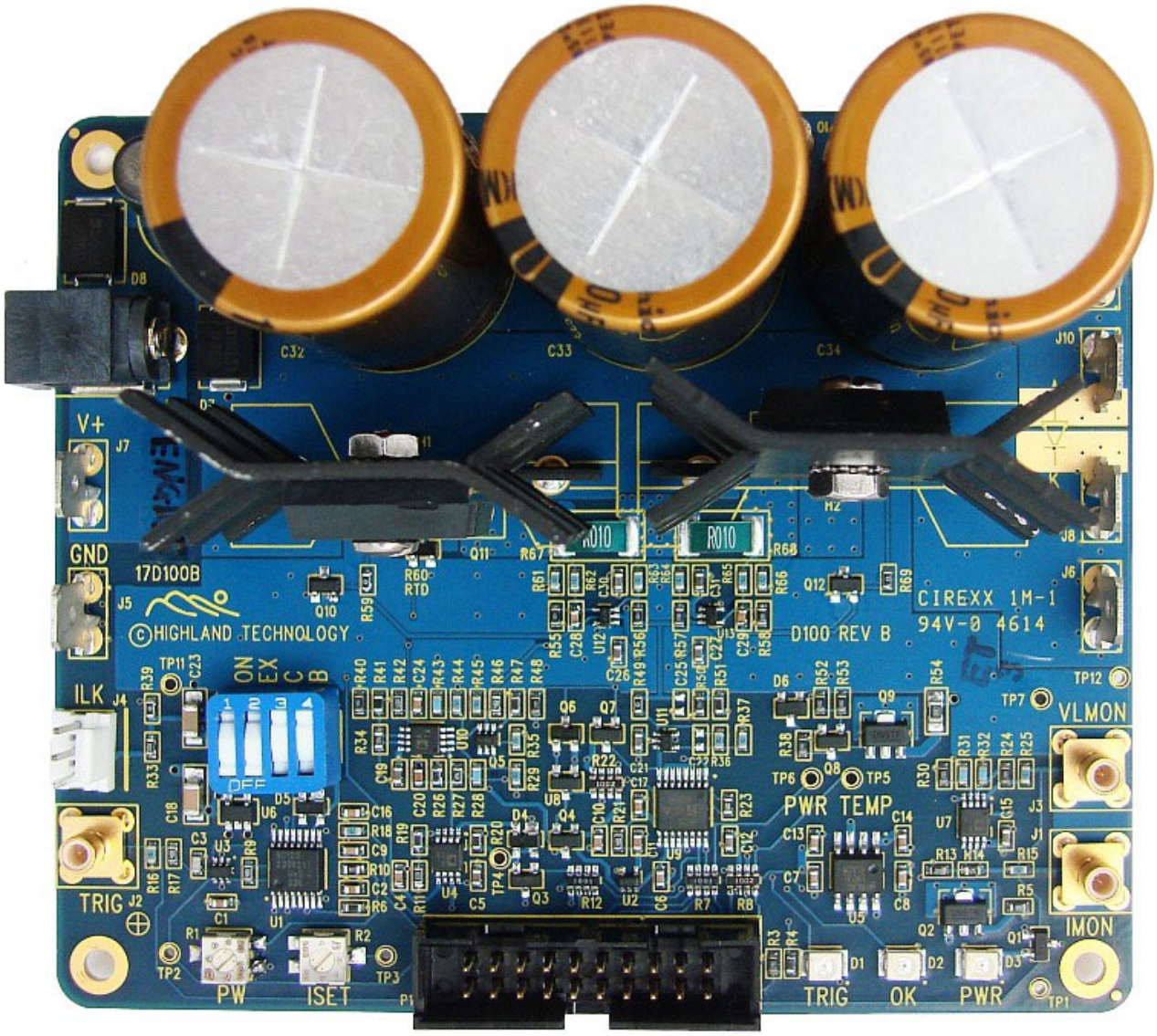


Photo 1: D100 PCB

4.1 Power Input

Power is applied to the V+ (J7) and GND (J5) Faston spade lugs. A suitable crimp connector is Panduit DNF10-250FIB (10-12 gauge) or Panduit DPF14-250FIB (14-16 gauge). External current limiting and fusing are recommended. The average current requirement is average laser current (Ipeak times duty cycle) plus 50 mA.

Peak inrush current is limited by 3Ω power resistor R1.

Alternately, power can be applied to the 2.1 x 5.5 mm barrel connector J9, positive center. 24 and 48 volt laptop-type universal power supplies are available from Highland.

4.2 Interlock Connector

The D100 includes a safety laser lock-out ILOK connector header (J4), AMP part number 640456-3. Standard production D100 units bypass the ILOK connector with an onboard 0Ω jumper populating R39. In order to activate the ILOK connector, carefully unsolder R39. When the D100 is activated, the +12 volt power to the power MOSFET gate drivers passes from pin 1 to pin 3, so 1 must be externally jumpered to 3 to enable laser drive. A suitable mating connector is TE Connectivity 640442-3 or 640440-3. Users may elect to use an external switch or relay for the interlock function. Pin 2, the center pin, is ground.

4.3 DIP Switch

The DIP switch (S1) has four sections. In the picture below, the ON and EX sections are set ON.

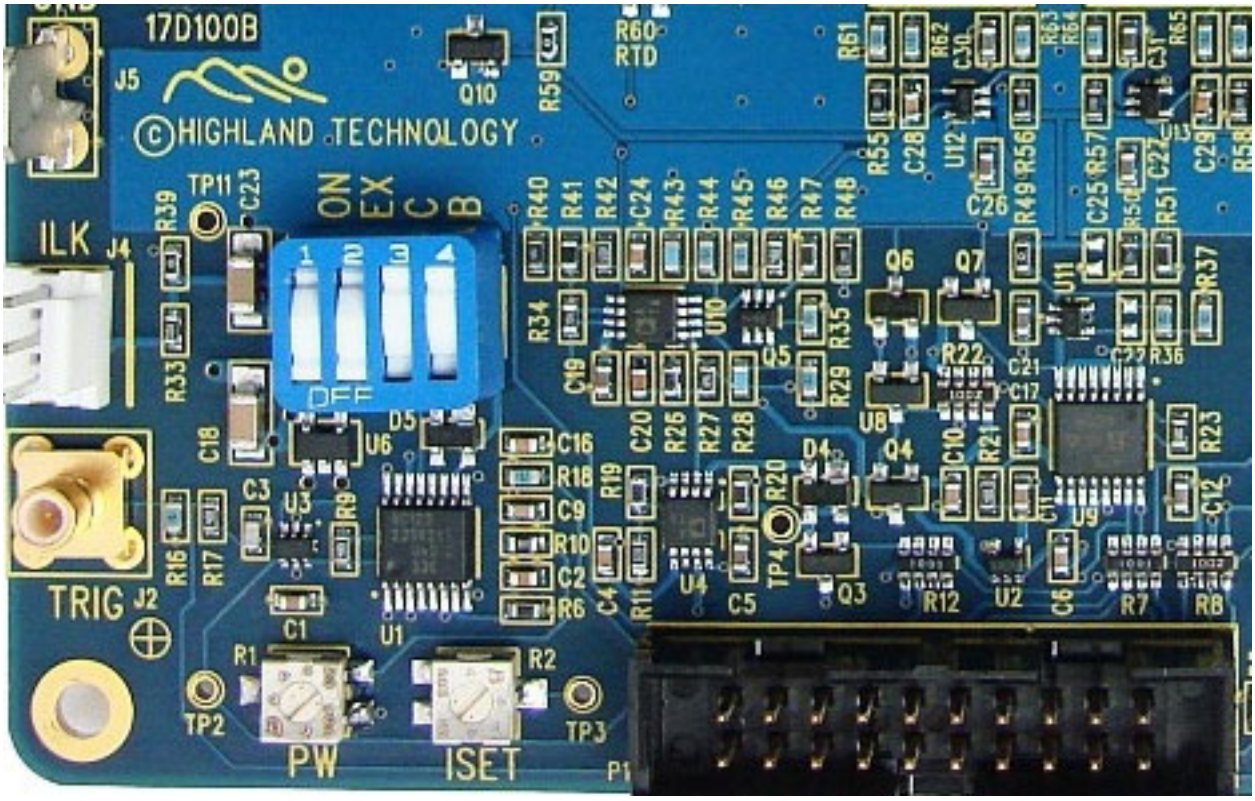


Photo 2: DIP Switch PCB location

The first section has positions ON and OFF. When OFF, power is removed from the MOSFET gate driver circuits. This setting can serve to inhibit laser drive while adjusting settings on the other switch sections or the trimpots. **DO NOT RELY ON THIS SWITCH FOR LASER SAFETY PROTECTION.**

The second DIP switch section labeled EX selects whether the laser-current setpoint is derived from the ISET pot (the OFF position) or from the ISET pin of P1 (the EX position.) If EX is selected, the ISET pot setting becomes a maximum current limit.

The two right-most switch sections control pulse width logic.

The three pulse width modes are

A. This is the follower mode when both the B and C switches are OFF. Laser current is directly gated by the TRIG input.

B. If the B switch is ON, the laser current is gated by the TRIG input, but the maximum pulse width is limited by the setting of the PW trimpot.

C. If the C switch is ON, the laser is pulsed at the rising edge of TRIG and the width is determined by the PW pot. The B switch position is irrelevant in this mode.

The D100 ships with the DIP switch configured as follows: MOSFET drive OFF, trimpot current setting control, and rising edge triggering with trimpot PW control.

4.4 Trimpots

The ISET trimpot sets the laser current (in POT mode) or the laser current limit (in EX mode.) CCW is 0 amps and CW is 250 amps. A test point (TP3) is located immediately to the right of the ISET pot. It may be measured, against ground, with a high impedance voltmeter. 0 volts at the test point is zero laser current, and 5 volts scales to 250 amps. Actual laser current should be used for precise setting of the ISET pot. The ISET control voltage is applied to the ribbon cable connector P1 pin 9 when operating in EX mode.

The PW pot sets the laser pulse width in timing mode C, or the pulse width limit in mode B. A test point (TP2) is available immediately to the left of the PW pot. It is a +3.3 volt level that pulses high when the PW timer fires. To set the pot, disable the laser using the dipswitch OFF option and/or open the ILOK connection. Apply TRIG pulses and monitor the test point with an oscilloscope, and adjust the PW pot. CCW is nominally 50 microseconds and full CW rotation is 1 millisecond.

For safety purposes, the D100 is shipped with drive current and PW trimpot settings minimized.

4.5 TRIG SMB Connector

TTL or CMOS trigger pulses may be applied to the SMB TRIG connector (J2). The trigger level is +1.4 volt typ, active high. The D100 presents a 1k load to ground, and can tolerate ±20 volts without damage. Noise filtering is incorporated, so the minimum pulse width requirement is 2 microseconds.

Trigger inputs can also be applied through ribbon cable connector P1 pin 2.

4.6 IMON SMB Connector

The IMON SMB connector (J1) is an output that monitors the actual laser current. Scaling is 5 volts at 250 amps, 50 amps per volt. Source impedance is 1kΩ and would normally be used to drive a high impedance oscilloscope. If a 50Ω scope is used, the 1kΩ impedance forms a -26dB voltage divider into the scope input; actual laser current scaling becomes 50 amps per 50 mV.

IMON is also available on P1 pin 5.

4.7 VLMON SMB Connector

The VLMON SMB connector (J3) is a ground-referenced differential amplifier output that monitors the voltage drop across the laser. Scaling is laser voltage divided by 5, with a 1kΩ source impedance. If a 50Ω scope is used, the 1kΩ impedance forms a -40dB voltage divider into the scope input; actual laser voltage scaling becomes laser voltage divided by 100.

VLMON is also available on P1 pin 7.

4.8 Laser Connections

Four male Faston spade lugs are available to connect to the laser, J10 and J11 for the positive/anode connection, J6 and J8 for the negative/cathode connection. If the J10 and J8 Faston tabs are removed, a laser can be soldered directly to the A and K gold-plated PCB pads.

4.9 Ribbon Cable Connector P1

P1 is a standard density (50 mil cable pitch) 20-pin male ribbon cable connector. Pin 1 is the square pad, closest to the "P1" reference designator.

The interface signals are:

GND six common grounds are provided. It is recommended that all be grounded on the user end.

TRIG Active-high laser pulse trigger input, in parallel with the TRIG SMB connector. The D100 presents a 1kΩ load to ground, followed by a 1.5 µs lowpass filter and a CMOS schmitt trigger with nominal threshold of +1.4 volts.

IMON An analog output that indicates instantaneous laser current. Scaling is 50 amps per volt, 5 volts at 250 amps. Source impedance is 1k.

VLMON An analog output that indicates the instantaneous voltage across the laser. Scaling is laser voltage / 5, source impedance is 1k.

HVMON An analog output that indicates the voltage on the capacitor bank. Scaling is VP / 10, source impedance 10k.

ISET An analog input to the D100. This sets the laser current. Scaling is 50 amps/volt, 250 amps at 5 volts. The D100 presents a 10k load to ground.

OK A logic output. +5 volts indicates that the D100 is ready to pulse. This will be zero volts if the dipswitch is OFF, if the interlock is open, or if the shutdown logic is active. Source impedance is 1k.

GO A logic output that reflects the laser gating pulse. This tracks TRIG in timing mode A, width-limited TRIG in mode B, and the internal one-shot in mode C. Level is 0 / +3.3 volts, 1k source impedance. GO is functional even if the laser is disabled, and may be used to adjust the PWID trimpot. GO also connects to test point TP2.

TEMP An analog output that indicates the temperature of the MOSFETs. Scaling is 0 volts at 0 °C, +5 volts at 100 °C, source impedance is 10k.

PWR An analog output that indicates the instantaneous MOSFET power dissipation. Scaling is 1 volt per kilowatt, source impedance is 1k.

ID A 10K resistor to ground indicates that a D100-1 is present.

4.10 LEDs

Three LEDs are provided

PWR	Orange	Indicates that voltage is present on the internal capacitor bank.
OK	Green	Indicates that the D100 is ready to pulse. OK goes out if the VBB voltage is too low (< 15 V), if the laser drive is not enabled, or if the MOSFET SOAR protection shutdown is active.

TRIG	Blue	Flashes whenever the laser is triggered.

4.11 Test Points

Three turret-terminal test points are provided near the upper edge of the board. They are

G (TP10): PC board ground, a suitable place to clip a scope probe or voltmeter ground lead. This is common to the PCB ground plane, the power supply ground, and the four mounting holes.

A (TP9): This is V+ and the laser anode. It is useful for monitoring capacitor bank voltage and droop during pulsing.

K (TP8): This is the laser cathode. It is useful for determining laser voltage drop and saturation behavior of the power MOSFETs.

Several PCB pad test points are provided. These can be monitored with an oscilloscope or a high impedance DVM, referenced to ground.

TP2	GO	Indicates pulse width from the trigger logic.
TP3	ISET	ISET trimpot setting, 5 volts at 250 amps. This does not reflect the external ISET signal applied to P1 pin 9.
TP5	TEMP	MOSFET temperature, 0-5 volts from 0-100 °C.
TP6	PWR	MOSFET power dissipation, 1 volt per kW.

4.12 Connector Summary

The following table summarizes D100 connectors:

CON	TYPE	PIN	I/O	NAME	FUNCTION	IMPEDANCE
J7	FASTON		IN	V+	Power input positive	
J5	FASTON			GND	common ground	
J10	FASTON		OUT	A	Laser positive/anode	
J11	FASTON		OUT	A	Laser positive/anode	
J6	FASTON		OUT	K	Laser negative/cathode	
J8	FASTON		OUT	K	Laser negative/cathode	
J2	SMB		IN	TRIG	TTL/CMOS trigger input	1kΩ to gnd
J1	SMB		OUT	IMON	Laser current monitor 5v at 250A	1kΩ out
J3	SMB		OUT	VLMON	Laser anode-cathode voltage 1v per $5V_{a-k}$	1kΩ out
J4	AMP 3pin	1	OUT	ILOKA	+12 source jump to J4-3 to enable	20Ω
J4	AMP 3pin	2		GND		
J4	AMP 3pin	3	IN	ILOKB	+12 to MOSFET drivers	
NOTE: J4 factory bypassed with R39 0Ω jumper – remove to activate ILOK						
P1	Ribbon	1		GND	common ground	
P1	Ribbon	2	IN	TRIG+	TTL/CMOS trigger input	1k to gnd

CON	TYPE	PIN	I/O	NAME	FUNCTION	IMPEDANCE
P1	Ribbon	3			reserved	
P1	Ribbon	4		GND	common ground	
P1	Ribbon	5	OUT	IMON	Laser current monitor 5V at 250A	1k out
P1	Ribbon	6		GND	common ground	
P1	Ribbon	7	OUT	VLMON	Laser voltage monitor VL / 5	1k out
P1	Ribbon	8		GND	common ground	
P1	Ribbon	9	IN	ISET	Laser current setpoint 50 amps/volt	10k to gnd
P1	Ribbon	10			reserved	
P1	Ribbon	11	OUT	HVMON	Laser anode voltage monitor V_{anode} / 10	10k out
P1	Ribbon	12	OUT	OK	+5V if ready to fire	1k out
P1	Ribbon	13			reserved	
P1	Ribbon	14	OUT	ID	D100 present	10k to gnd
P1	Ribbon	15	OUT	TEMP	Mosfet temperature 0v at 0 °C 5v at 100 °C	10k out
P1	Ribbon	16			reserved	
P1	Ribbon	17	OUT	GO	pulse indicator	1k out
P1	Ribbon	18		GND	common ground	
P1	Ribbon	19	OUT	PWR	MOSFET power dissipation 1v per kilowatt	1k out
P1	Ribbon	20		GND	common ground	
TP9	Turret TP		OUT	A	Laser anode test point	

CON	TYPE	PIN	I/O	NAME	FUNCTION	IMPEDANCE
TP8	Turret TP		OUT	K	Laser cathode test point	
TP3	Turret TP			G	common ground	

5. POWER AND THERMAL ISSUES

5.1 Circuit Description

The D100 is powered by a DC source from 20 to 48 volts.

Assume

VS is the external power supply voltage, volts

ISLIM is the power supply current limit, amps

VA is the laser anode voltage, also the capacitor bank voltage, volts

VK is the laser cathode voltage, also the mosfet drain voltage, volts

IL is the programmed laser pulse current, amps

VL is the laser voltage drop at IL, volts, including any wire drops.

W is the pulse width, seconds

P is the pulse period, seconds; 1/P is the pulse frequency in Hz.

N is the pulse duty cycle, W/P

C is the capacitance of the capacitor bank, 0.03 farads

ESR is the internal resistance of the capacitor bank, 0.01 ohms

The simplified driver circuit is:

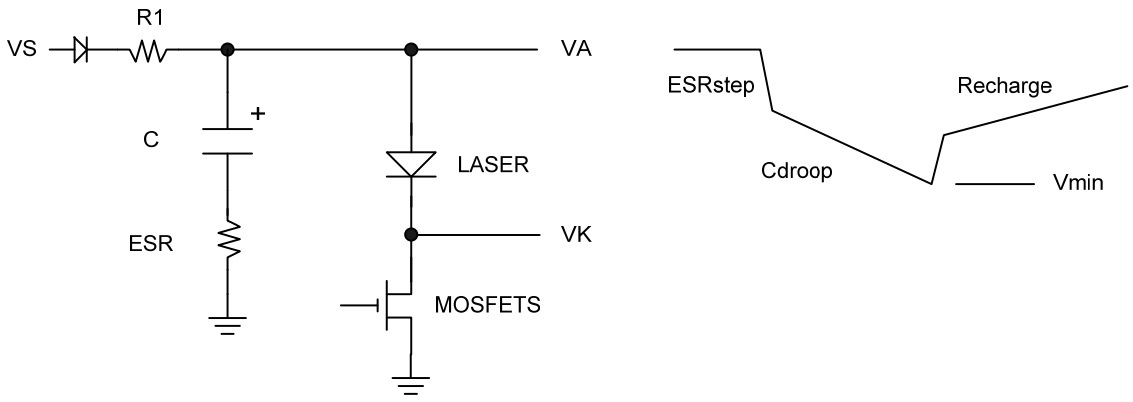


Diagram 2: Simplified D100 Circuit

5.2 Circuit Operation

When VS is applied, it charges the capacitor bank C, through the diode and resistor R1. The laser is usually pulsed when C is fully charged.

The MOSFETs are turned on, in controlled-current mode, to drive the laser. Voltage VA will immediately drop by voltage step IL * ESR due to the internal resistance of the capacitors, typically about 0.01Ω at room temperature. The voltage at VA will then droop linearly, as the capacitors are discharged by the laser current. The total amount of such droop is Vd = IL * W / C, which is about 8 millivolts per microsecond at 250 amps.

The voltage at VK follows the VA waveform, but is lower by the laser voltage drop VL. The voltage at VK should not be allowed to droop below 8 volts to ensure linear operation of the MOSFETs.

During the current pulse, the MOSFETs are heated by their internal power dissipation; this is instantaneously, VK * IL. VK is drooping as the capacitor bank discharges, so we approximate the power dissipation over the pulse as IL times the average voltage VK. The power dissipation of the MOSFETs during the pulse is

Pp = IL * VKavg

and the longterm averaged power dissipation is Pa = Pp * N, where N is the pulse duty cycle.

The MOSFETs can dissipate an average power Pa of 12 watts if the D100 is in still air at an ambient air temperature of 50 °C. In an air stream of 500 LFPM, at 50 °C, they can dissipate up to 30 watts.

The D100 includes a SOAR protection feature, where it continuously computes a dynamic model of MOSFET junction temperature, based on MOSFET package temperature and actual MOSFET power dissipation. If the modeled junction temperature hits 175 °C, the output pulse will be shut down for 100 milliseconds to protect the MOSFETs. Operation resumes when the junction temperatures recover.

The D100 has provision for increased heat sinking; contact Highland for information.

The power supply voltage should be selected such as to minimize MOSFET power dissipation. A good target is to have VK droop to about 10 volts at the end of the longest expected pulse.

The "ESR jump", the voltage drop in the capacitor ESR, is usually small, for example about 2.5 volts at 250 amps. The D100 can operate at temperatures as low as -40 °C, but ESR increases below 0 °C, roughly doubling at -20 °C and increasing by 5x to 10x at -40 °C. ESR then becomes a serious consideration at low temperatures and high currents.

After each pulse, the external power supply must recharge C before the next pulse. If C is discharged much, the external power supply may enter current limit mode, recharging C at its current limit. R1, a 3 ohm power resistor, somewhat softens the recharge, such that the

power supply may not need to run at its current limit in many cases. The average current requirement of the V+ supply is

Iavg = IL * N + 0.05

where the 0.05 is the 50 mA nominal control-circuit current used by the D100.

If the TRIG input were to go steady high without a time limit, or if a circuit failure were to turn the drivers on hard, the full charge in the capacitor bank would be dumped into the laser. At 48 volts, the charge is about 1.5 coulombs, which would be fully depleted in about 6 milliseconds at 250 amps. Once the capacitors are discharged, the current-limited power supply is the only source of laser current; ISLIM should be as low as practical, below the laser threshold current if possible.

In most cases, if the TRIG input goes hard high, the D100 SOAR circuit will shut down the gate drive before the MOSFETs are damaged as the capacitor bank discharges.

CAUTION: It is still possible to damage the MOSFETs if the supplied energy exceeds 60 joules. This is especially critical for continuous duty operation with a high voltage, high current DC supply.

Timing modes B and C limit output pulse width, another recommended protection for the MOSFETs and the laser.

5.3 Application Example

Example:

VP = 24 volts
IL = 200 amps
W = 150 microseconds
P = 100 milliseconds (10 Hz pulse rate)
VL = 10 volts
N = 0.0015

The caps will charge to almost 24 volts. The ESR jump will be about 2 volts and the caps will discharge about an additional 1 volt by then end of the pulse.

The MOSFET drain voltage VK is 24-2-10 = 12 volts early in the pulse, drooping to about 11 volts at the end, averaging 11.5. MOSFET power dissipation is then 2.3 kilowatts during the pulse. Long term, thermal average MOSFET power dissipation will be 2300 * 0.0015 = 3.5 watts.

Power supply average current will be 200 * 0.0015 + 0.05 = 0.35 amps. Since the capacitor voltage jumps down 3 volts during the pulse, and R1 is 3 ohms, the peak recharge current from the power supply is limited to about 1 amp, so for example a 2 amp power supply would not current limit.

6. DIMENSIONS AND INSTALLATION

6.1 Dimensions

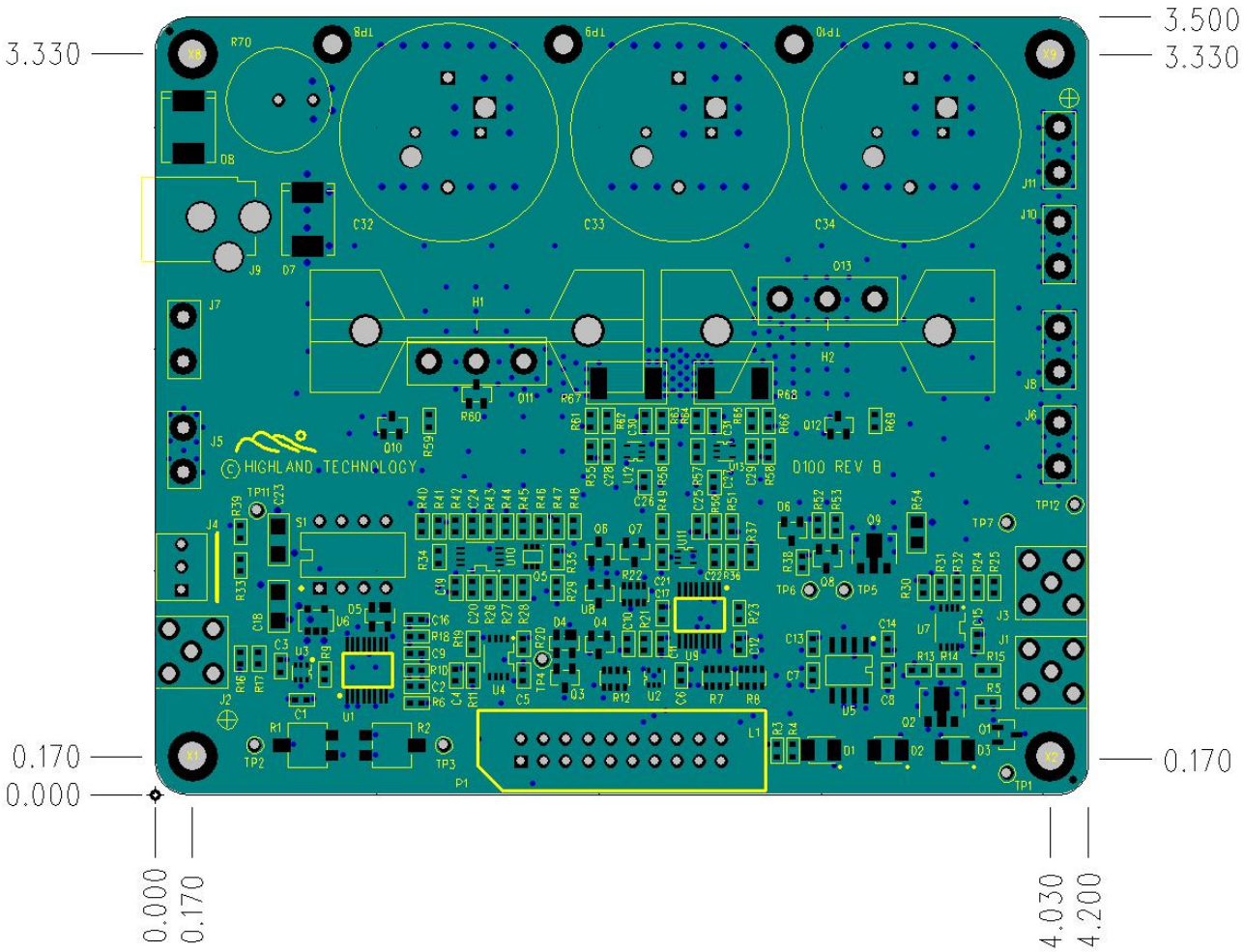


Illustration 1: D100 Dimensions

Dimensions are in inches. Mounting holes are 0.120-inch diameter, with 0.230-inch round copper pads on both sides. The board is 0.062-inches thick.

A Solidworks/STEP model of the D100 is available.

6.2 Installation and Grounding

The D100 is designed to be grounded to a metal enclosure or baseplate. Its four mounting screws are connected to the common power ground. Do **NOT** ground the laser; a momentary short of either laser lead to ground can make a dangerous spark and can destroy the laser.

If the laser is water cooled, ensure suitable water resistivity and isolation tubes to limit leakage currents.

Handle the D100 and the laser with full ESD precautions.

7. VERSIONS

Standard versions of the D100 include:

D100-1 compact 250A laser driver

D100-9 compact 250A laser driver evaluation kit (includes: D100-1 mounted on T567 mounting flange, J25-1 24 volt power supply, and two J53-1 SMB to BNC cables)

8. CUSTOMIZATION

Consult factory for information about additional custom versions.

9. HARDWARE REVISION HISTORY

Revision C Dec 2018
Functionality equivalent to Revision B
Improved IMON signal response

Revision B Jul 2014
Functionality equivalent to Revision A
Improved reliability, manufacturability, cooling, conductivity of high-current laser drive path, MOSFET drive tunability of circuitry, and layout
Minimized ground bounce
Reduced high-current EMI contamination into low level circuitry
Isolate signal ground from high-current ground

Revision A Jan 2014
Initial PCB release

10. ACCESSORIES

J25-1: 24 volt 65W power supply (furnished with purchase)

J40-1: 48 volt 1 amp power supply

J53-1: 3' SMB-BNC cable