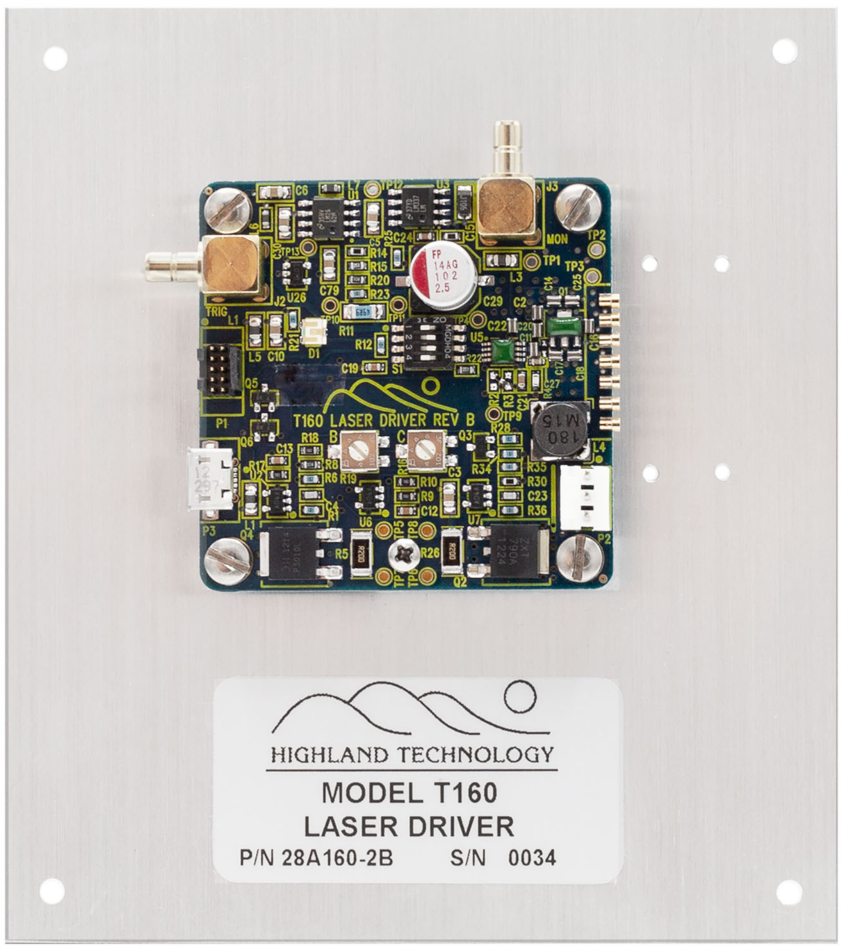
HIGHLAND TECHNOLOGY

MODEL T160

PICOSECOND TO NANOSECOND

LASER DIODE DRIVER



Technical Manual

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1. Introduction

This is the technical manual for the Highland Model T160 Laser Driver.

Features of the T160 include:

- Laser current up to 400 mA, 700 mA with heat sinking
- Optical pulse widths from 100 picoseconds to 50 microseconds
- Connects directly to floating anode Type-1 butterfly-packaged laser diodes through pin sockets; compatible with other laser packages
- Laser drive follows electrical input
- Highly stable constant-current laser drive
- Laser current and bias are settable with onboard trimpots or by external analog inputs
- Switchable TTL or LVDS/PECL/CML input trigger compatibility
- Powered by standard 5-volt micro-USB power supply or through ribbon cable interface connector
- Compact 2” x 2” PCB for embedded application
- Compatible with Highland models:

  P500 digital delay generator
  T660 digital delay generator
  T240 picosecond pulse generator

The very high speed components of the T160 are sensitive to electrostatic damage. To maintain picosecond performance, no explicit ESD protection is included.

Discharge cables before connecting to the T160. Do not apply trigger inputs over + 3.3 volts.

2. Specifications

Specifications are typical unless otherwise noted.

FUNCTION	Embedded laser diode driver
LOGIC INPUT	Switchable TTL or optional LVDS/PECL/CML input TTL threshold is +0.4 volts, 50 Ω load Differential input is LVDS or 3.3 volt PECL, 100 Ω load Laser current follows logic input
PROPAGATION DELAY	1 ns nominal
LASER OUTPUT	User adjustable 0 to 700 mA, 2.5 volt compliance Cooling required above 400 mA Limited to 60 % duty cycle and 50 µS max ON time
RISE/FALL TIMES	150 ps to 1ns nominal (-2 and -9 versions) 1 ns nominal (-14 version) Actual rise/fall times depend on laser electrical parasitics
JITTER	< 10 ps RMS (-2 and -9 versions) < 15 ps RMS (-14 and -15 versions)
CONTROL	Two trimpots or external analog inputs set laser ON current and laser OFF bias External inputs are 0 to +3 volts, >10 K load
BIAS RANGE	< 50 mV to +1.5 V, nominal, laser anode relative to ground
POWER	+5 volts via USB connector or ribbon header Current draw: 200 mA plus laser current Highland model J6 USB power supply available for use in trimpot mode up to 700 mA laser current (furnished with evaluation versions only)
CONNECTORS	TTL input: SMB connector LVDS/PECL, control, power: 10-pin 50-mil 2x5 ribbon cable header MONITOR output: SMB connector Micro-B USB alternate power connector 3-pin header provides access to laser TEC pins
LED INDICATORS	Green POWER
PACKAGING	2” x 2” printed circuit board

3. Architecture

The signal path of the T160 is shown below:

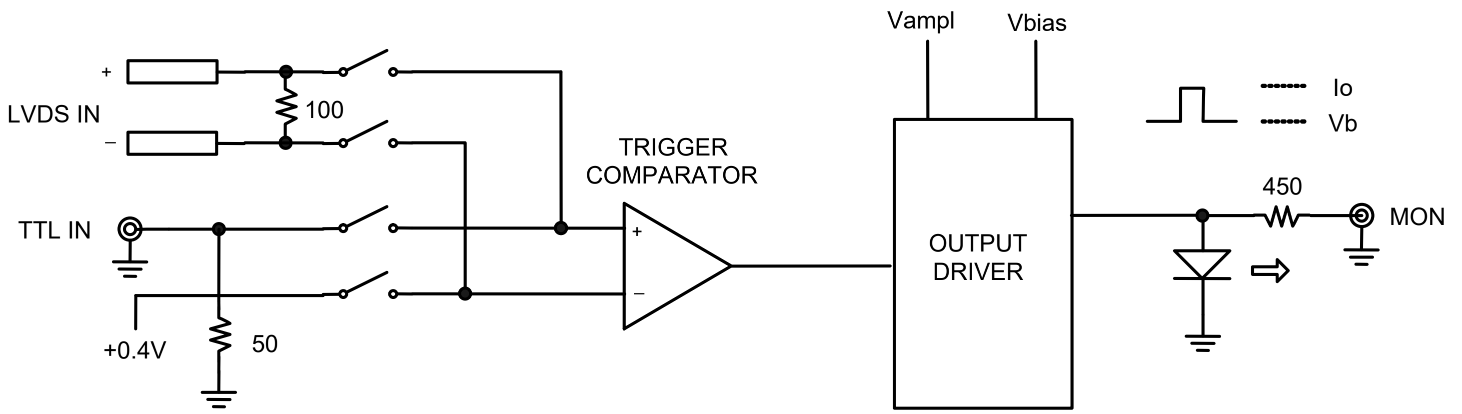


DIAGRAM 1: T160 Signal Path

A miniature dip switch (S1) selects the TTL or LVDS/PECL input signal.

Vampl programs the "ON" laser current, and Vbias programs the "OFF" laser bias voltage.

The output driver topology is as follows:

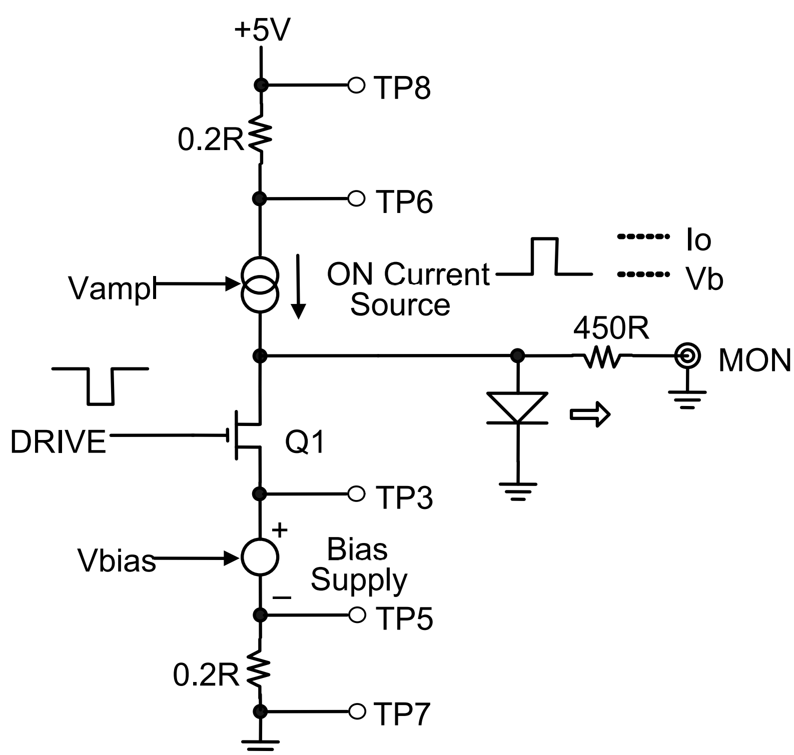


DIAGRAM 2: T160 Functional Topology

Classic telecom-style bias-tee laser drive results in soft turnoff and drive excursions that vary with laser repetition rate and duty cycle.

The T160 “OFF” laser bias is a voltage source, not a current source. The main current source is on continuously. When the drive signal is off, Q1 is shorted and diverts this current into the bias power supply, then to ground. Active drive turns Q1 off, allowing the ON current to flow into the laser.

This topology allows the laser OFF bias to be a low impedance source, which ensures fast recovery after a laser pulse, and allows faithful reproduction of input pulse patterns, even for high capacitance laser diodes. Additionally, at the end of a laser pulse, the laser is driven hard to the Vb bias voltage, ensuring sharp turnoff and minimal optical tails.

Most laser diodes have an exponential current-versus-voltage curve with a slope of about 100 millivolts per decade of current. So if a laser ON voltage is, say, 1.4 volts, the OFF current might be 1/1000 of the ON current if the bias voltage is set to about 300 mV below the ON voltage. The non-exponential ohmic component of diode impedance changes the curve somewhat, but an effective zero-light bias voltage will typically be 300-500 mV below the laser ON voltage. That bias setting will generally result in good rise/fall symmetry and faithful optical-output reproduction of electrical input waveforms.

Test points are provided for measuring the laser ON current and the baseline bias voltage. Actual laser anode voltage can be measured with a voltmeter at the MON connector.

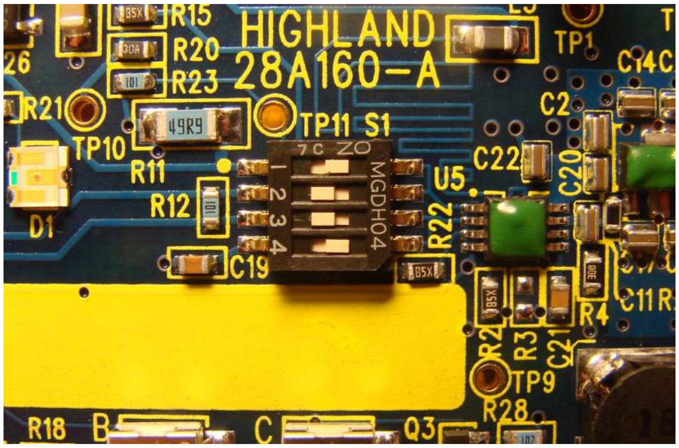
Laser waveforms can be monitored with a 50 Ω oscilloscope at the MON connector, with or without a DC block. The 450 Ω resistor functions as a 10:1 divider with a 50 Ω oscilloscope. MON can also be used as a very low jitter oscilloscope trigger when viewing optical waveforms.

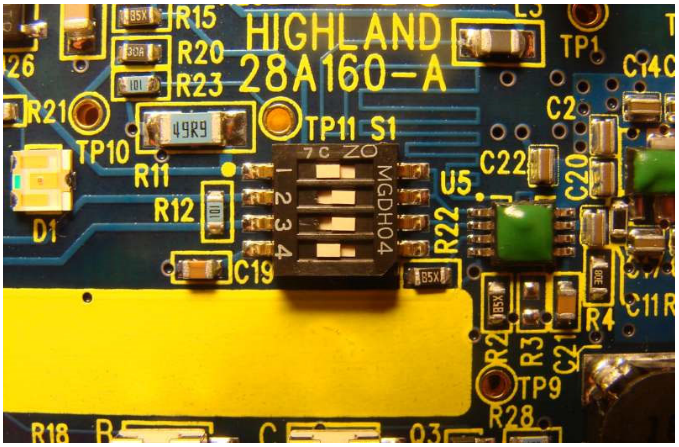
4. Connection and Operation

The standard T160 receives power over Micro-B USB connector or through the ribbon cable header.

4.1 Trigger DIP Switch Settings

Miniature dip switch S1 selects TTL or LVDS/PECL input. Settings are…





TTL LVDS/PECL

PHOTO 1: Trigger DIP Switch Settings

TTL input is applied to SMB connector J2. The T160 terminates this input with 50 Ω to ground. Input threshold is +0.4 volts, which is compatible with most TTL drivers, fast pulse/clock generators such as the Highland T240, and capacitor-coupled ECL.

Differential LVDS/PECL inputs are applied to the P1 ribbon cable connector, pins noted below. The T160 provides a 100 Ω differential termination. Common-mode voltage should be in the range of +0.5 to +3 volts, which accommodates most LVDS, PECL, and positive-supply CML sources. Minimum differential input swing is 200 mV p-p.

4.2 Ribbon Cable Connector

P1 is a 50-mil-pitch, 10-pin, 5x2 ribbon cable connector that can be used to apply power and control signals to the T160. The PCB header is Samtec # FTSH-105-01-L-D-K, and mates with Samtec FFSD series connectors. A convenient method of connecting to the T160 ribbon header is with a readily available, pre-fabricated ribbon cable assembly. The ribbon cable can be cut in half, providing two ribbon connector pigtails. A useful, 12-inch

cable assembly is the Samtec # FFSD-05-D-12.00-01-N, available from Digikey as # SAM8219-ND. If P1 is not used, apply power through the USB connector. In that case, trimpots set the laser BIAS and ON current, and the trigger input is via the J2 TTL input. If control inputs are applied via P1, turn all trimpots fully CCW.
A yellow dot identifies pin 1 of P1. The pinout is:

PIN	SIGNAL	FUNCTION
1	+5V	Power to T160
2	+5V	Power to T160
3	ILset	external voltage sets Laser ON current
4	VBset	external voltage sets Laser OFF bias voltage
5	Ground	
6	LVDS+	LVDS/PECL input +
7	LVDS-	LVDS/PECL input –
8	Ground	
9	Ground	
10	n/c	

TABLE 1: T160 10-Pin Ribbon Header Signals

Use all + 5 V and Ground pins, to minimize voltage drop in ribbon cables. The +5 supply must never drop below +4.50 V for normal operation. To avoid damage, never exceed +6.00 V. The P1 connector grounds, PCB ground plane, SMB shells, and mounting holes are all connected. + 5 supply voltage is accessible at TP8.

ILset is an analog input which sets the laser drive current, namely the current applied to the laser during an active pulse. An input range of 0 to + 3 volts sets the laser drive current from 0 to + 700 mA.

The VBset input controls the off-state laser bias voltage. 0 volts input forward-biases the laser by < 50 mV (cathode voltage is > -50 mV) and +3 volts input will forward-bias the laser by +1.5 volts (cathode voltage is -1.5 volts.) The laser anode voltage will rise by about +0.4 volts at full drive current due to the R_{DS-On} of Q1 and bias supply sense resistor (refer to Section 5.3.6).

4.3 USB Power Connector

The micro-B USB connector can be used to apply +5 volt power to the T160. The Highland model J6 can power the T160, and allow for laser drive up to 700 mA. The recommended USB cable is a 6 foot or shorter, Type A male to micro B male, Mediabridge #30-004-06B or Monoprice #5458. Other cables may be substituted, provided that the voltage drop due to resistive cable losses never cause the +5 supply to drop below +4.50 V at the T160. The + 5 supply voltage is accessible on the T160 at TP8.

4.4 Trimpots

Two trimpots are provided for use when the P1 connector is not used. The pot labeled "B" sets the bias voltage, and the "C" pot sets laser ON current. Clockwise increases both.

Set both pots fully counter-clockwise (CCW) when P1 programming is used.

One possible setup procedure is:

1. Turn both pots to minimum, CCW. Select TTL mode with no input. Apply power.

2. Measure the voltage from TP8 to TP6 and set the C trimpot for the desired laser ON current. The sense resistor is 0.2 Ω, so current in amps is measured voltage times 5.

3. Measure the voltage from TP5 to TP7. It should be close to the voltage measured in step 2. Advance the B trimpot slowly until this voltage begins to drop. That indicates the beginning of laser conduction. Now measure the voltage from TP3 to ground (TP7); this is the bias voltage that initiates laser conduction. Turn the B pot CCW to reduce this voltage by about 300 mV.

4. Apply actual logic inputs and observe optical output. Fine tune B and C for best optical performance.

Refer to Section 5.2 for method of adjusting T160 settings for optimal width and laser output

4.5 Monitor Connector

J3 MON is an SMB connector that can be used to monitor laser quiescent bias voltage with a voltmeter, or, laser waveforms with a 50 Ω oscilloscope. It can also be used as a low-jitter oscilloscope trigger. The MON path has a series 450 Ω resistor, functioning as a 10:1 divider of laser voltage into a 50 Ω oscilloscope.

4.6 Test Points

Test points allow measurement of laser BIAS and ON current. See section 3.

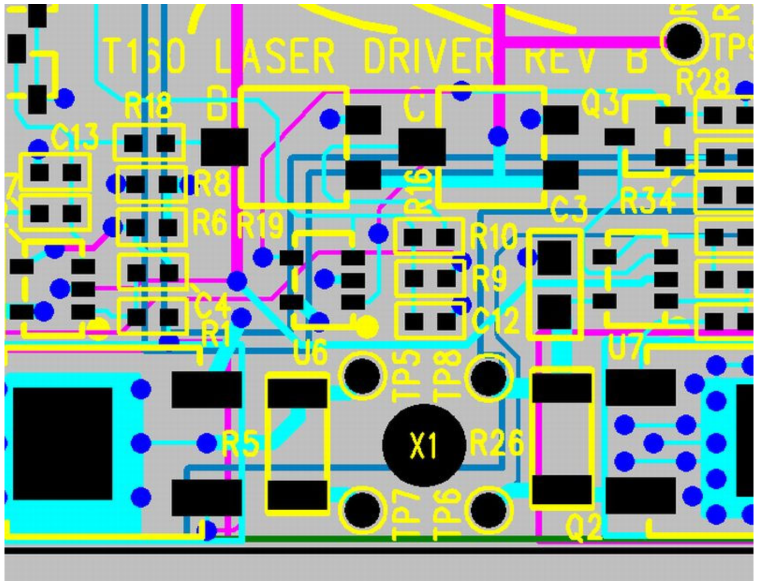
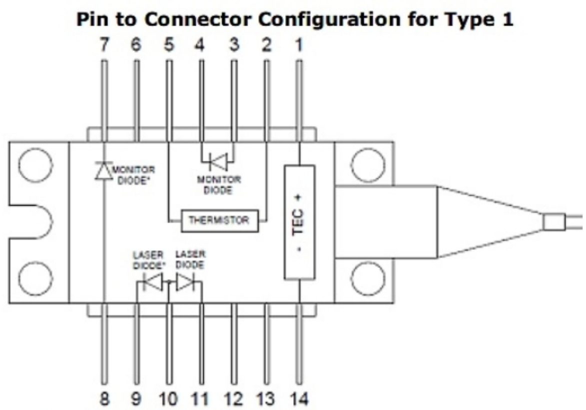


DIAGRAM 3: T160 Output Drive Current Test Points

4.7 Laser Connections

The Standard Type-1 butterfly package pinout is as follows:



1	TEC Anode
2	Thermistor
3	PD Anode
4	PD Cathode
5	Thermistor
6	N.C.
7	PD Cathode
8	PD Anode
9	LD Cathode
10	LD Anode
11	LD Cathode
12	N.C.
13	Ground
14	TEC Cathode

DIAGRAM 4: Type-1 Butterfly Laser Connections

Seven pads are provided to solder to the laser side of a standard butterfly package. Pin assignments are:

PCB PIN	BUTTERFLY PIN	FUNCTION	CONNECTION
1	8	not used	Connects to TP2
2	9	laser cathode	ground
3	10	laser anode	
4	11	laser cathode	ground
5	12	not used	connects to P2-2
6	13	ground	connects to P2-3
7	14	not used	connects to P2-1

TABLE 2: T160 / Type-1 Laser Corresponding Connections

NOTE: Type-1 butterfly lasers typically assign the negative TEC connection to pin 14. The T160 provides access to this pin at P2-1.

The T160-2 and T160-14 includes horizontal spring sockets to provide a removable, non-soldered connection to the butterfly leads.

The laser lead diameter must be between 0.015-inches to 0.026-inches to be compatible with the T160 pinsockets. Plunge depth must not exceed 0.095-inches into the pin sockets to avoid damaging onboard components on the T160.

Laser anode and cathode lead lengths must be minimized to reduce parasitic inductance that can lead to laser-drive anomalies.

Butterfly packages are available with various lead heights above the mounting surface. The T160 pin socket centerline is nominally 0.274-inches above the mounting flange (T160-9, T160-14 evaluation versions), or, 0.087-inches above the bottom of the T160 PCB (OEM versions). Typically, standard butterfly package leads are located approximately 0.200-inches to 0.220-inches (5 – 5.5 mm) above the bottom mounting surface. #2 stainless steel washers may be utilized, to shim up the laser lead height into alignment with the T160 pin sockets.

The T160 is optionally available with solder pads instead of pin sockets, providing a secure, soldered connection to the butterfly in OEM applications. Minimum quantities apply, contact factory for details.

4.8 Mounting and Cooling

The T160 is provided with four 4-40 sized mounting holes. It is recommended that the T160 is bolted to a T163 or equivalent baseplate shared with the laser, using suitable aluminum spacers. The mounting holes provide ground and a path for heat flow to the baseplate.

An additional hole is provided on the lower edge of the board about midway between the main mounting holes. This helps to clamp the board to an optional heat transfer block located between the PCB and the baseplate. The T160 power dissipation is proportional to the programmed laser drive current:

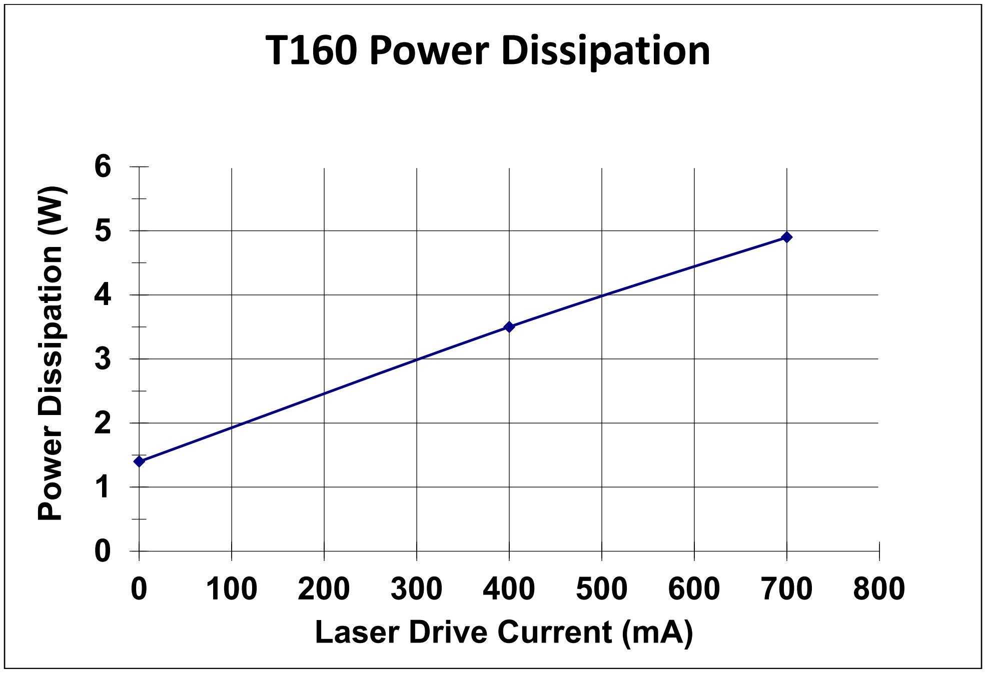


CHART 1: T160 Power Dissipation vs. Laser Drive Current

Air flow is recommended, minimum 150 LFPM at laser currents up to 400 mA. At higher laser program currents, additional air flow or underside heat sinking to the baseplate is recommended; consult Highland about specific applications.

4.9 Connecting a TEC Controller

Most butterfly lasers include an internal thermal electric cooler (TEC) and thermistor for closed-loop temperature control. The T160 connects to one side of the butterfly package, with provisions to connect to an external thermal electric cooler (TEC) controller. Type-1 butterfly laser packages typically assign pin 14 to the negative TEC pin, accessible on the T160 at P2, pin 1 (refer to Section 4.7). The positive TEC pin and thermistor pins are not accessible from the T160, as they are located on the opposite side of the laser. For optimal pulse performance, care should be given to keep laser lead length as short as possible by mounting the butterfly flush against the T160. TEC controller connections can be made with longer leads (refer to PHOTO 2).

5. Basic Operation and Performance

5.1 System Setup

The T160 evaluation kit includes a convenient mounting plate / heatsink, power supply, and associated cabling. The evaluation kit is recommended for those experimenting with laser performance under varying electrical conditions, such as research and development applications. OEM versions are also available for integration into existing systems.

5.1.1 Recommended Equipment

In order to operate the T160, the following equipment is recommended:

- + 5 volt power supply capable of sourcing at least 1 Amp, and low-loss micro-B USB cable (included in evaluation kit)
- Heatsink / laser mount for applications exceeding 400 mA laser drive (included in evaluation kit)
- 50 Ω SMB trigger and monitor cables (included in evaluation kit)
- Pulse generator trigger source (such as the Highland Technology, P500 DDG)
- Oscilloscope with ≥ 12 GHz analog bandwidth
- High-speed photodetector with ≥ 12 GHz analog bandwidth (such as the New Focus, Model 1434 or 1434-50)

5.1.2 Connecting the T160

Refer to Section 4.4 for recommended initial trimpot settings.

a) Start with power supply disconnected. Connect the T160 trigger input to a suitable trigger source. For most applications, this connection is made with a 50 Ω SMB coax cable to the TTL Trig input jack.

b) Connect the laser to the T160. Trim the leads so that they register the full pinsocket depth, without protruding past the opposite end. When the T160 evaluation kit is used, it may be necessary to place shims between the butterfly package and mounting flange, so that the leads are aligned with the pinsocket centerlines.

c) Connect the power source to the T160. The Highland Technology Model J6 power supply and USB micro-B cable, included in the T160 evaluation kit version, is recommended.

d) Set the trigger switch (S1) to accept TTL triggers by sliding S1-1 and S1-4 "ON" and S1-2 and S1-3 "OFF"(refer to Section 4.1).

e) Provide necessary oscilloscope trigger provisions. If the oscilloscope requires an external pre-trigger, one approach is to electrically trigger the oscilloscope before the T160. A convenient method of electrically pre-triggering the oscilloscope is with a DDG, such as the Highland Technology P500. Alternatively, if only one trigger source is available, a suitable length of low-loss, 50 Ω coax can be used with a 50 Ω, -6dB power combiner, to provide a delayed trigger signal to the T160.

f) Couple the laser to the photodetector. Connectorized fiber coupled lasers are convenient to work with because they provide a stable method of transporting light directly between the laser and photodetector.

5.1.3 Initial Power-up

Start the trigger source, and verify that the oscilloscope is triggered. Check that the T160 'C' trimpot is rotated fully counterclockwise before applying power to the T160. When power is applied to the T160, a green onboard LED (D1) will illuminate.

5.2 Optimizing Pulse Width and Laser Output

The T160 provides onboard trimpots for adjusting laser BIAS voltage, and DRIVE current. Alternatively, parameter adjustments can be made using analog control voltages and the 10-pin ribbon header. Embedded OEM applications are well suited for using the ribbon header for system control integration. Under certain evaluation circumstances, analog parameter adjustment via the ribbon header is advised.

5.2.1 Performance tuning for gain switched pulses < 10 ns

The T160-2 is optimized for generating laser drive pulses < 10 ns wide. Since the T160 is a pulse follower, a trigger source capable of making narrow pulses is necessary. The Highland Technology T240 is an example of a pulse generator that is capable of converting a slow trigger into a fast, user-defined T160 trigger.

The following general adjustment procedure is recommended for sub-nanosecond pulse generation:

a) Rotate the bias control trimpot ('B') fully counter-clockwise (CCW). This translates to a measured voltage at TP3 of < 50 mV, and a laser 'OFF' bias condition.

b) Set the laser drive current trimpot ('C') to a nominal current that is compatible with the laser being evaluated. Laser drive current is calculated by measuring the voltage drop across a 0.2 Ω sense resistor, accessible between TP8 and TP6; Laser ON current is equal to 5 * $V_{TP8-TP6}$.

c) Activate the trigger pulse generator. Set the trigger generator to a pulse width that is wider than the desired laser drive pulse width. For very narrow pulse generation, a good starting trigger pulse width is around 20 ns. Starting with a wide pulse makes it easier to locate the optical waveform on the oscilloscope.

d) Begin narrowing the laser drive pulse by ***slowly*** decreasing the trigger source pulse width. For example, if a Highland T240 is used to trigger the T160, adjust the pulse width of the T240, not the generator triggering the T240. At one point, the optical pulse tail will diminish as the active region carrier accumulation approaches the lasing threshold. This transition can occur suddenly, well under 100 ps. Since the adjustment is not yet optimized, a post-pulse due to relaxation oscillation, may still be visible.

e) At this point, the pulse shape can be improved by ***carefully*** rotating the laser DRIVE current trimpot ('C'). Note that minor adjustments can have major effects.

f) Further optimizations require iterative adjustments to the BIAS ('B') and DRIVE current ('C') trimpots. Typically, the narrowest pulses are obtained with a minimal BIAS setting. Changing any of these parameters, including the pulse-repetition rate, will require re-adjustment of the other parameters.

Note that the minimum optical pulse width which can be obtained using the T160 depends greatly on the parasitic properties of the laser and laser package (refer to Section 5.3).

Although the T160-14 pulse width adjustment range spans 0 to 50 μs, the T160-2 is recommended for generating optical pulse widths less than 1 ns, since it provides faster rising edges.

The T160 duty-cycle should be limited to 60%, or less. Depending on the laser program current setting and pulse repetition rate (PRR), the maximum pulse width is limited according to Chart 2 below:

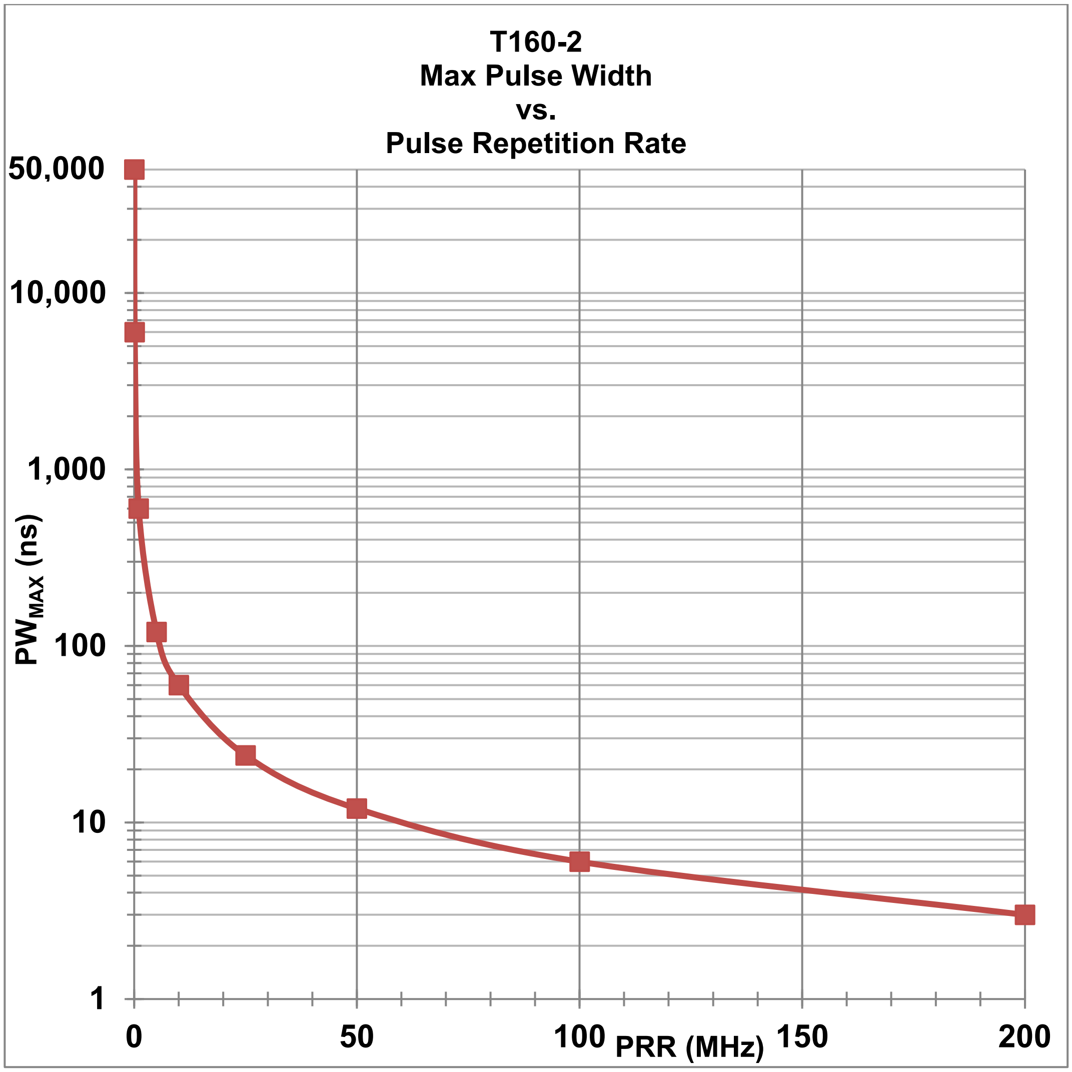
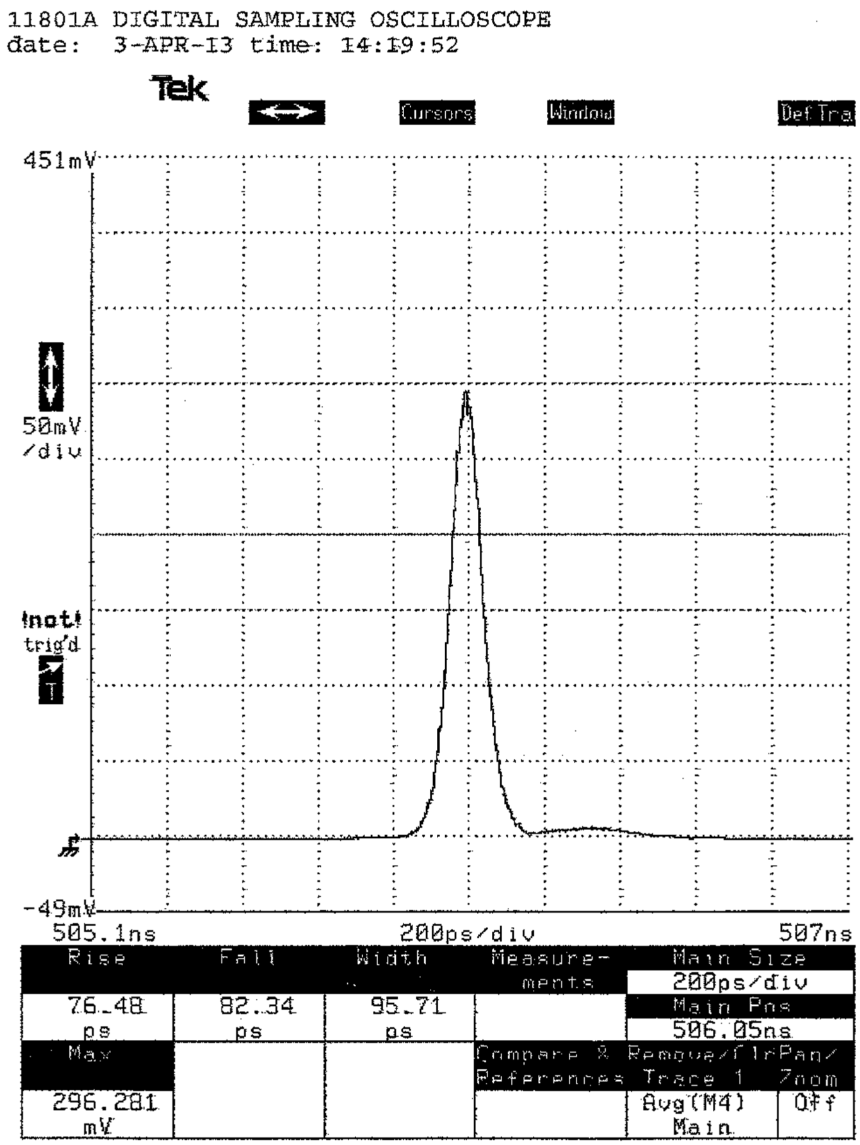


CHART 2: T160-2 PW_{max} vs. PRR and Program Current

PRR (MHz)	0.010	0.100	1	5	10	25	50	100	200
PW max (ns)	50,000	6,000	600	120	60	24	12	6	3

TABLE 3: T160-2 PW_{max} (ns) vs. PRR (MHz) and Program Current (mA)



WAVEFORM 1: Sub 100 ps impulse, Photodigm 1064 DBR laser, 50 mW$_{pk}$

5.2.2 Performance tuning for gain switched pulses > 10 ns

The T160-14 is optimized for generating laser drive pulses > 10 ns wide. The T160-14 has a slower rising-edge than the T160-2, providing fewer waveform anomalies due to circuit parasitics. Since the T160 is a pulse follower, a trigger source capable of making pulses at least 10 ns wide is necessary. The Highland P500 and T660 Digital Delay Generators are suitable trigger sources for pulse-repetition rates up to 16 MHz.

The following general adjustment procedure is recommended for pulse generation from 10 ns to 50 µs:

a) Rotate the bias control trimpot (‘B’) fully counter-clockwise (CCW). This translates to a measured voltage at TP3 of < 50 mV, and a laser ‘OFF’ bias condition.

b) Set the laser drive current trimpot (‘C’) to a nominal current that is compatible with the laser being evaluated. The nominal laser drive current is calculated by measuring the voltage drop across a 0.2 Ω sense resistor, accessible between TP8 and TP6; Laser ON current is equal to 5 * $V_{TP8-TP6}$.

c) Activate the trigger pulse generator. Adjust the trigger generator pulse width to produce the desired optical pulse width. Starting with a wider pulse, and narrowing from there, provides a working area to tune the trigger source pulse to match the target pulse width.

d) Further optimizations require iterative adjustments to the trigger generator pulse width, and BIAS (‘B’) and DRIVE current (‘C’) trimpots. Changing any of these parameters, including the pulse-repetition rate, will require re-adjustment of the other parameters.

Note that the minimum optical pulse width which can be obtained using the T160 depends greatly on the parasitic properties of the laser and laser package (refer to Section 5.3).

Although the T160-14 pulse width adjustment range spans 0 to 50 μs, the T160-2 is recommended for generating optical pulse widths less than 10 ns, since it provides faster rising edges.

The T160 duty-cycle should be limited to 60%, or less. Depending on the laser program current setting and pulse repetition rate (PRR), the maximum pulse width is limited according to Chart 3 below:

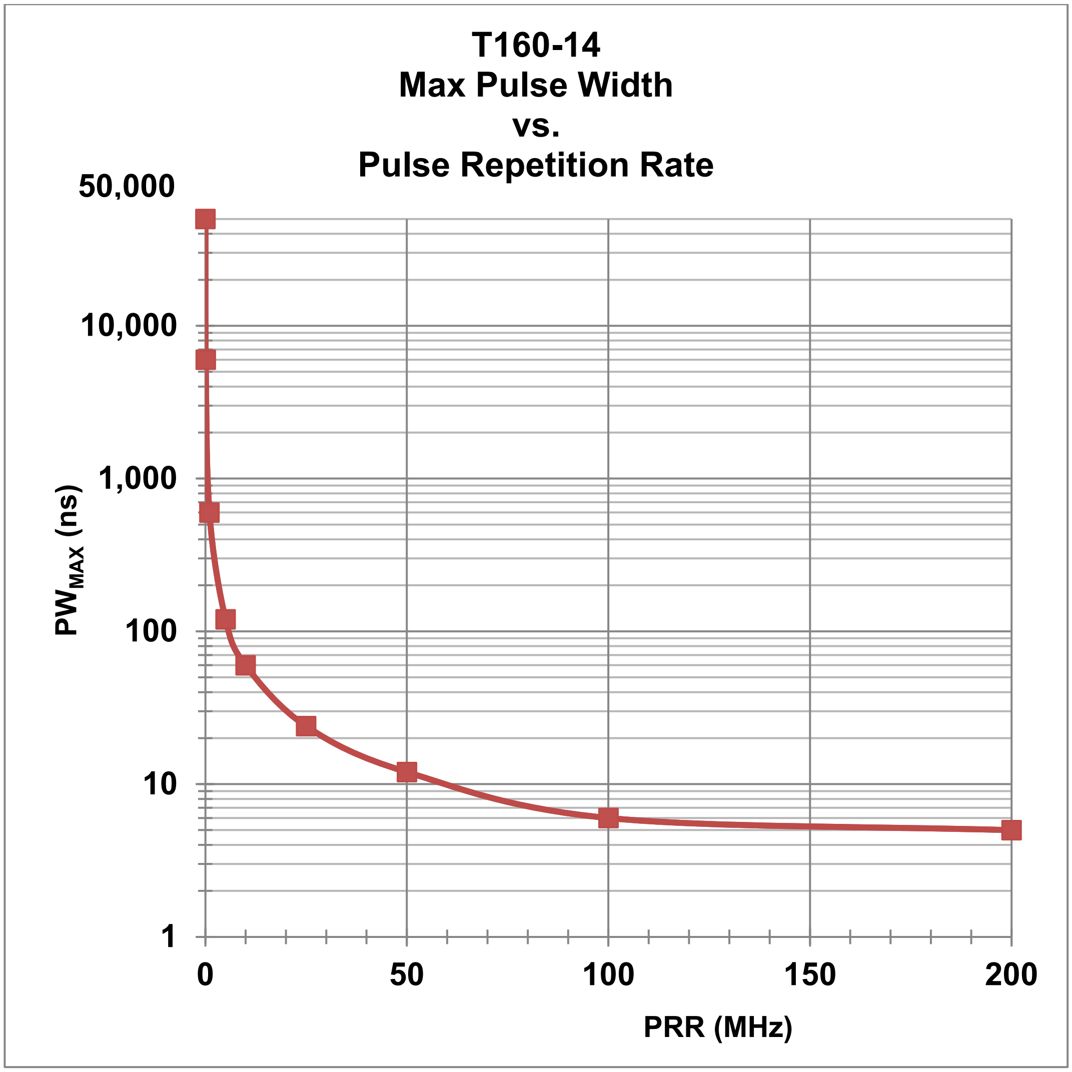


CHART 3: T160-14 PW$_{max}$ vs. PRR and Program Current

PRR (MHz)	0.010	0.100	1	5	10	25	50	100	200
PW max (ns)	50,000	6,000	600	120	60	24	12	6	5

TABLE 4: T160-14 PW$_{max}$ (ns) vs. PRR (MHz) and Program Current (mA)

5.3 Common Unexpected Optical Behavior

Solid state lasers can exhibit various anomalous optical phenomena that can be attributed to laser physics and electrical drive conditions. The following unexpected optical behaviors are frequently experienced during laser evaluation:

5.3.1 Overshoot

Overshoot is commonly observed in laser diode optical waveforms, peaking up to more than twice the level of the settled maximum. One possible cause is the fast, gain-switched optical spike that results when carrier accumulation just crosses the laser diode's lasing threshold in the laser's active region. This phenomenon is desirable for applications requiring the production of fast Gaussian optical impulses below 100 ps, but it requires very precise electrical drive conditions (refer to section 5.2.1). Even wide, rectangular optical pulses can exhibit very fast, narrow, gain-switched overshoot following the rising-edge, before settling at the pulse plateau level.

Excess lead inductance can also cause overshoot, but typically also causes post rising-edge ringing in the laser's current drive path (refer to section 5.3.3).

One method of determining whether an observed optical overshoot is caused by the electrical drive, is to compare optical and monitor waveforms. If the two waveforms resemble each other, the overshoot is likely electrical, and the laser is reproducing it. If the electrical waveform doesn't resemble the optical waveform, then, the laser is likely introducing the overshoot.

5.3.2 Spikes

A series of optical spikes, with successively diminishing amplitude, can be attributed to the laser itself, or, the electrical drive.

Laser relaxation oscillation is an optical phenomenon that can result when a laser is quickly switched on from far below threshold. As the carrier pairs rapidly accumulate and recombine, light output peaks are generated until the carriers and photons reach equilibrium. Typically, the spike interval is reduced as the 'ON' drive current is increased above lasing threshold. If relaxation oscillations are the cause of optical spikes, the electrical monitor output waveform will have a negligible series of spikes, and look significantly different than the optical output.

Ringing in the electrical drive path can also cause a series of optical peaks corresponding to the electrical waveform. If the laser 'ON' drive is set to operate just above threshold, the optical spikes will likely be separated by an interval of no light output. If the laser 'ON' drive is set to operate well above lasing threshold, the optical peak variations will appear more sinusoidal. If electrical ringing is the cause of optical peak variations, it will be visible at the monitor output (see section 5.3.3).

5.3.3 Ringing

The primary cause of ringing in the laser drive path is series inductance reacting with parasitic shunt capacitance. Series inductance can result from excess lead length and wirebonds within the butterfly package. Shunt capacitance results from a combination of the laser diode junction and mounting techniques within the butterfly package. The product of circuit inductance (L) and capacitance (C) is related to the ringing interval and period according to the equations:

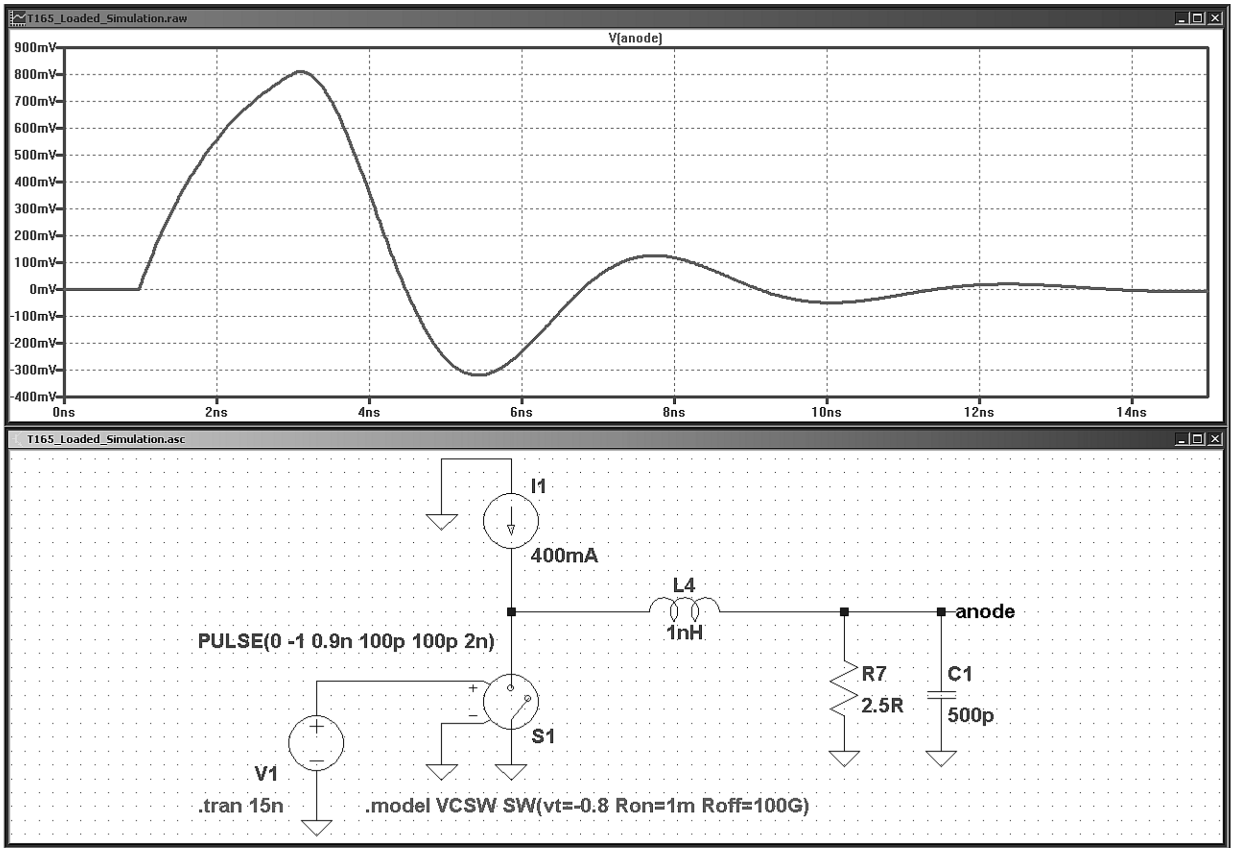
Estimating LC by observing the ringing Period (P): **$LC = (P / 2\pi)^2$**

Estimating LC by observing the ringing frequency (F_0): **$LC = (1 / [2\pi * F_0])^2$**

Typically, the butterfly laser diode contributes the majority of shunt capacitance, as much as several hundreds of picofarads. This capacitance can be directly measured using a capacitance meter capable of resolving tens to hundreds of picofarads. If desired, the circuit inductance can be calculated by substituting the directly measured capacitance in the appropriate formula and solving for L.

Ringing observed on the electrical monitor output is typically of greater amplitude than actually present at the laser's anode pin. The electrical monitor output is a passive, single-ended pickoff, originating at the laser anode. EMI generated by quickly switching high laser program currents can couple into the monitor output, producing hash and other artifacts. Suspicious electrical monitor waveforms can be cross-checked with a low inductance, ground-shielded probe at the laser's anode pin.

If the desired optical pulse width is ≥ 10 ns, the T160-14 may be more appropriate for the application. The slower ~ 2.5 ns T160-14 edge speeds will reduce ringing resulting from parasitic capacitance and inductance.



WAVEFORM 2: Effects of parasitic inductance and capacitance on laser drive

5.3.4 Dipping

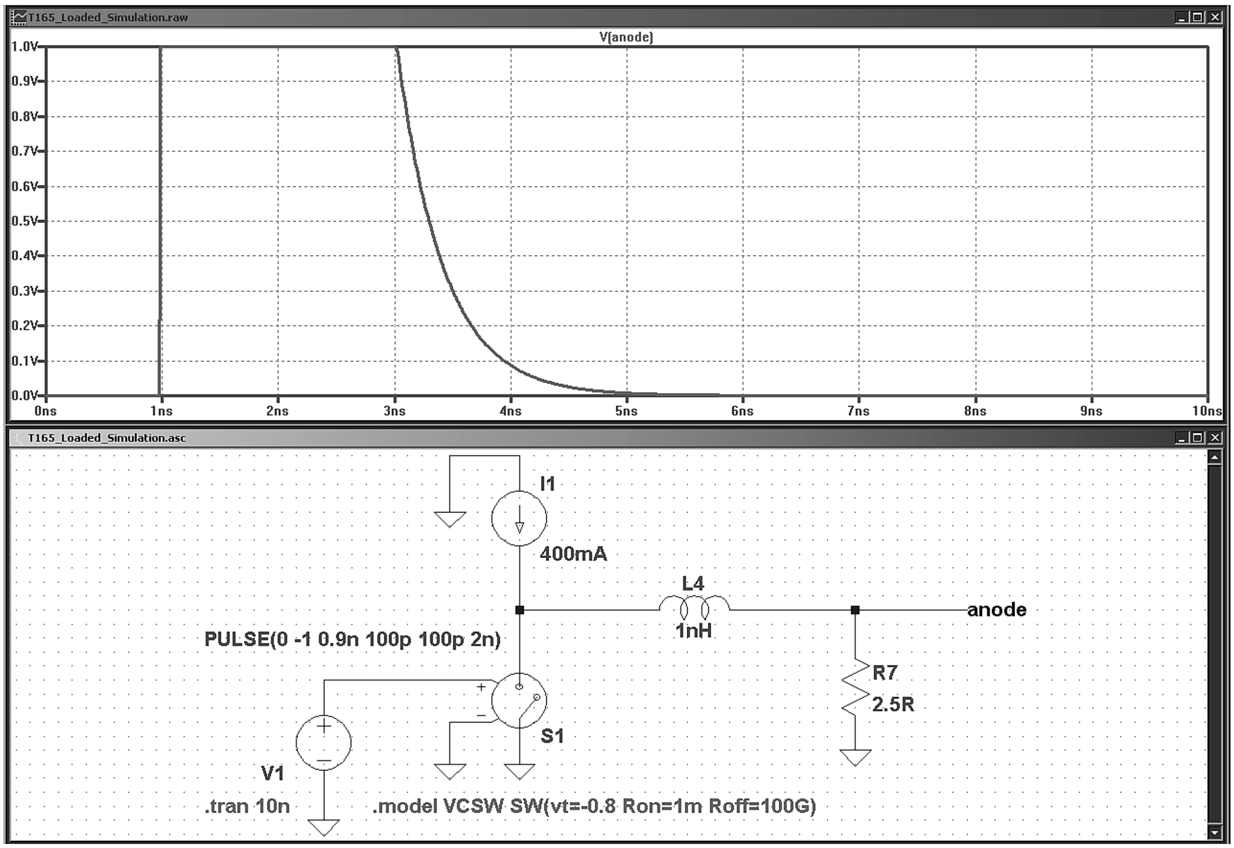
Some laser diodes will produce a dip in optical output amplitude, hundreds of nanoseconds following the rising-edge.

5.3.5 Falling-edge Tail

Parasitic inductance in the current path between the driver and load can slow down the falling-edge. When the laser is OFF between shots, laser drive current is diverted to ground (refer to Q1 in Section 3). A suitable trigger causes the full program current to quickly flow into the laser diode, resulting in a fast ON rising-edge. A small amount of parasitic inductance doesn't critically impede the rising-edge voltage excursion, as full current is actively available. When the laser drive returns to the OFF state, the laser anode and current source are both shorted to ground. Since the OFF transition is passive, less current is available to return the anode to ground. This results in a lengthened L(di/dt) transition.

Parasitic inductance is additive, commonly resulting from device lead length and internal bond wire structuring. A typical 0.020-inch diameter butterfly lead can contribute more than 1 nH per 0.100-inch lead length, and, a single 0.001-inch diameter wirebond can contribute up to 3 nH per 0.100-inch. As a general rule-of-thumb, keep lead length below 0.100-inch and mount the laser with the lead frame abutting the T160 (see section 4.7). Wirebond inductance can be high, especially if a laser wasn't designed for high-frequency operation. Lasers designed for fast pulse operation often utilize multiple parallel wirebonds in an effort to reduce inductance.

A simplified circuit, simulating the current drive response of a simulated laser's dynamic resistance, is provided below. The 1 nH series parasitic inductance causes a falling-edge tail.



WAVEFORM 3: Effects of parasitic inductance on laser drive.

Minimizing the anode and cathode lead lengths is necessary to achieve fast edges. Additionally, utilize a laser that is manufactured with low-inductance wirebond techniques, to minimize excess butterfly package inductance.

5.3.6 DC Offset

In between trigger events, the laser drive current is diverted to the bias supply (refer to Q1 in Section 3). At high program currents, the finite resistance of Q1 can result in a positive DC offset at the laser anode pin (refer to Chart 4 and Waveform 4 below):

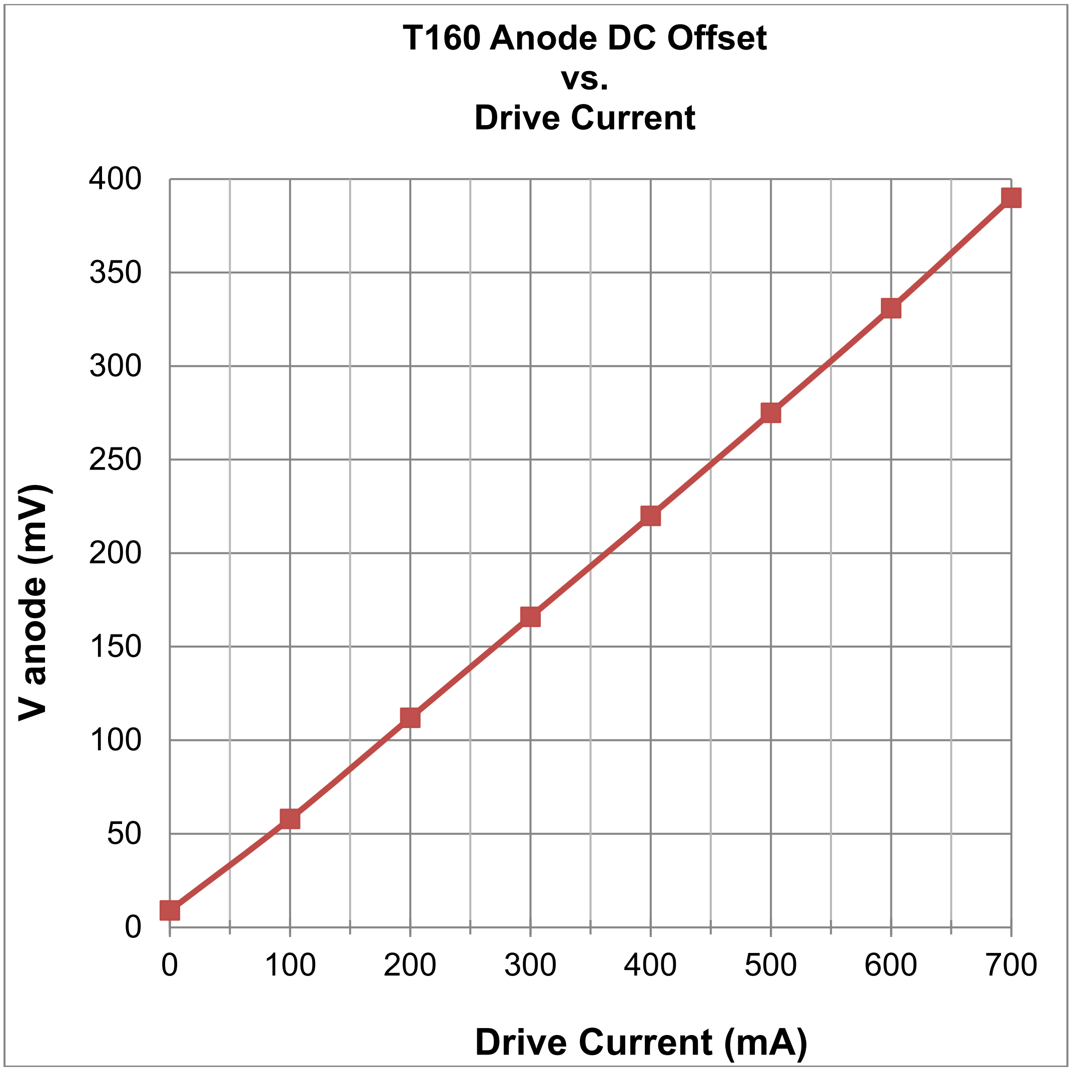
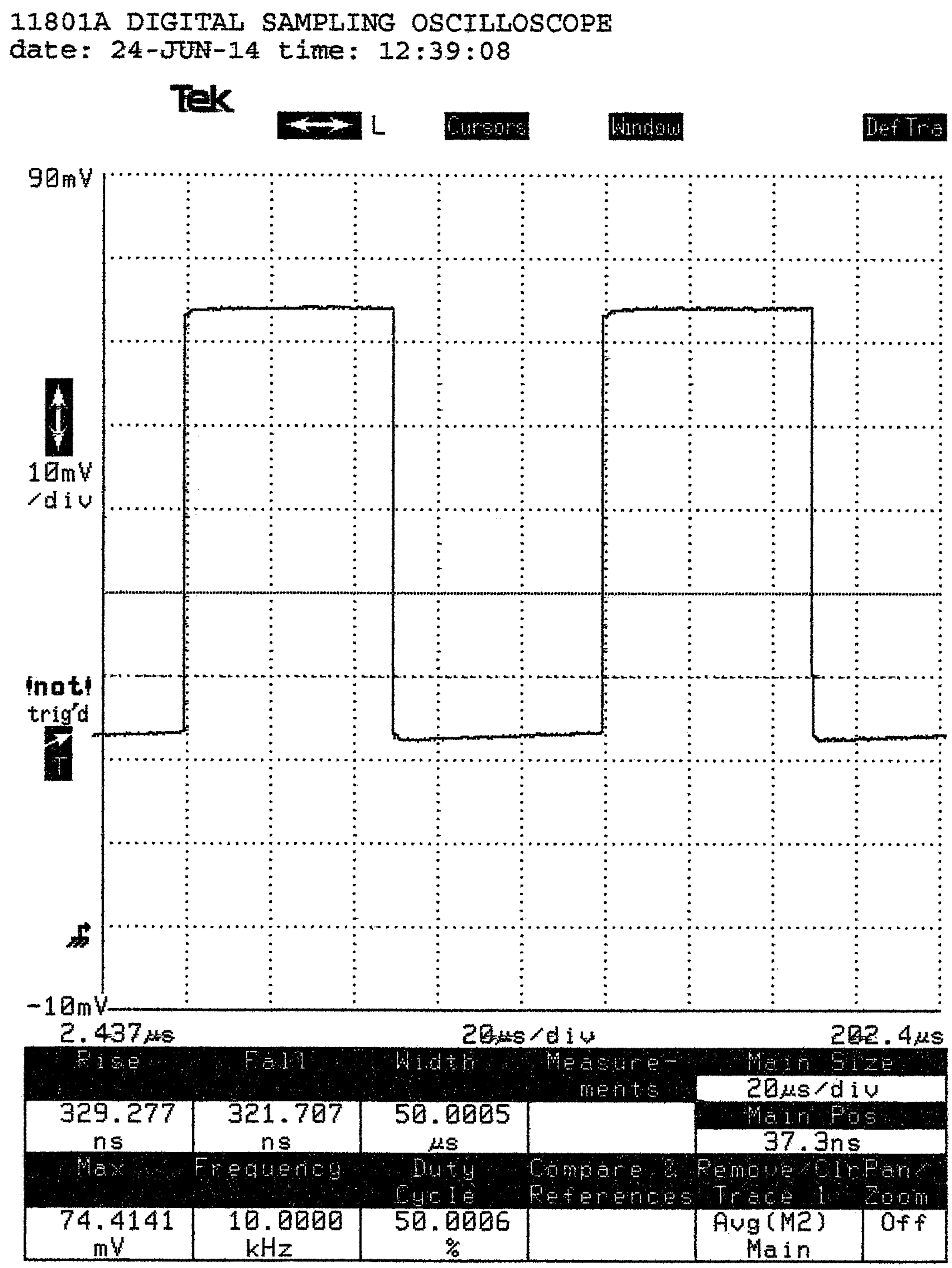


CHART 4: Unloaded Anode DC Offset as a function of drive current

Iset (mA)	0	100	200	300	400	500	600	700
Vanode (mV)	9	58	112	166	220	275	331	390

TABLE 5: Unloaded Anode DC Offset (mV) as a function of drive current (mA)



WAVEFORM 4: ~30 % Baseline DC offset while driving 1 Ω resistive load at 750 mA

In this example, the 1 Ω resistor load forms a current divider with the bias supply resistor and drive switch (Q1) (Refer to Section 3). Approximately 70% of the ON current source flows through the bias supply, with the remaining 30% flowing through the load resistor. The 0.2 Ω resistor in the bias supply path, causes approximately 102 mV DC offset (observed across TP 5 – TP 7). The remaining 110 mV offset is due to the finite ON resistance of the drive switch (Q1). If the 1 Ω resistor was replaced by a butterfly laser in this example, 100% of the ON current source would flow through the bias supply, resulting in an OFF state DC offset of approximately 400 mV. Since butterfly laser diodes require around +2 V to conduct, a dead-band of about 1.6 V maintains a safe, no-light margin between triggers.

5.3.7 Temporal Jitter

Applications requiring minimal temporal jitter, with pulse widths ≤ 10 ns, should utilize the T160-2 version. The slower rise-time of the T160-14 exhibit slightly more temporal jitter, and may be problematic when attempting to make stable, sub 100 ps pulses.

Also be aware that an externally triggered oscilloscope may report excessive jitter if the observed waveform is far out in time, relative to the trigger event. This can be avoided by zooming in on the waveform closest in time to the trigger event, minimizing the oscilloscope's timebase jitter.

5.3.8 No Optical Output

Check that the pinout of the laser diode matches the pinout of the T160.

Check that the trigger select switch (S1) is set configured to accept a trigger signal on the appropriate connector (refer to Section 4.1).

The T160 has a +2.5 V maximum rated compliance. In order to emit coherent light, the laser's rated anode voltage must be less than or equal to +2.5 V (ground referenced) at operating current.

The T160 is designed to drive low-impedance laser diodes. Many Type-2 telecom lasers include an internal 50 Ω resistor in series with the anode, and are designed to be driven by a 50 Ω RF voltage source. If this type of laser is to be driven, the laser will quickly reach the +2.5 V T160 compliance limit (the resistor drops +50 mV / mA, in addition to the laser's forward voltage). At moderate to high program current, there won't be enough voltage available across the laser to operate.

Since the T160 is a follower, it requires a trigger pulse as long as the desired output pulse. For very narrow pulses, this requires a trigger source that is capable of generating narrow pulses.

The T160 is not designed to operate under continuous wave (CW) conditions. Optical pulses correspond with trigger events; in the absence of a trigger signal, laser program current does not flow through the laser. Unlike the T165 that has a ≤ 50 mA quiescent current limit, the T160 can accommodate up to 700 mA for up to 50 µs. If the bias adjustment is adjusted to shift the anode +1.5 V, relative to the cathode, the quiescent current can still be up to 700 mA. Since most butterfly laser diodes require at least +2 V forward bias to conduct, little to no laser light would be produced.

5.4 Using a TEC Controller

5.4.1 Benefits of using a TEC

A properly adjusted TEC cooler / controller can provide improved spectral, temporal and amplitude stability of a butterfly laser.

5.4.2 Connecting a TEC Controller

Most Type-1 butterfly packaged laser diodes incorporate an internal Peltier cooler and thermistor for closed-loop thermal regulation. Since the TEC response time is typically on the order of seconds, parasitic lead inductance is not critical to normal operation. Mount the butterfly package directly against the T160, in order to minimize the anode and cathode lead length. The T160 provides a 3-pin male header (P2) that connects to pins 12 – 14 of the butterfly. Typically, the negative TEC connection is pin 14 of the butterfly, corresponding to P2-1. The header pins of P2 are 0.010-inches in diameter, and will accept a 3-pin mating female plug (e.g. TE Connectivity 3-640440-3), or, single-wire pin socket. Thermistor and positive TEC connections usually are located on the butterfly leads that don't connect to the T160. One method of making these connections is to terminate the leads of a ribbon cable with a 0.100-inch pitch, 7-pin terminal block (e.g. Phoenix Contact 1725708). The leads of the terminal block are designed to mount to a PCB, and will require a 90-degree bend to avoid interference with the T160 base plate. Refer to the example configuration below:

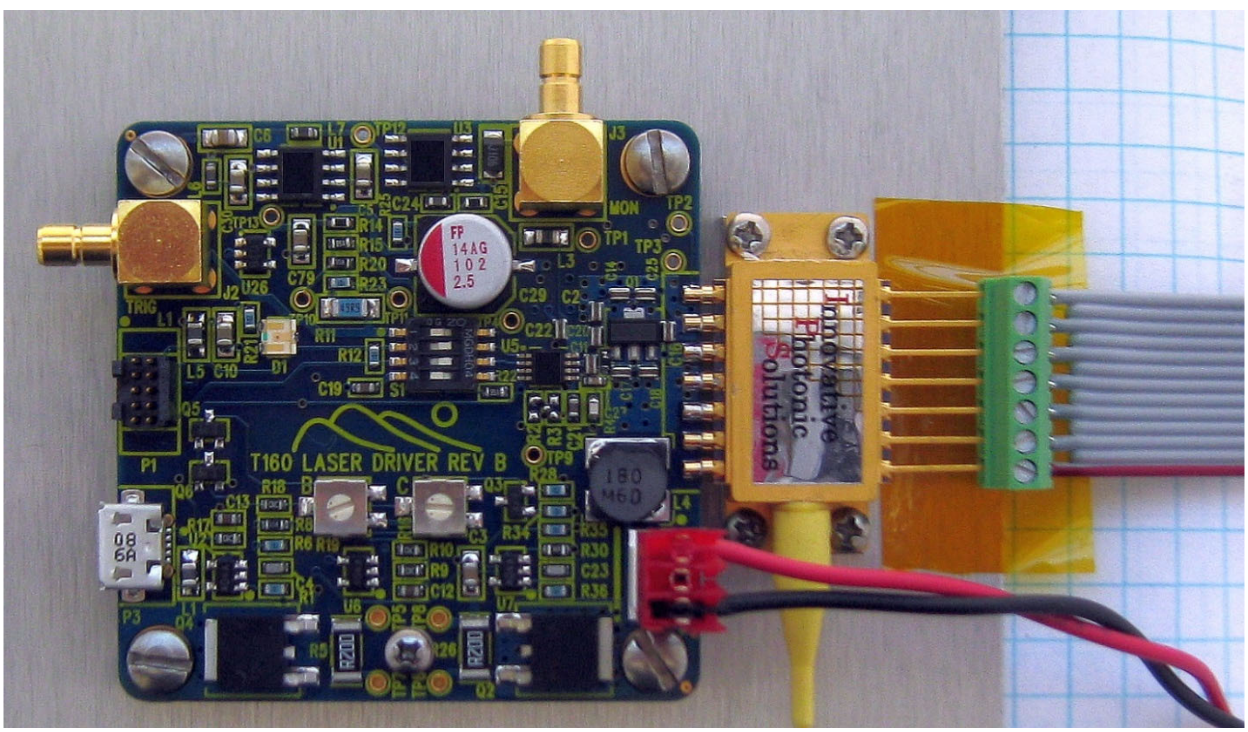


PHOTO 2: Example of TEC connections using onboard header P2 and terminal block

6. Dimensions

Dimensions are in inches. Mounting holes are 0.120-inch diameter, with 0.230-inch round copper pads on both sides. The hole at X 1.000-inch, Y 0.175-inch is 0.094-inch diameter and may be used to secure the board to an insulated heat sink block below. The board is 0.062-inches thick.

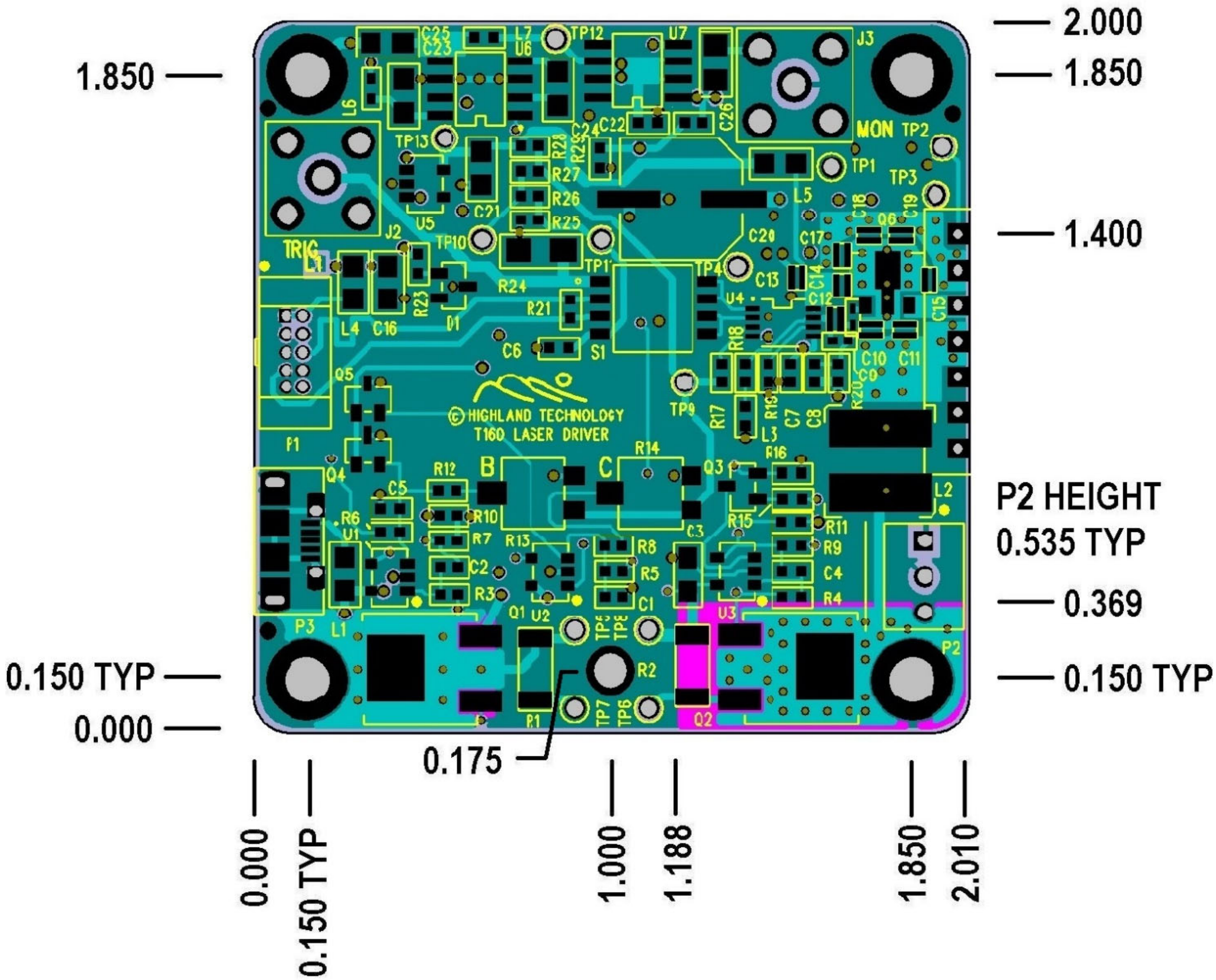


DIAGRAM 5: T160 layout and dimensions

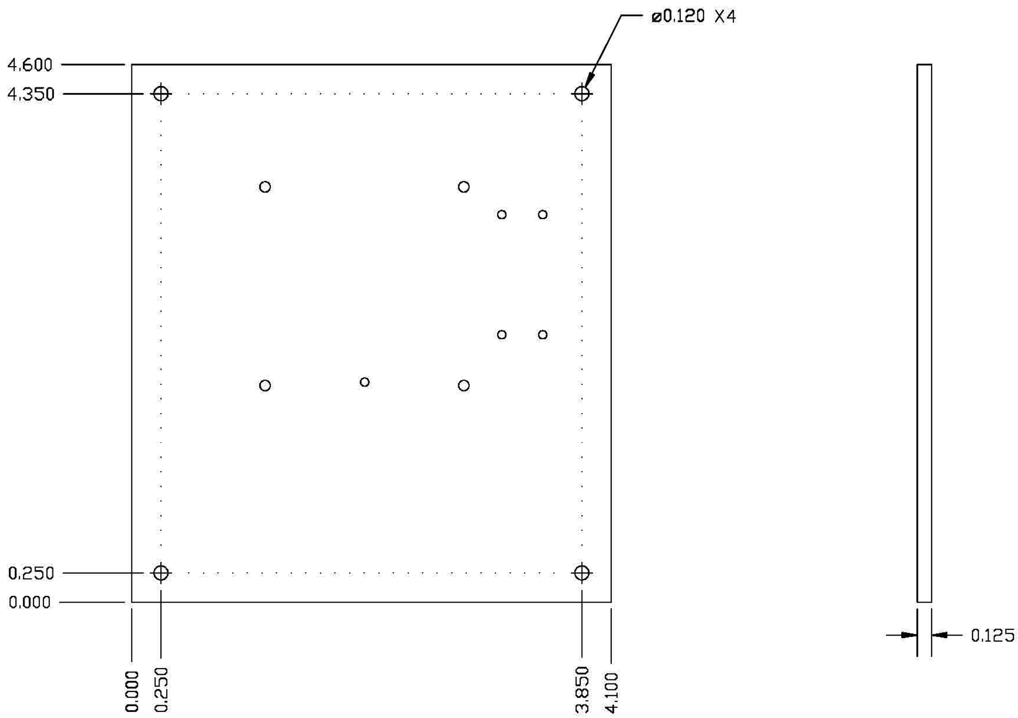


DIAGRAM 6: T163 mounting flange dimensions

7. Versions

Standard (recommended) evaluation versions of the T160 include:

T160-9: picosecond laser diode driver evaluation kit (includes T160-2 installed on T163 mounting flange with J6-1 USB power supply and two J53-1 3' SMB to BNC cables)

T160-15: nanosecond laser diode driver evaluation kit (includes T160-14 installed on T163 mounting flange with J6-1 USB power supply and two J53-1 3' SMB to BNC cables)

Standard integration (board-only) versions of the T160 include:

T160-2: picosecond laser diode driver with TTL trigger, differential trigger, and pin sockets

T160-14: nanosecond laser diode driver with TTL trigger, differential trigger, and pin sockets

8. Customization

Consult factory for information about additional custom versions.

9. Hardware Revision History

Revision D	Aug 2022 Functionally equivalent to Revisions A thru C Adds suppressed output upon power-cycle
Revision C	Jan 2014 Functionally equivalent to Revisions A and B
Revision B	Mar 2013 Functionally equivalent to Revision A Adds additional heatsink screw hole near TP8, and changes SMB connectors from vertical to right-angle exit
Revision A	Aug 2012 Initial PCB release

10. Accessories

J6-1:	5 volt USB power supply (1 included with evaluation kit purchase)
J42-1:	3’ SMB to SMA cable
J53-1:	3’ SMB to BNC cable (2 included with evaluation kit purchase)
J53-2:	6” SMB to BNC cable
T163-1:	butterfly laser driver mounting flange (must be installed at factory, 1 included with evaluation kit purchase)

Note: Some accessories listed above are furnished with the purchase of the T160 evaluation versions (-9 and -15). Accessories must be purchased separately for T160 integration/board-only versions (-2 and -14).