PCO-6141
60A CW/QCW Laser Diode Driver

OPERATION MANUAL

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************ WARNING ************

SAFE OPERATING PROCEDURES AND PROPER USE OF THE EQUIPMENT ARE THE RESPONSIBILITY OF THE USER OF THIS SYSTEM.

Directed Energy, Inc (DEI) provides information on its products and associated hazards, but it assumes no responsibility for the after-sale operation and safety practices.

ALL PERSONNEL WHO WORK WITH OR ARE EXPOSED TO THIS EQUIPMENT MUST TAKE PRECAUTIONS TO PROTECT THEMSELVES AGAINST POSSIBLE SERIOUS AND/OR FATAL BODILY INJURY.

1.0 Safety

The high power nature of this device dictates the use of caution when operating or servicing this equipment. OBSERVE ALL SAFETY PRECAUTIONS LISTED BELOW. FAILURE TO DO SO COULD RESULT IN INJURY OR DEATH.

Precautions:

1. The Laser Diode Driver should be serviced only by personnel experienced in high power pulsed power systems.

2. Service personnel should be instructed to observe all safety precautions as stated in the operating instructions, and those safety precautions standard to the high voltage pulsed power community. Failure to do so could result in serious injury.

3. Do not handle the load or terminations, or remove the input or output cables, while the driver is in operation. Ensure that the 24VDC power supply has fully discharged before handling the load. Failure to observe these precautions can result in potential electric shock to personnel, arcing, and damage to the connectors and system.

4. The Laser Diode Driver contains reference planes that are elevated to the potential of the output pulse. Extreme caution should be exercised when servicing the equipment.

5. The Laser Diode Driver contains electrolytic capacitors. Do not reverse the polarity of the input DC power supply, and do not exceed the maximum ratings for the support power supplies. Doing so may result in damage to the capacitors or to the driver, or personal injury due to venting of the capacitors.

6. Pulsed power systems are capable of random triggering via transients and therefore when the driver is turned on or high voltage is present in the module, assume it is possible to get a pulse on the output stripline.

2.0 Overview

The PCO-6141 is a compact, OEM-style high power pulsed current source designed to drive diode lasers, bars and arraysin pulsed, QCW or CW modes. It delivers output current variable from 1A to 60A, pulse widths variable from <100ns to DC, and pulse repetition frequencies variable from single-shot to 500KHz at duty cycles up to 100%.

The PCO-6141 is based on a hysteretic, average current, switch-mode regulator. This type of regulator is a variable frequency, variable pulse width design which maintains current in an energy storage inductor between a minimum and maximum level. The ripple is limited to the minimum and maximum current determined by the hysteretic controller. The controller turns on to charge the energy storage inductor when the current drops to the lower limit and turns off when the current reaches the upper limit and repeats this operation as necessary to maintain the proper current. The time for these operations will vary dependent on the load voltage and the input voltage, therefore the pulse width of the controller will change as necessary to charge the inductor and the period will change dependent on the rate at which theinductor discharges. The relationship for this operation is tied to V = L di/dt. When the output is shorted such as when no pulse is being outputted, the voltage applied to the inductor is 24 Volts. This results in a very fast increase in current so very short on times are necessary. When the controller switches off then a very small voltage is across the inductor so the current decays very slowly and therefore the off time is quite large. All of this reverses when the output is going to a load. When the load is near the maximum V, the time to charge the inductor is very large but the decay time is very short. The advantage of this controller is that the current is controlled to an upper and lower limit regardless of the pulse width. It can generate short or long pulses, and performs as a current source.

The current regulator is started when the TTL "enable" line is taken high and runs as long as the enable is high. This happens when the control gate is taken high and will continue until the gate control is taken low. It will take a finite time for the current source to charge to the proper current (i.e. a ramp-up time), after which a pulse can be generated. The use of the hysteretic regulator provides a large input range and high efficiency.

The current source is combined with a crowbar (shorting switch). The shunting crowbar switch shorts the output of the regulator until output current is needed. The pulse is generated by opening the shunt switch for the length of the input pulse. A pulseis generated when the control gate is high, the shunt switch is opened for the length of the input control gate, forcing the current to flow through the laser diode load. The pulse rise and fall times are then limited only by the stray/parasitic capacitance and inductance of the shunting switch and output leads.

The control signal for the current source is called the “enable” and has thresholds compatible with TTL logic. The “gate” control has thresholds compatible with CMOS (CMOS is complementary metal oxide semiconductor) logic.

Very little power is dissipated in the driver until it is enabled. When enabled, at 60A maximum output approximately 80W is continuously dissipated in the driver to maintain the current in the energy storage inductor (see note #1 under specifications). The load power is added to this continuous power and the pulse rate will further increase power consumption.

This architecture provides a high performance driver in a small form factor, with high operating efficiency and low stored energy. At 60A output current, the stored energy in the driver is approximately 1 Joule, dramatically lower than the stored energy in comparable linear current sources.

The PCO-6141 features a user-adjustable variable rise time control. This innovative feature allows the user to adjust the rise time within a range of <12ns to >1.5µs by means of a PCB-mounted potentiometer, to optimize the driver's rise time for the user's application. In applications in which the laser diode or interconnection between the driver and the diode is somewhat inductive, the fast rise time of the PCO-6141 may induce ringing on the leading edge of the pulse. The rise time may be slowed down using the variable rise time control to minimize or eliminate this ringing.

The PCO-6141 requires user-supplied +24VDC support power, a CMOS (+5V) gate signal, and a TTL-level enable/disable signal. The high current output is derived from the +24VDC DC input. The output pulse width and frequency are controlled by the gate signal. The output current amplitude is controlled by a PCB-mount potentiometer. A current monitor output may be viewed with an oscilloscope, providing a straightforward means to observe the diode current waveform in real-time.

To protect the laser diode and the driver, circuitry is incorporated into the driver that disables the output if the +24VDC support power drops below 18V. Clamp diodes are incorporated into the output network to protect the laser diode against reverse voltage conditions.

Open circuit protection is provided by an 80 Ampere diode connected from the output to the 24VDC supply. The user should be aware that even if the output is an open-circuit, the output current (determined by the current set point) will flow into this protection diode. Therefore care should be taken to ensure the load is properly connected to the PCO-6141 before pulsing.

The PCO-6141 is mounted on an air-cooled heatsink.

3.0 Specifications

The PCO-6141 laser diode driver will meet or exceed the following specifications. All specifications are measured into a low inductance diode load connected with 1 meter of stripline interconnect cable:

PARAMETER	VALUE
PULSE OUTPUT CURRENT	
Amplitude Range	0A to 60A
Means Of Adjustment	Trimpot mounted on PCB, or external 0-5V or 0-10V Analog Voltage Program, jumper-selectable
Output Polarity	Positive
Pulse Rise Time	Variable from <12ns to >1.5µs (10%-90%), user-adjustable through trimpot mounted on PCB
Pulse Width	<100ns to DC
Pulse Recurrence Frequency Range	Single Shot to 500KHz
Maximum Duty Cycle	100%
Output Pulse Ripple/Droop	~600mA (<1% at 60A output)
Jitter	<3ns First Sigma
Efficiency	>65% at 50% duty cycle, 60A output (1)
Output Connector	High Current DSUB, PCB-Mounted
DIODE FORWARD VOLTAGE	
Amplitude	20V maximum
GATE INPUT	
Type	Positive Edge Trigger
Gate Input	+5V CMOS
CURRENT MONITOR OUTPUT	
Current Monitor	200A/1V terminated into 50Ω, ±3% of the actual current
Current Monitor Connector	BNC
CONTROL FUNCTIONS	
Output Enable/Disable	TTL Input, High = Enabled
GENERAL	
Input Power	+24VDC ±4V (2)
Operating Temperature	0C to 40C
Cooling	Air cooled
Dimensions (H X W X D)	2.05" x 8.9" x 6.25" (5.2cm x 22.6cm x 15.9cm)
SPECIFICATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE	

1. The idle power consumption (power consumed when the driver is enabled but not pulsing) varies non-linearly with output current, and can be approximated by the formula $P_{IDLE}=I^2 \times 0.023$ where I is the output current setpoint. When pulsing, the switching losses (P_{SW}) are about 30W. Therefore the 24VDC power requirements can be approximated by the formula $P_{SW} + [I_{OUT}V_{OUT} + I_{OUT}^2(0.030)]DC + P_{IDLE}(1\text{-}DC)$ where V_{OUT} is the diode forward voltage and DC is the duty cycle. For example, at 40A output current, 10V diode voltage and 30% duty cycle, the power consumption is $30W + [40A \times 10V + 40A^2 \times 0.03].3 + [40A^2 \times 0.023](1-.3) = 190W$. The +24VDC support power should be sized to provide this average power.

2. The +24VDC support power should be sized for the average output power (Power x Duty Cycle) plus the idle power consumption, as defined above. The +24VDC supply may be unregulated, provided that the voltage does not exceed the +24V ±4V window.

4.0 Connector Pin-Outs And User Adjustments

The support power and control signals are on a 14 pin FCI Connector header, part number 66429-055. This header mates with an FCI housing, part number 65846-008 or equivalent. The sockets for use with this housing are FCI Connector part number 48236-000 or equivalent. The pin-out of this connector follows:

Pin Number	Description
2	Not Used
4	Current Setpoint Input (See Section 5.7)
6	Output Current Setpoint Monitor, Scaling is 20mV/A into High Impedance
8	Pulse Input (Gate), +5V CMOS
10	Enable/Disable, TTL High = Enabled
12	+5VDC Monitor (Output) 15mA Max
14	Not Used
Odd Pins	Ground

The setpoint monitor provides a scaled output of the current in the inductor. This output can be used to set the output current amplitude prior to generating an output pulse.

The indicator LEDs are only to show function and are not tolerance controlled.

The +24VDC input are screw terminals located on the main circuit board. Connector E1 and E4 are +24VDC, and E2 and E3 are ground.

The output pulse current may be monitor through the PCA-9150 (available separately).

These connectors are shown in the photo below:

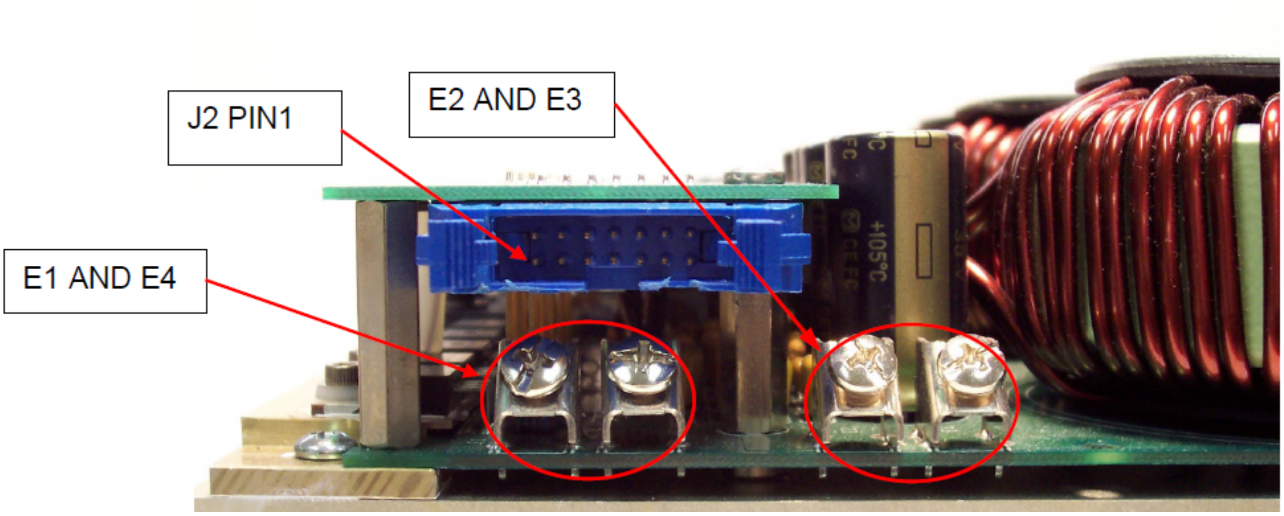


Figure 1: Connectors J2, E1, E2, E3 and E4 Locations

The output is provided on a high current PCB-mount DSUB connector (Amphenol #77TW-C-8W8-S-MP3V-4R or Conec #3008W8SXX57A30X).

The driver is provided with a mating output connector (Amphenol # 717TW C-8W8-P-P3Y or Conec #3008W8PXX51A10X) and stripline. Pins 2, 4, 6 & 8 are the positive pulse output, and pins 1, 3, 5 & 7 are the return. See Figure 2A.

The Output current is set by the Current Set potentiometer, located on the edge of the smaller logic circuit board. The current may also be set by a remote analog input. See Section 5.0 formore details.

The variable rise time is adjusted by the Rise Time potentiometer, located on the edge of the smaller logic circuit board. (See Section 5.0)

All potentiometers can be adjusted while the unit is operating. A suitable insulated adjustment tod should be used. Actual operation is usually necessary so that the correct waveforms can be made and adjusted to suit the user's needs.

The photo below shows the location of the control potentiometers, jumpers and indicator LEDs:

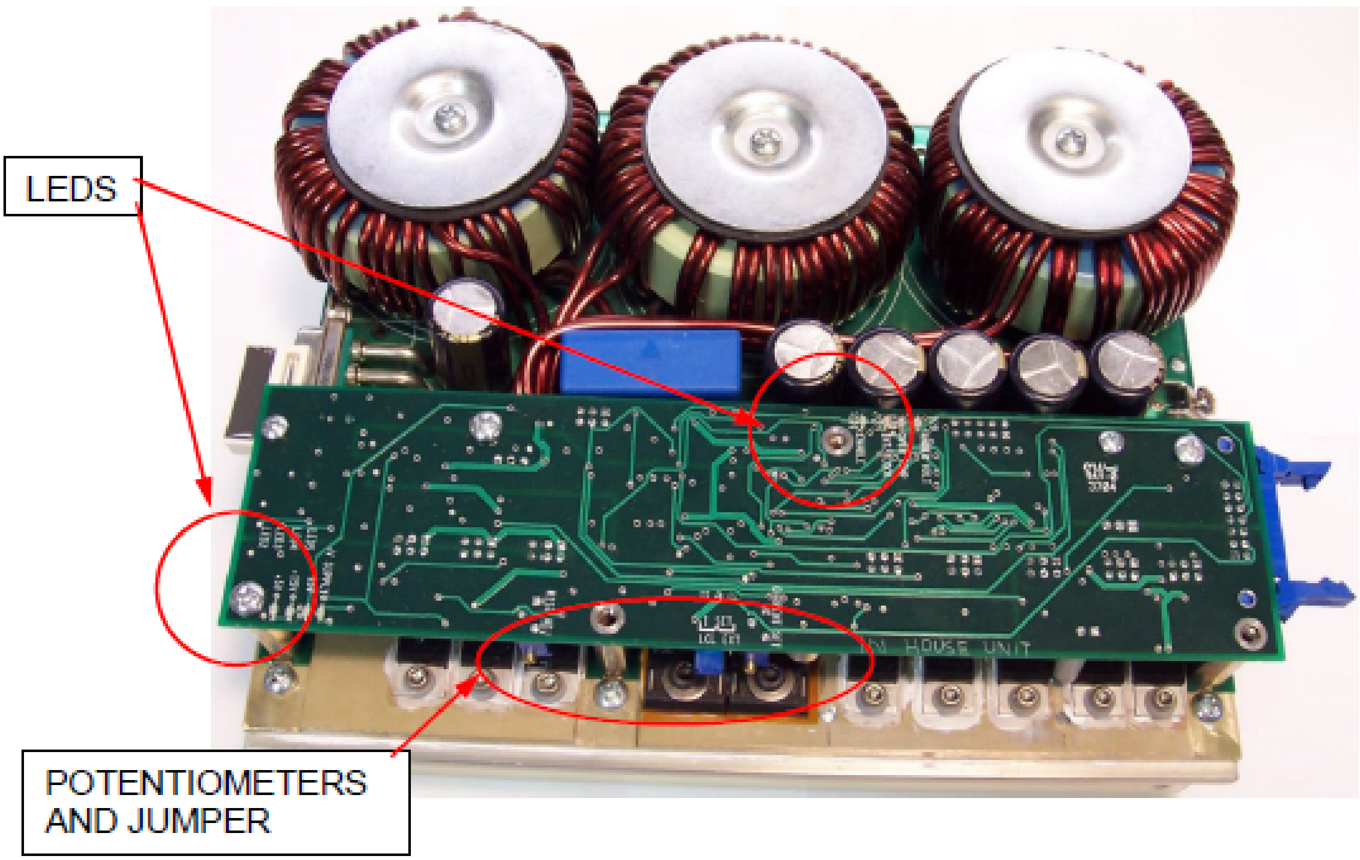


Figure 2: Control Potentiometers, Jumper and LED Locations

5.0 Operating Instructions

WARNING

1. Do not remove the input or output cables while the driver is in operation. Do not operate the driver without an appropriate load connected to the output stripline. Failure to observe these precautions

can result in potential electric shock to personnel, arcing, and damage to the connectors and system.

2. Pulsed power systems are capable of random triggering via transients and therefore when the pulse generator is turned on, or high voltage is present in the chassis, assume it is possible to get a pulse on the output connector.

5.1 Output Stripline

The PCO-6141 is provided with a low impedance output stripline cable. The laser diode should always be connected to the driver using this stripline cable. Wire or twisted pair are too inductive, and may seriously degrade the fidelity of the output current waveform.

5.2 Load Interconnection

The output is provided on a high current PCB-mount DSUB connector (Amphenol #77TW-C-8W8-S-MP3V-4R or Conec #3008W8SXX57A30X), terminated with a low-inductance stripline cable. Pins 2, 4, 6 & 8 of the connector are the positive pulse output, and pins 1, 3,5 & 7 are the return.

The output stripline is marked with a + and-. The "+" side is the positive output pulse, and the "-" side of the stripline is the return. The laser diode anodes connects to the "+" side of the stripline, and the laser diode cathode connects to the "-" side.

The laser diode should be connected directly to the end of the stripline. If wire interconnections are needed between the end of the stripline and the diode, they should be kept as short as possible, preferably no more than 2 inches (5 cm) in order to minimize interconnection inductance. Excessive inductance in the interconnections or laser diode package may lead to ringing on the leading edge of the pulse waveform. This ringing may be reduced or eliminated by lengthening the pulse rise time using the variable rise time feature (See Section 5.8).

See Section 6.0 for additional information on interconnection inductance and its affect on pulse rise and fall times.

5.3 Gate Input

An input gate of +5V ±1V (CMOS) is required to gate onthe PCO-6141. Departure from these values can result in a loss of performance. Any high quality low voltage pulse generator meets this trigger requirement.

The gate signal should be connected to J1-8 using 50Ω coaxial cable. The shield of the coaxial cable should be connected to any one of the ground pins of connector J1. To improve pulse fidelity, all connections should be as short as possible.

The output pulse's width and frequency follow the width and frequency of the input gate. To generate a CW output, the gate should be held high.

5.4 Enable Input

The "enable" signal is used to enable and disable the output of the PCO-6141. This input must be pulled TTL "High" in order to enable the driver. This input can be connected to an interlock or key switch in the user's system, or may be controlled by the system's control computer.

When the driver is enabled but not pulsing, it dissipates a fixed amount of power (see Section 5.5 below). Therefore for optimum efficiency and minimum power consumption, the driver should be disabled when not in use.

5.5 Output Current Setpoint Monitor

The output current setpoint monitor (J1 Pin 6) can be used to set the output current flowing in the inductor prior to generating an output pulse. This allows the user to set the current that will be applied to the diode, without actually applying power to the diode. To set the current using the setpoint monitor, the PCO-6141 must be enabled, while the gate input is held low.

See the Power Up Procedures below for more information.

5.6 Internal and External Current Setpoint

In internal mode, the potentiometer labeled Current Set controls the output current amplitude. 0A is full counter-clockwise. The output current setpoint monitor may be used to set the output current without applying a pulse to the laser diode.

The external current setpoint (J1 Pin 4) allows the user to apply an external voltage to the potentiometer circuit. The on-board potentiometer then can be used as a range scaling potentiometer. In order to use this feature, the Current Set External/Local jumper must be set to the External setting (see Figure 2). If the jumper is set to the Local setting, this input is not used.

For example, to use 0-10V input and scale the output accordingly, the potentiometer may be adjusted to correlate the maximum output current to 10V maximum input. In the local mode with the unit enabled and the gate input held low, set the potentiometer to 0A output, and then change the jumper to External Mode. Apply the maximum input voltage desired to the Current Setpoint Input (i.e. 10V). Then slowly adjust the current setpoint potentiometer until the desired output current is obtained on the Output Set Point Monitor. **<u>DO NOT OPERATE OR PULSE THE UNIT INTO AN OPEN OR HIGH IMPEDANCE LOAD WHILE MAKING THIS ADJUSTMENT.</u>** The output current may be monitored using the internal monitor on J1 pin 6. This allows the user to scale the output current to any analog voltage program up to 20V.

<u>5.7 Leading Edge Risetime Control Potentiometer</u>

The PCO-6141 features a user-adjustable variable rise time control. This feature allows the user to adjust the rise time within a range of <12ns to >1.5µs by means of the PCB-mounted potentiometer (see Figure 2), to optimize the driver's rise time for the user's application. In applications in which the laser diode or interconnection between the driver and the diode is somewhat inductive, the fast rise time of thePCO-6141 may induce ringing on the leading edge of the pulse. The rise time may be slowed down usig the variable rise time control to minimize or eliminate this ringing.

Full counter-clockwise is the fastest rise time, and full clockwise is the longest rise time. Please note that this feature does not affect the pulse fall time.

<u>5.8 Indicator LEDs</u>

Several LEDs on the driver logic board may be used for verification of functionality and for troubleshooting. The LEDs and their function are listed below:

LED	**FUNCTION**
LED1	-15VDC Monitor. If the –15VDC on-board regulator is functioning correctly, this LED will be illuminated.
LED2	+24VDC Monitor. Indicates +24VDC is applied to the driver.
LED3	+15VDC Monitor. If the +15VDC on-board regulator is functioning correctly, this LED will be illuminated.
LED4	+5VDC Monitor. If the +5VDC on-board regulator is functioning correctly, this LED will be illuminated.
LED5	Enable Indicator. If the driver is enabled, the LED will be illuminated. If it is disabled, the LED will be off.
D27	Interlock Fault. If output interlock is not made, this LED will be illuminated and the output will be disabled.
D28	Over Temperature Fault. If the temperature of the heatsink is greater than 70C this LED will be illuminated and the output will be disabled.
D29	Under Voltage Fault. If the input voltage is less than 18V this LED will be illuminated and the output will be disabled.

5.9 +24VDC Input

The +24VDC input provides the power for the output current. This voltage may be in the range of +20V to +28V. It may be unregulated, provided that it does not vary below 20V or above 28V.

At 60A output, the driver dissipates ~80W when enabled but not pulsing. Efficiency is therefore the ratio of output power to the idle power consumption. The idle power consumption varies nonlinearly with output current, and can be approximated by the formula $P=I^2 \times 0.022$ where I is the output current. For example, at 40A output current, the idle power consumption is $40^2 \times 0.022 = 35W$.

The +24VDC support power should be sized for the average output power (Power x Duty Cycle) plus the idle power consumption as defined above, and an additional 20% for pulse switching losses.

5.10 Power-Up Procedures

1. The unit should be powered up using the following procedures:
2. Before connecting the input pulse generator to the PCO-6141 pulser, set up the pulse generator output to deliver a CMOS level pulse with a repetition rate and pulse width appropriate for the laser diode being driven. Before connecting input connector J1 to the driver, turn off or disable the output of the pulse generator.
3. Connect the +24VDC support power to connectors E1 and E4 and the +24VDC return to connectors E2 and E3.
4. Connect the input connector J1.
5. Connect the laser diode to the output connector using the stripline (see Section 5.1 above).
6. Apply +24VDC (±4V) power to the module.
7. To set the output current prior to enabling the output, follow the procedure in steps 8-11 below.
8. Ensure that the input gate signal is low (i.e. the input pulse generator is turned off or is disabled).
9. Enable the PCO-6141 by pulling the enable input HIGH
10. Monitoring the voltage of the Output Current Setpoint Monitor (J1 Pin 6) with an oscilloscope or Digital Volt Meter (DVM), set the output voltage

to correspond to the appropriate output current by adjusting the Current Set potentiometer. See Section 5.7 for remote current set instructions.

11. When the current is set to the appropriate level, disable the output by pulling the enable input LOW.

12. If the output current has not been set using the Output Current Setpoint Monitor and the procedure detailed in steps 811 above, turn the Current Set potentiometer fully counterclockwise (to set the output current to zero).

13. Enable the PCO-6141 by pulling the enable input HIGH

14. Turn on or enable the input gate signal.

15. If the output current has not been preset, slowly turn up the output current by the Current Set potentiometer clockwise. The PCO-6141 should produce an output pulse, with a pulse width and pulse recurrence frequency following that of the incoming gate. The output pulse current may be monitored through the PCA-9150 (available separately). Scaling is 200A/V into 50 Ohms.

16. If there is no output from the PCO-6141, or the output is severely distorted, disable the output, and turn OFF the +24VDC power supply. Leave the PCO-6141 connected to the DC input support power without voltage applied and with all connectors in place for approximately one minute to bleed off the stored energy, then disconnect the DC power to the unit and refer to the Troubleshooting Section of this manual.

5.11 Power-Down Procedures

1. Disable the output.

2. Turn off the +24VDC power supply.

3. Leave the PCO-6141 connected to the +24VDC input with the voltage turned off and with all connectors in place for approximately one minute to bleed off the stored energy.

4. Disconnect the DC support power to the unit.

6.0 Laser Diode Interconnection Inductance

Application of the PCO-6141 requires an attention to detail to prevent problems with inductance in the leads and load. DEI has tested the PCO-

6141 with laser diodes to determine how best to apply high current pulses to laser diodes, and the result of this investigation is presented below.

A stripline is very integral to obtaining good fidelity of current pulses. The strip line shown in the figures in this note is the stripline supplied with the PCO-6141, and is available from DEI.

When a stripline is used and connected directly to the laser diode, the fall time was in the range of 500ns. When the laser diode was connected to the stripline with about 6 inches of wire, the fall time degraded to about 6 microseconds. Inductance negatively affects fall time, and the performance seen with these two interconnection topologies is consistent with the inductance introduced into the circuit by the wire interconnections.

For all tests, the laser diode was driven at approximately 50 Amperes. A diode forward voltage of about 2.4V was measured, confirming that the laser diode was correctly wired into the circuit. The repetition frequency was limited to a few Hertz, eliminating the need to heatsink the laser diode.

NOTE: These tests were performed with a PCO-6130 125A driver, however the data applies to the PCO-6141.

Figure 3 is a photo of the test setup.

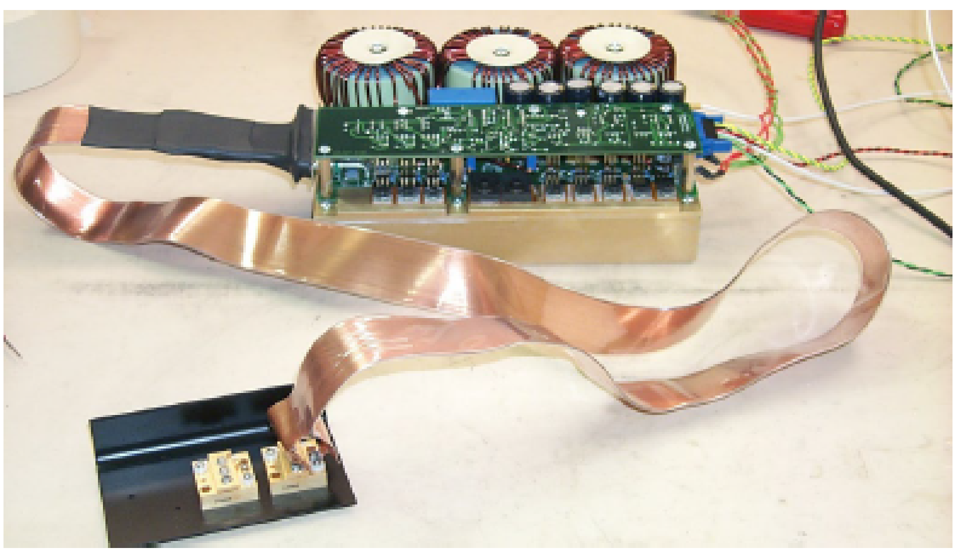


Figure 3 - Test Setup

Figure 4 and 5 show how the output stripline was connected to the laser diode for the first set of tests. In Figure 4, the stripline was intentionally separated to show connections. Normally it is best if the stripline conductors are closely coupled to each other to minimize inductance.

Figure 4 - Stripline Connection To Laser Diode

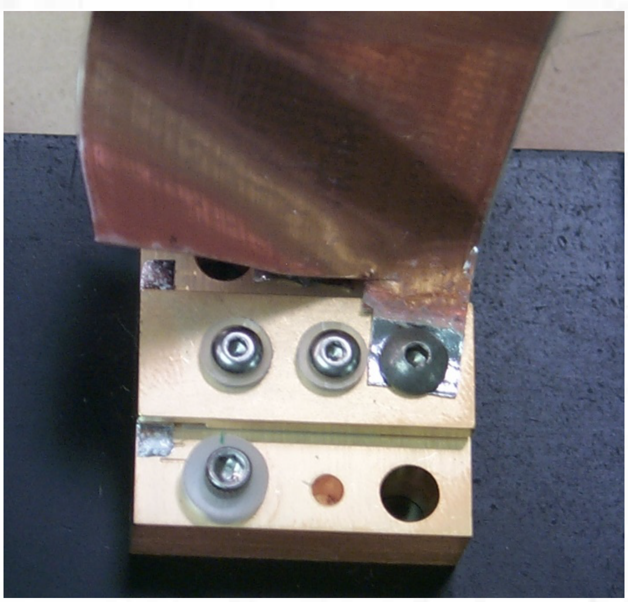


Figure 5 - Stripline Connection To Laser Diode

Using this interconnection, at 50A output the following electrical performance was measured. For all photos, the top trace is the input gate to the PCO-6130, and the bottom trace is the output current pulse measured with the PCO-6130's current monitor.

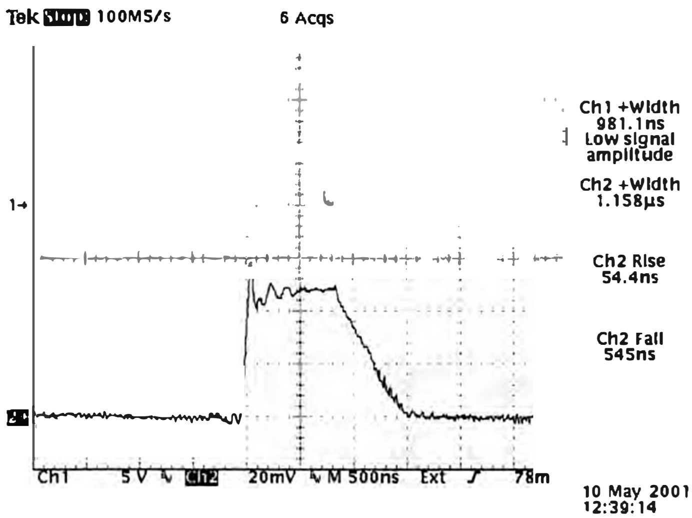


Figure 6 - 1 Microsecond Pulse Width
545ns Fall Time, 55ns Rise Time Using a Stripline

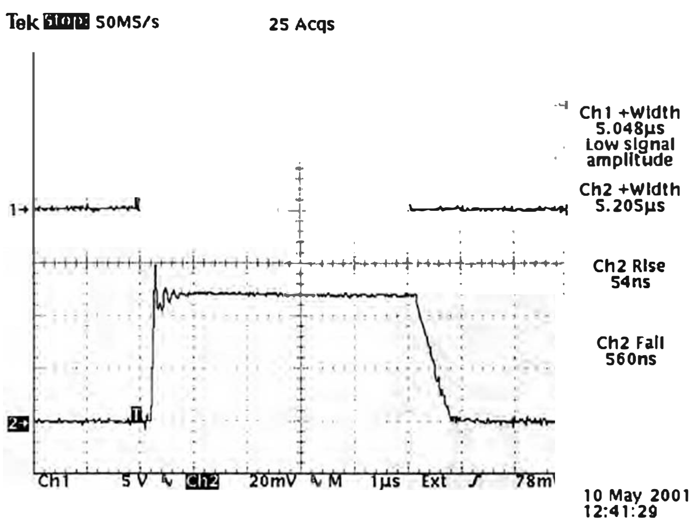


Figure 7 - 5 Microsecond Pulse Width
560ns Fall Time, 54ns Rise Time Using a Stripline

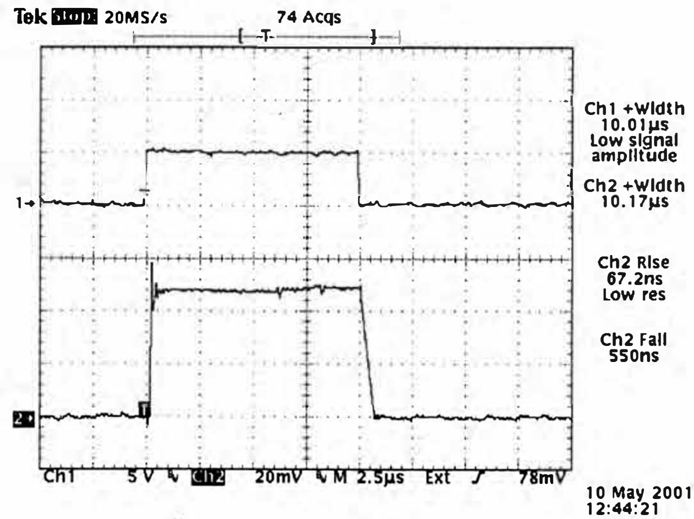


Figure 8 - 10 Microsecond Pulse Width
550ns Fall Time, 67ns Rise Time Using a Stripline

We then connected the laser diode to the PCO6130 output stripline using approximately 6 inches of wire. Ring lugs were used to attach the wires to the laser diode, and the other ends of the wires were soldered to the ends of the striplines. This interconnection is shown in Figure 9.

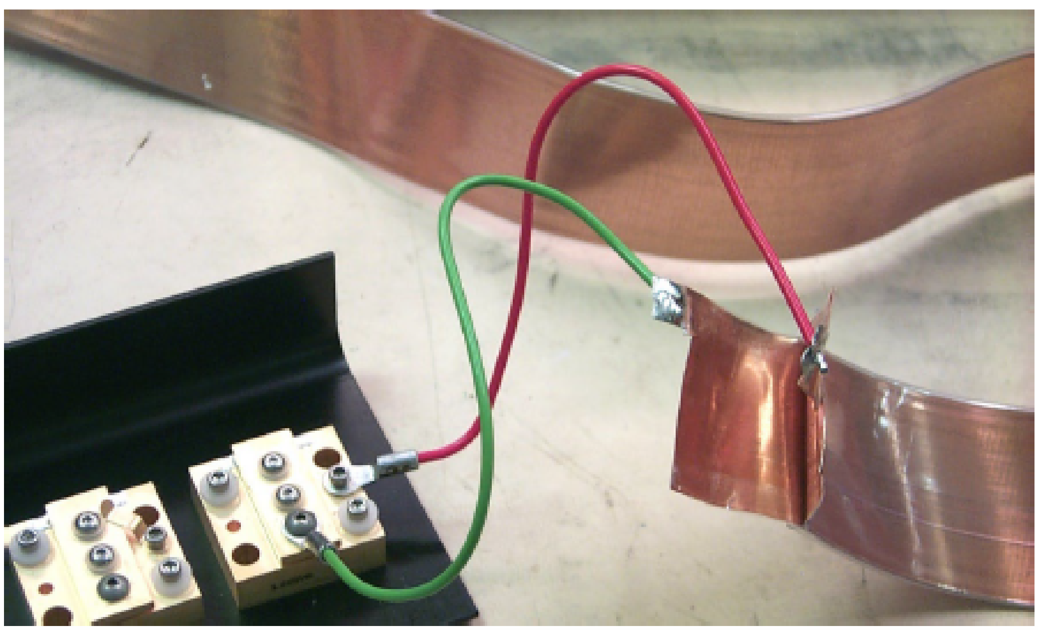


Figure 9 - Laser Diode Connected Using Approximately 6 Inches of Wire

Using this interconnection, at 50A output the following electrical performance was measured. For all photos, the top trace isthe input gate to the PCO-6130, and the bottom trace is the output current pulse measured with the PCO-6130's current monitor.

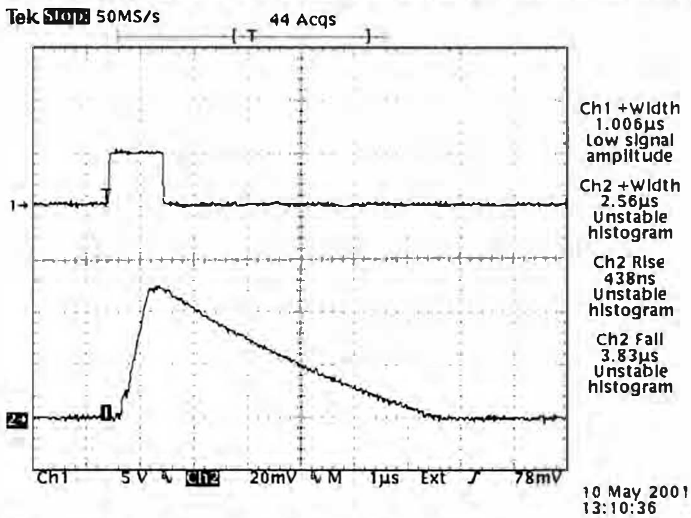


Figure 10 - 1 Microsecond Pulse Width – Wire Interconnection 3.8 Microsecond Fall Time, 438ns Rise Time

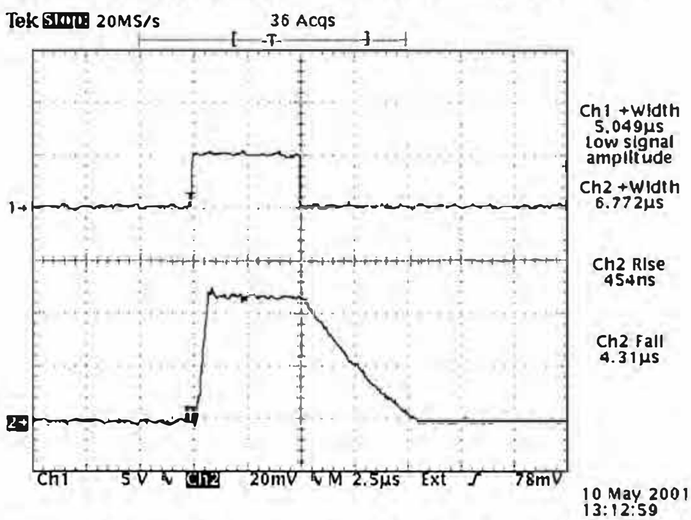


Figure 12 - 5 Microsecond Pulse Width – Wire Interconnection 4.3 Microsecond Fall Time, 454ns Rise Time

As can be seen from the data above, even the inductance of 6 inches of wire in the connection between the stripline and the laser diode can result in a 5X to 8X degradation in the rise time and fall time.

7.0 Troubleshooting

WARNING

The module contains capacitors that are used as energy storage elements. When charged, these capacitors contain in excess of 7 joules of stored energy. This is sufficient energy to cause injury Assure that the +24VDC power is disconnected from the pulser, and that the capacitor bank is fully discharged before any repairs or adjustments are attempted. Verify with a voltmeter that all circuits are de-energized before servicing. Dangerous voltages, floating ground planes and energy storage exist at several locations in the module. Touching connections or components could result in serious injury

7.1 Troubleshooting Procedures

The table below summarizes potential problems and their solutions. If these recommendations do not resolve the problem, DEI customer service can be contacted for further assistance.

SYMPTOM	SOLUTIONS
No output pulse	• No input gate • Input gate voltage too low • Input gate pulse width too short. Increase width • Input gate frequency too high. Reduce frequency • No +24VDC input voltage. Check input supply and connections • Enable circuit not satisfied • Output not connected correctly. Check all cables and connections • Pulser is damaged. Contact DEI customer service • Input voltage <13V. Increase input voltage. • Interlock not made. Ensure output stripline is properly attached. • Heatsink temperature is greater than 70C. Improved cooling to PCO-6141

7.2 Factory Service

If the procedures above fail to resolve an operational problem,please contact the factory for further assistance:

8.0 Warranty

There are no warranties, express or implied, including any implied warranty of fitness for a particular purpose nor any IMPLIED WARRANTY OF MERCHANTIBILITY made by Directed Energy, Inc. (DEI) except as follows:

DEI warrants equipment manufactured by it to be free from defects in materials and/or workmanship under conditions of normal use for a period of one year from the date of shipment to the purchaser. DEI will repair or replace, at DEI's option, any product manufactured by it that is shown to be defective or fails to perform within specificatons within one year from the date of shipment to the purchaser. OEM, modified and custom items of equipment are similarly warranted, for a period of ninety (90) days from date of shipment to the purchaser.

Equipment claimed to be defective must be returned transportation prepaid, to DEI's factory in Fort Collins, Colorado within the warranty period. Returns must be preauthorized by contact with DEI's customer service department. Written documentation of such preauthorization shall be included with the returned item.

At DEI's discretion, DEI may elect to repair or replace the equipment claimed to be defective or refund the original purchase price, plus taxes and transportation charges incurred by the purchaser.

This Warranty shall not apply to any product hat has been:

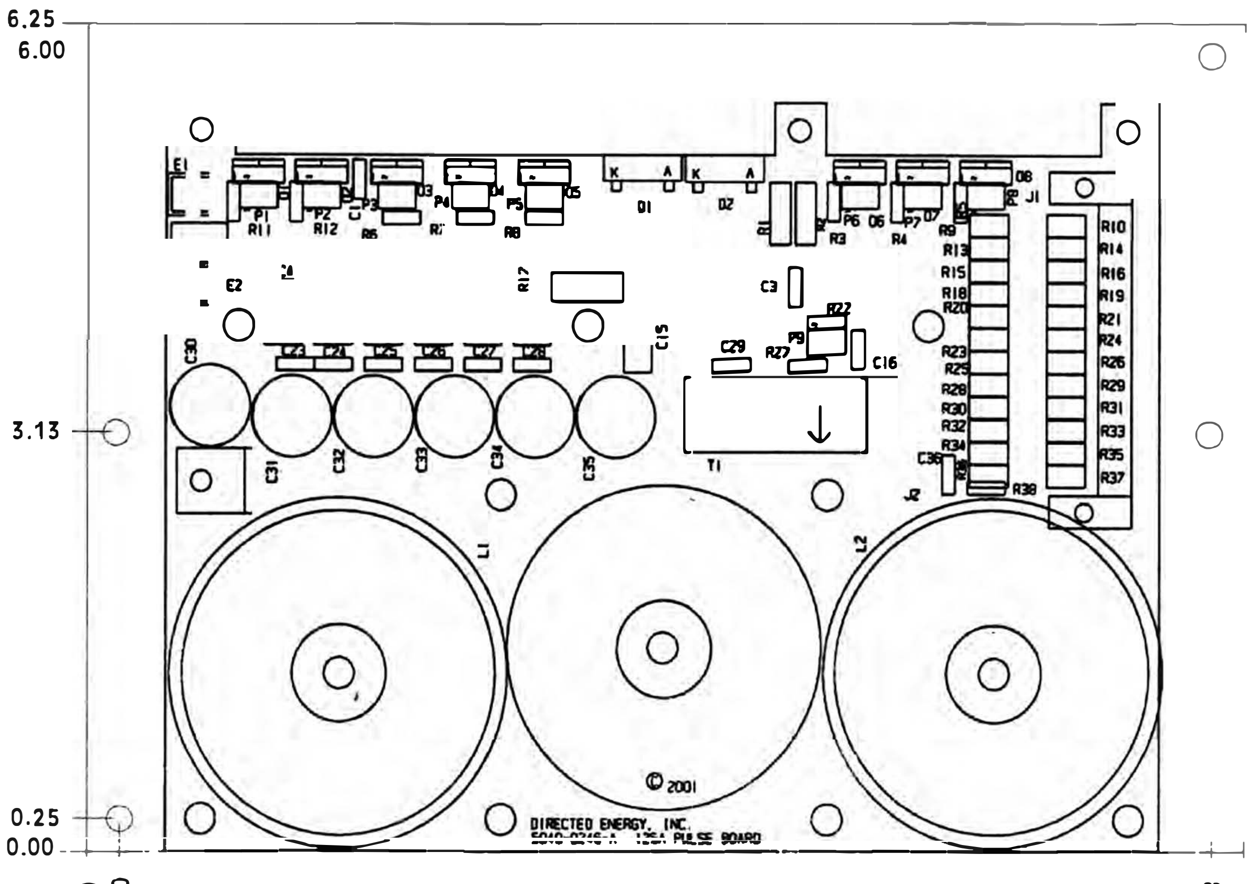
1. Repaired, worked on, or altered by persons unauthorized by DEI;
2. Subjected to misuse, neglect, or damage by others; or
3. Connected, installed, adjusted, or used in a manner not authorized in the instructions or specifications furnished by DEI.

This warranty is the purchaser's sole remedy for claimed defects in the equipment sold or manufactured by DEI. DEI's liability to the purchaser is limited to the repair or replacement of the claimed defective equipment or, at DEI's option, refund of the puchase price, taxes and transportation charges incurred by the purchaser. DEI will not be responsible for or liable to the purchaser for consequential losses or damages asserted to be attributable to a claimed defect in the equipment provided.

Changes made by DEI in the design or manufacture of similar equipment which are effected subsequent to the date of shipment of the warranted equipment to the purchaser are reflective of DEI's program of constant product development and improvement and shall not be construed as an acknowledgement of deficiency in the product shipped to purchaser. DEI will be under no obligation to make any changes to product previously shipped.

Appendix

PCO-6141 Dimensional Drawing



Heat spreader is 1/4" Al
Thru holes are 0.201" dia X6

PCO-6141 Dimensional Drawing