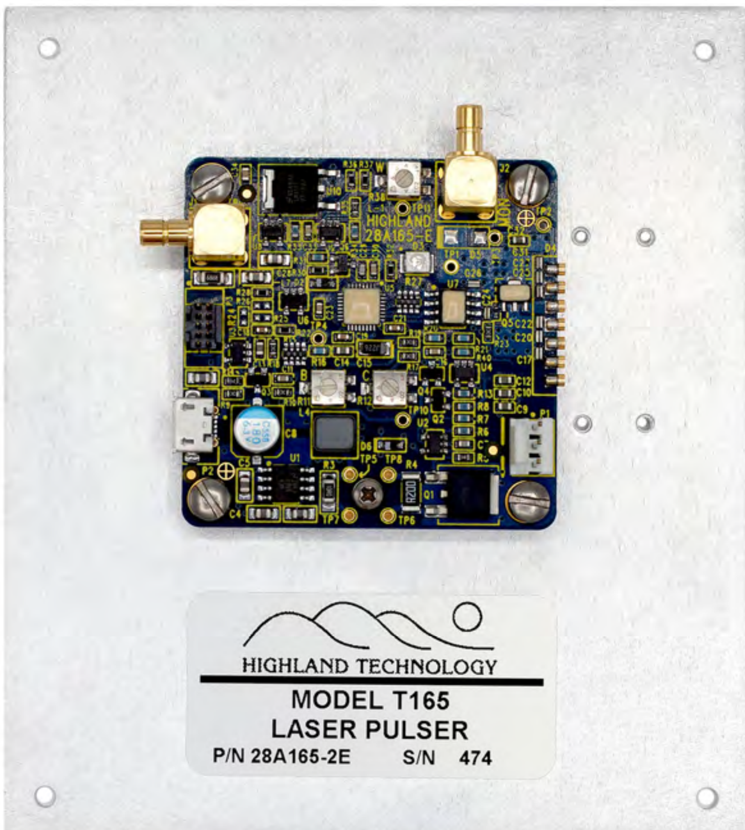
HIGHLAND TECHNOLOGY

# MODEL T165

# PICOSECOND TO NANOSECOND

# LASER DIODE PULSER




## Technical Manual

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# Contents

# 1. Introduction

This is the technical manual for the Highland Model T165 Laser Pulser.

## *1.1 Features of the T165 include:*

- Edge-triggered pulse, user adjustable width
- Optical pulse widths from 100 picoseconds to 850 nanoseconds
- Laser pulse current up to 400 mA, 700 mA with heat sinking
- Pin socket connection to Type-1 butterfly-packaged laser diodes with floating anode; compatible with other diode packages
- Highly stable constant-current laser drive
- Laser current, bias, and pulse widths are settable with onboard trimpots or by external analog inputs
- Accepts LVTTL or LVCMOS trigger levels
- Powered by standard 10 Watt, 5-volt micro-USB power supply or through ribbon cable interface connector
- 2" x 2" PCB for embedded application
- Compatible with Highland models

  P400 digital delay generator
  T560 digital delay generator

## 1.2 Choosing T165 Version for Application

Three T165 types are available, each optimized for a specific range of applications and each offered as an “evaluation” (recommended, with accessories for quick startup) version or “integration” (board-only) version:

The T165-9 (evaluation version) and T165-2 (integration version) are designed to produce a narrow range of user-adjustable, fixed-current pulses, from 200 ps to 2 ns pulse width, at up to 200 MHz repetition rates. The fast rising and falling laser drive edges, and narrow pulse width adjustment range, is optimal for producing sub 100 ps gain-switched optical impulses.

The T165-13 (evaluation version) and T165-12 (integration version) retain fast rising and falling-edge speeds, and, expand the maximum adjustable pulse width range to 850 ns. The combination of a wide width range, with fast edge speeds, provides an ideal platform for experimenting with a variety of different lasers under different operating conditions. The extended-range pulse width generator limits maximum pulse repetition rate to 2 MHz, or less. For optimal resolution and set ability, narrow pulse width programming is best accomplished using a control voltage via the onboard 10-pin header.

The T165-15 (evaluation version) and T164-14 (integration version) are recommended for applications where optimal pulse smoothness is desired, rather than edge speed. The T165-14/-15 are optimal for producing pulses tens to hundreds of nanoseconds wide. Additionally, the slower edge speeds reduce the waveform anomalies that result from electrical parasitics. Pulse repetition rate is limited to 2 MHz, or less. Note that the slower edge speeds of the T165-14/-15 nanosecond laser pulser effectively widen the pulse width by several nanoseconds.

## 1.3 T160 vs T165

The Highland Technology T160 is a variable width, pulse-follower variation of the T165, without the onboard edge-triggered pulse width generator circuit. The T160 can translate very wide pulses, up to 50 µs wide. This version has less propagation delay, compared to the T165, and is recommended for pulse-train, burst and spatially modulated applications operating at up to 200 MHz pulse repetition rates. Since the T160 doesn’t have an onboard width generator, narrow output current pulses require a trigger source capable of generating narrow voltage pulses. The T165 provides a ± 1.2 V laser anode-to-cathode DC bias adjustment range; the T160 provides + 50 mV to + 1.5 V. The T160 can accept LVDS / LVPECL trigger signals over the ribbon connector, in addition to single-ended LVTTL / LVCMOS triggers, by DIP switch selection.

**The very high speed components of the T165 are sensitive to electrostatic damage. To maintain picosecond performance, no explicit ESD protection is included.**

**Discharge cables before connecting to the T165. Do not apply trigger inputs over + 2.5 volts.**

## 2. Specifications

| | |
|---|---|
| FUNCTION | Embedded pulse generator and laser diode driver |
| TRIGGER INPUT | LVTTL/LVCMOS input<br>Triggers on input rising-edge, max input: +2.5 volts<br>min trigger width: 2.5 ns (-2 and -9 versions)<br>250 ns + width program setting (-12 thru -15 versions)<br>Trigger rate: 0 to 200 MHz (-2 and -9 versions)<br>0 to 2 MHz (-12 thru -15 versions) |
| PROPAGATION DELAY | 4 ns nominal (-2 and -9 versions)<br>250 ns nominal (-12 thru -15 versions) |
| LASER OUTPUT | Pulsed laser current adjustable 0 to 700 mA, + 2.5 volt compliance<br>Heat sinking required above 400 mA<br>Average laser current 50 mA max<br>Width adjustable from:<br>< 300 ps to 2 ns, nominal (-2 and -9 versions)<br>< 5 ns to 850 ns, nominal (-12 and -13 versions)<br>< 5 ns to 850 ns, nominal (-14 and -15 versions) |
| RISE/FALL TIMES | 150 ps to 1 ns nominal (-2 thru -13 versions)<br>2.5 ns nominal (-14 and -15 versions)<br>Actual rise/fall times depend on laser electrical parasitics |
| JITTER | < 12 ps RMS (-2 and -9 versions)<br>< 120 ps RMS (-12 thru -15 versions) |
| CONTROL | Three trimpots or external analog inputs set laser ON current, laser OFF bias voltage, pulse width<br>External inputs are 0 to +3 volts, > 10 KΩ load |
| BIAS RANGE | -1.2 V to +1.2 V, nominal, laser cathode relative to anode, ground referenced |
| POWER | +5 volts ± 5% at PCB via USB connector or ribbon header<br>Current 300 mA plus laser current<br>Highland model J6 USB power supply available for use up to 700 mA laser current (furnished with evaluation versions only) |
| CONNECTORS | LVTTL input: SMB connector<br>Control and power: 10-pin 50-mil 2x5 ribbon header<br>MONITOR output: SMB connector<br>Micro-B USB alternate power connector<br>3-pin header provides access to laser TEC pins |
| LED INDICATORS | Orange POWER |
| PACKAGING | 2" x 2" printed circuit board |

Specifications are typical unless otherwise noted.

# 3. Architecture

The signal path of the T165 is shown below:

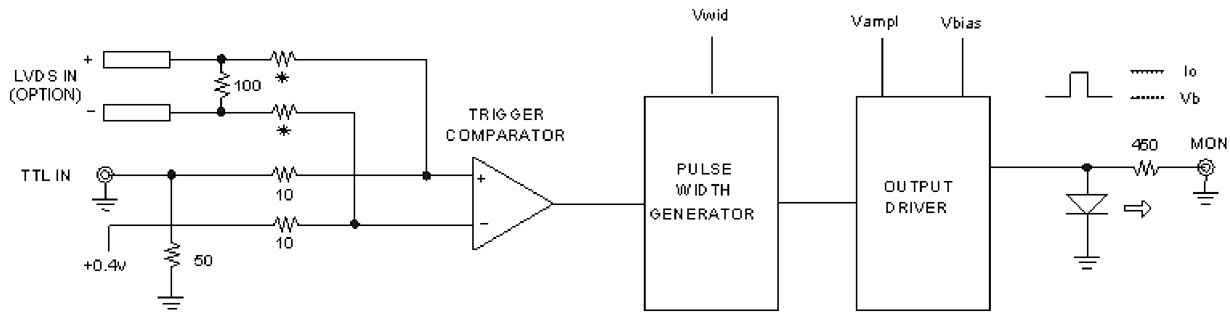



**Diagram 1: T165 Signal Path**

A custom version is available that accepts LVTTL or LVDS / LVPECL input trigger as a factory option. Minimum purchase quantity required, please contact factory for details.

Vampl programs the "ON" laser current, Vbias programs the "OFF" laser bias voltage, and Vwid programs the laser drive pulse WIDTH.

The output driver topology is as follows:

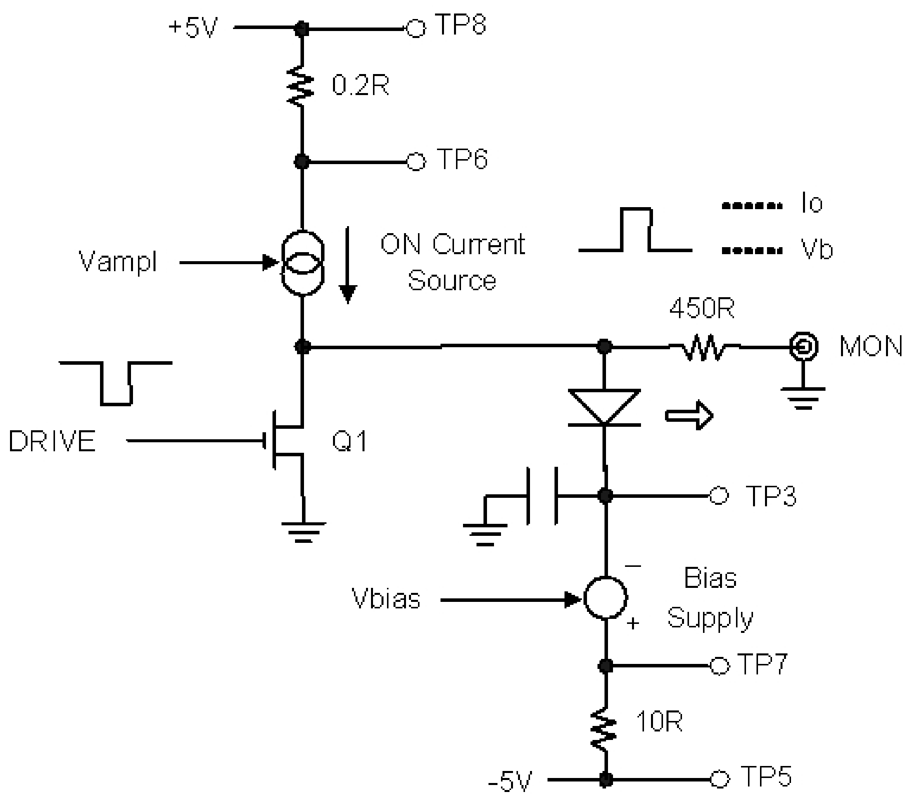



**Diagram 2: T165 Functional Topology**

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

The T165 "OFF" laser bias is a voltage source, not a current source. The main current source is on continuously. When the pulse generator output is off, Q1 is shorted and diverts this current to ground. Active pulse 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 fast optical pulses, even for high capacitance laser diodes. At the end of a laser pulse, the laser anode is driven hard to ground, or even back-biased, allowing sharp turnoff and minimal optical tails.

Test points are provided for measuring the laser ON current and the cathode 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 acts 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 Controls

## 4.1 Trigger Input

T165 is available standard with 2.5V LVTTL, or optional LVDS / 2.5V LVPECL trigger input.

LVTTL input is applied to SMB connector J1. The T165 terminates this input with 50 Ω to ground. Input threshold is +0.4 volts, which is compatible with most LVTTL drivers, fast pulse/clock generators, and capacitor-coupled ECL. The maximum input voltage must not exceed +2.5V at the LVTTL input.

The optional differential trigger equipped versions provide additional noise immunity in high EMI and RFI environments. Differential LVDS / 2.5V LVPECL inputs are applied to the P3 ribbon cable connector, pins noted below. This version provides a 100 Ω differential termination. Common-mode voltage should be in the range of +0.5 to +2.5 volts, which accommodates most LVDS, LVPECL, and positive-supply CML sources. Minimum differential input swing is 200 mV p-p. A minimum order quantity applies, please contact factory for details.

The input trigger pulse width must be at least 2.5 ns, and the trigger must be low for at least 2.5 ns between pulses (-2 and -9 versions). Wide-width versions (-12 thru -15 versions) require a trigger pulse width that is at least 250 ns + programmed output trigger pulse widths, and must be logic low for at least 250 ns between pulses. Expect some small variation in laser pulse width at high trigger rates.

## 4.2 Ribbon Cable Connector

P3 is a 50-mil-pitch, 10 pin, 5x2 ribbon cable connector that can be used to apply power and control signals to the T165. 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 T165 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 P3 is not used, apply power through the USB connector. In that case, trimpots set the laser BIAS, ON current, and WIDTH, and the trigger input is via the J1 LVTTL input.

If a parameter control input is applied via P3, turn the associated trimpot(s) fully CCW.

A yellow dot identifies pin 1 of P3. The pinout is:

| PIN | FUNCTION | |
|---|---|---|
| 1 | + 5 V | Power to T165 |
| 2 | + 5 V | Power to T165 |
| 3 | ILset | Laser ON current program |

| | | | |
|---|---|---|---|
| 4 | VBset | Laser OFF bias voltage program | |
| 5 | Ground | | |
| 6 | LVDS+ | LVDS / PECL input + | (LVDS version only) |
| 7 | LVDS- | LVDS / PECL input - | (LVDS version only) |
| 8 | Ground | | |
| 9 | Ground | | |
| 10 | WIDset | Pulse width program | |

**Table 1: T165 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 + 4.75 V for proper operation. The P3 grounds, the PCB ground plane, the SMB shells, and the mounting holes are all connected.

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 reverse-biases the laser by 1.2 V (cathode voltage is + 1.2 volts) and + 3 volts input will forward-bias the laser by 1.2 volts (cathode voltage is - 1.2 volts.) The laser anode voltage will rise by about + 0.2 volts at full drive current due to the $R_{DS\text{-}On}$ of Q1.

WIDset controls the pulse width generator. Zero width corresponds to about + 0.7 volts, and + 3 volts makes a pulse width of about 2.5 ns (-2 and -9 versions), or 850 ns (-12 thru -15 versions). The slower edge speeds of the T165-14 nanosecond laser pulser, effectively widens the pulse width by several nanoseconds. For optimal resolution and set ability, narrow pulse width programming of the T165-12 and T165-14 is best accomplished using an analog control voltage instead of the onboard trimpot; otherwise, the equivalent pulse width scaling is about 4 ns / degree of trimpot rotation.
If computer control over ILset, VBset and WIDset is required, a 12-bit or better DAC capable of spanning 0 to + 3.3 V, can be used to control the analog ribbon connector control inputs.

## *4.3 USB Power Connector*

The micro-B USB connector can be used to apply +5 volt power to the T165. The Highland model J6 can power the T165; it can drive lasers up to 700 mA. The recommended USB cable is 6 feet or shorter, Type A male to micro B male, Mediabridge #30-004-06B. Other cables may be substituted, provided that the voltage drop due to resistive cable losses never cause the + 5 supply to drop below +4.75 V at the T165. The + 5 supply voltage is accessible on the T165 at TP8.

## *4.4 Trimpots*

Three trimpots are provided for use when P3 programming is not used. The pot labeled "B" sets the OFF BIAS voltage, the "C" pot sets laser ON current, and "W" sets pulse WIDTH. Clockwise increases all.

Set all pots fully counter-clockwise (CCW) when P3 ribbon connector programming is used.

One possible setup procedure is:

1. Turn C and B pots to minimum, CCW. Set W pot clockwise. 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 TP3 to ground; this is the laser cathode voltage. Use the B trimpot to set a suitable bias voltage, based on laser data sheet curves. Zero is a reasonable starting point.

4. Apply trigger inputs and observe optical output. Fine tune B and C for best optical performance. Adjust the W pot for desired optical pulse width.

Refer to Section 5.2 for method of adjusting T165 settings for optimal width and laser output.

## *4.5 Monitor Connector*

J2 MON is an SMB connector used to monitor laser waveforms with a 50 Ω oscilloscope. It can also be used as a low-jitter oscilloscope trigger. MON connects to the laser anode through a 450 Ω resistor, forming a passive, wideband 10:1 probe into a 50 Ω scope.

## *4.6 Test Points*

Test points allow measurement of laser bias and ON current. See Diagram 2 in Section 3.

## *4.7 Laser Connections*

A typical Type-1 butterfly package pinout is as follows:

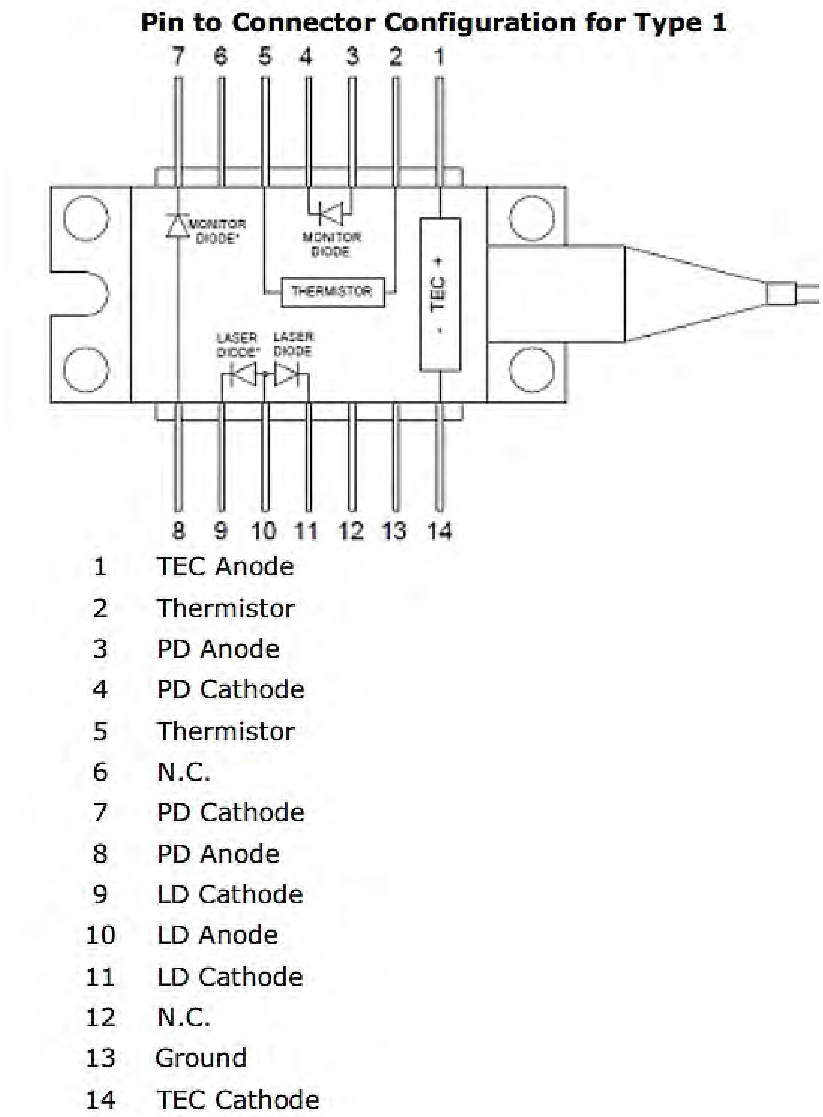



**Diagram 3: Type-1 Butterfly Laser Connections**

Seven pin sockets are provided for convenient connection to the laser diode side of a standard Type-1 butterfly package. Pin assignments are:

| PCB PIN | BUTTERFLY PIN | FUNCTION | CONNECTION |
|---|---|---|---|
| 1 | 8 | not used | connects to TP2 |
| 2 | 9 | laser cathode | |
| 3 | 10 | laser anode | |
| 4 | 11 | laser cathode | |
| 5 | 12 | not used | connects to P1-2 |
| 6 | 13 | ground | connects to P1-3 |
| 7 | 14 | not used | connects to P1-1 |

**Table 2: T165 / Type-1 Laser Corresponding Connections**

The T165 pinsockets are spaced on 0.100-inch centers.

The laser lead diameter must be between 0.015-inches to 0.026-inches in order to properly register with the T165 pin sockets. Plunge depth must not exceed 0.095-inches into the pin sockets to avoid damaging onboard components on the T165.

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 T165 pin socket centerline is nominally 0.274-inches above the mounting flange (T165-9 evaluation version), or, 0.087-inches above the bottom of the T165 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 T165 pin sockets.

The T165 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 T165 is provided with four 4-40 sized mounting holes. It is recommended that the T165 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 T165 power dissipation is proportional to the programmed laser drive current:

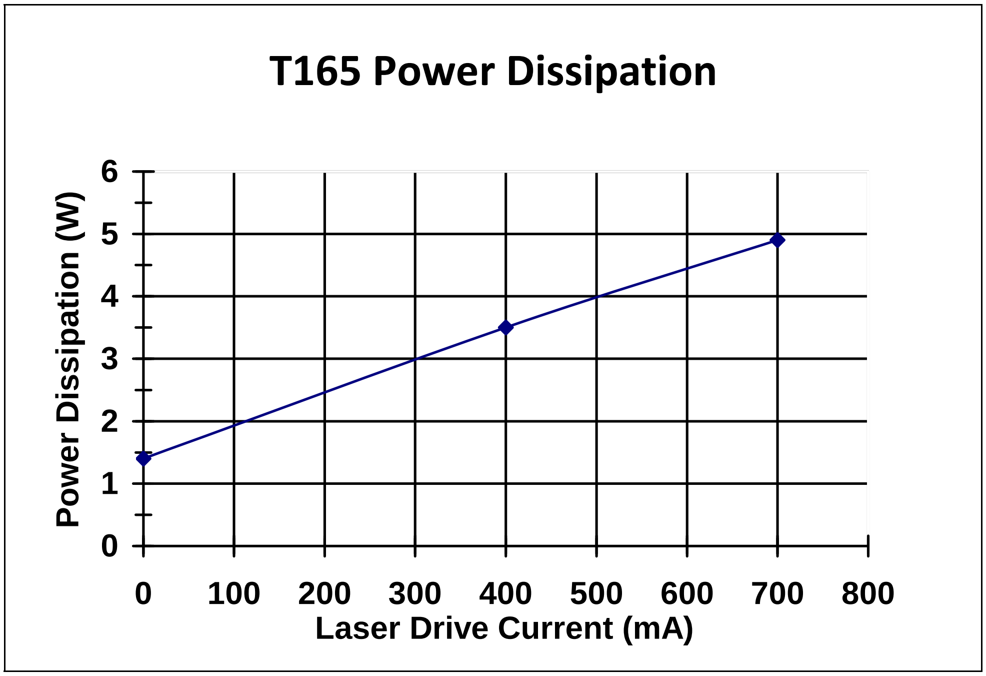



**Chart 1: T165 Power Dissipation vs. Laser Drive Current**

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 T165 connects to one side of the butterfly package, and provides 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 T165 at P1, pin 1 (refer to Section 4.7). The positive TEC pin and thermistor pins are not accessible from the T165, 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 T165. The TEC controller connections can be made with longer leads (refer to Photo 1).

# 5. Basic Operation and Performance

## *5.1 System Setup*

The T165 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 T165, 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, P400 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 T165

Refer to Section 4.4 for recommended initial trimpot settings.

a) Start with power supply disconnected. Connect the T165 trigger input to a suitable trigger source. For most applications, this connection is made with a 50 Ω SMB coax cable to the LVTTL Trig input jack.

b) Connect the laser to the T165. Trim the leads so that they register the full pinsocket depth, without protruding past the opposite end. When the T165 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 T165. The Highland Technology Model J6 power supply and USB micro-B cable, included in the T165 evaluation kit version, is recommended.

d) Provide necessary oscilloscope trigger provisions. If the oscilloscope requires an external pre-trigger, one approach is to electrically trigger the oscilloscope before the T165. A convenient method of electrically pre-triggering the oscilloscope is with a DDG, such as the Highland Technology P400. Alternatively, if only one trigger source is available, a suitable length of low-loss, 50Ω coax can be used with a 50Ω -6dB power combiner, to provide a delayed trigger signal to the T165.

e) 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 T165 'C' trimpot is rotated fully counterclockwise before applying power to the T165. When power is applied to the T165, an orange onboard LED will illuminate.

## *5.2 Optimizing Pulse Width and Laser Output*

The T165 provides onboard trimpots for adjusting laser BIAS voltage, WIDTH 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 < 1ns

The T165-2 is optimized for generating laser drive pulses < 1 ns wide. Trimpot pulse width control is convenient with the T165-2, with approximately 10 ps pulse width adjustment per degree of trimpot rotation. The following general adjustment procedure is recommended for sub-nanosecond pulse generation:

a) Rotate the bias control trimpot ('B') to the 12:00 position. This translates to a measured voltage at TP3 of about 0 volts, and a 0 volt laser 'OFF' bias condition.

b) Rotate the pulse width trimpot ('W') fully clockwise. This sets the laser drive pulse for a wide pulse, enabling easier waveform location on the oscilloscope.

c) 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 * $V_{TP8-TP6}$.

d) Activate the pulse generator and locate the optical waveform on the oscilloscope.

e) Begin narrowing the laser drive pulse by ***slowly*** rotating the WIDTH trimpot (‘W’) counterclockwise. At one point, the optical pulse tail will diminish as the number of active region carrier accumulation approaches the lasing threshold. This transition can occur suddenly, in a fraction of a degree of WIDTH trimpot rotation. Since the adjustment is not yet optimized, a post-pulse due to relaxation oscillation, may still be visible.

f) Once the drive pulse width has been nominally optimized, continue to shape the gain switched Gaussian by applying negative bias to the laser. This is accomplished by ***slowly*** rotating the BIAS control trimpot (‘B’) counterclockwise, while observing the optical waveform. Fine tune the setting for minimal post-pulse relaxation oscillation bumps and a smooth falling-edge.

g) 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.

h) Further optimizations require iterative adjustments to the BIAS control (‘B’), WIDTH (‘W’), 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 T165 depends greatly on the parasitic properties of the laser and laser package (refer to Section 5.3).

Although the T165-12 pulse width adjustment range spans 0 to 850 ns, the T165-2 is recommended for generating optical pulse widths less than 1 ns, since it provides finer adjustment resolution. For example, the T165-2 trimpot pulse width resolution is nominally 12 ps / degree of rotation. If the ribbon cable analog control voltage is used to adjust pulse width, the resolution is about 830 ps / Volt. With the T165-12, trimpot pulse width resolution is nominally 4 ns / degree of rotation, and, around 280 ns / Volt using the ribbon cable analog control. The courser resolution can make narrow pulse adjustments more difficult with the T165-12.

The T165-2 is duty-cycle limited to 40%. Depending on the laser program current setting and pulse repetition rate (PRR), the maximum pulse width is limited according to the chart below:

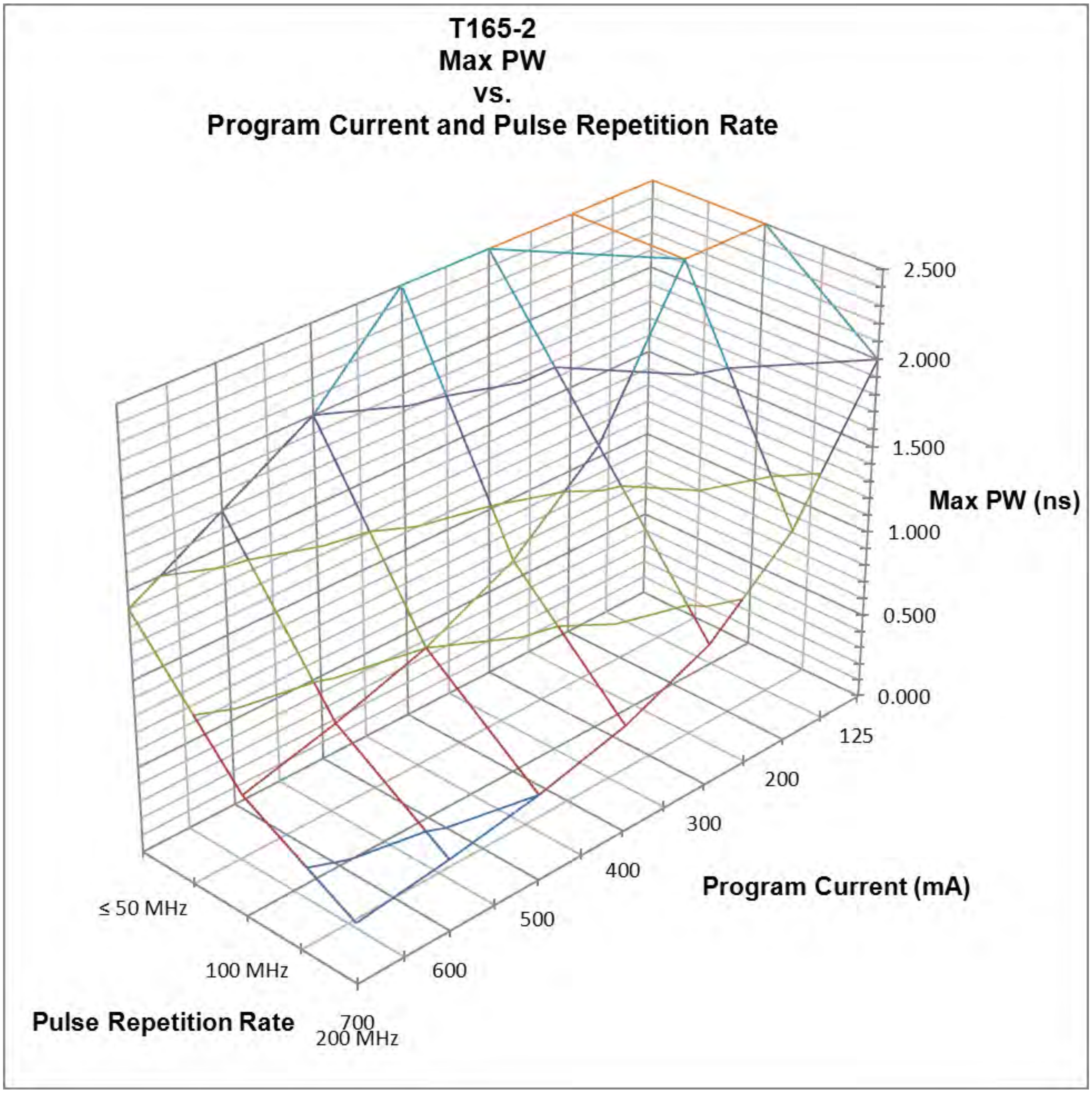
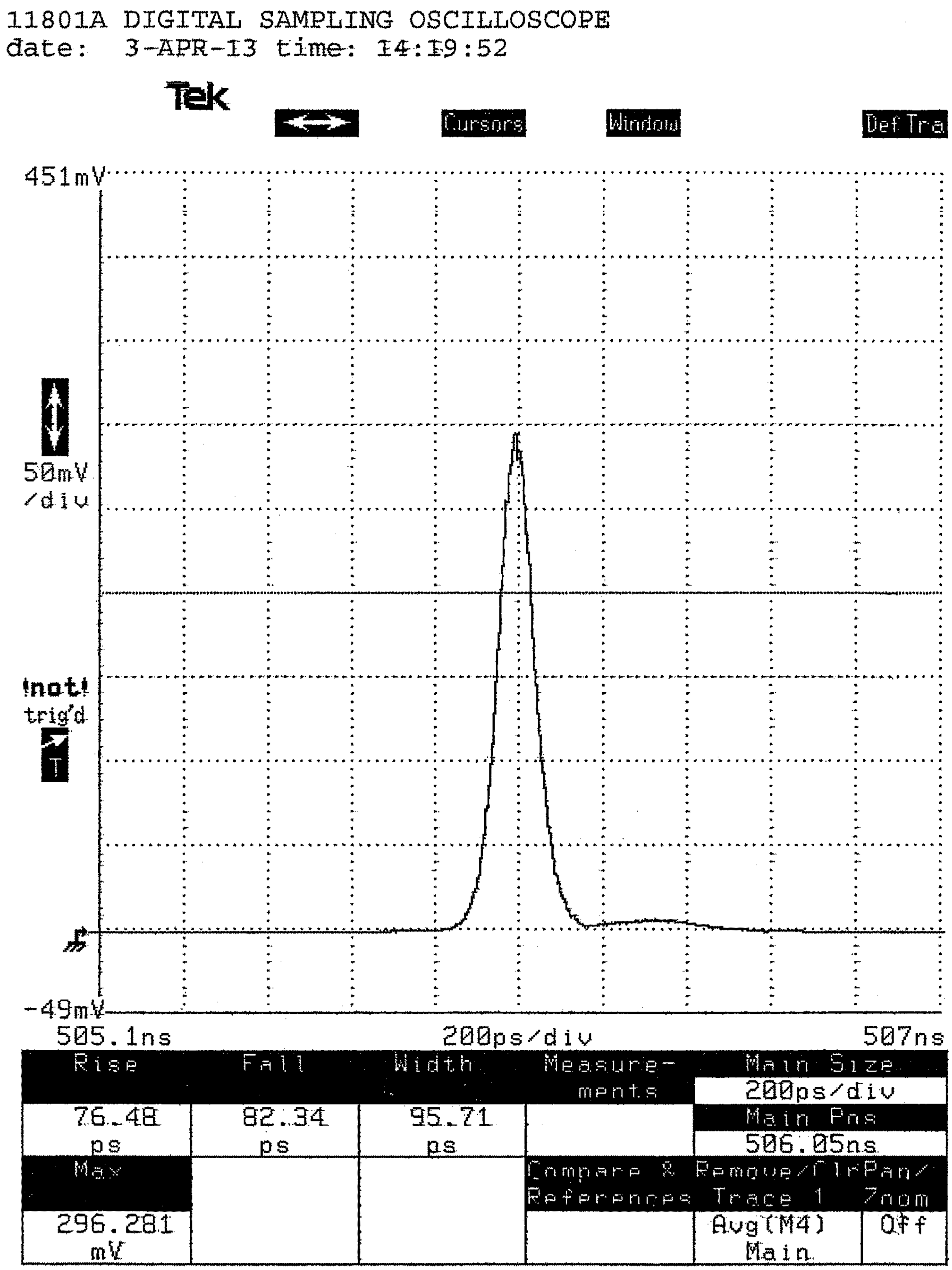



**Chart 2: T165-2 PW$_{max}$ vs. PRR and Program Current**

| PRR (MHz) | Ipgm (mA) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 125 | 200 | 300 | 400 | 500 | 600 | 700 |
| | PW max (ns) | | | | | | |
| ≤ 50 | 2.500 | 2.500 | 2.500 | 2.500 | 2.000 | 1.700 | 1.400 |
| 100 | 2.500 | 2.500 | 1.670 | 1.250 | 1.000 | 0.833 | 0.700 |
| 200 | 2.000 | 1.250 | 0.835 | 0.625 | 0.500 | 0.415 | 0.350 |

**Table 3: T165-2 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 pulses from 1 ns to 100 ns

The T165-12 and T165-14 are optimized for generating laser drive pulses up to 850 nanoseconds wide. Sub nanosecond laser pulses can be produced by the T165-12, however, the approximate 4 ns per degree of trimpot rotation can make width adjustments extremely difficult. Applications requiring a wide range of pulse width settings are easier to adjust with analog control voltages on the 10-pin header, instead of using trimpot control (refer to section 4.2). The following general adjustment procedure is recommended for generating pulse widths up to 100 ns :

a) Rotate the BIAS control trimpot ('B') to the 12:00 position. This translates to a measured voltage at TP3 of about 0 volts, and a 0 volt laser 'OFF' bias condition.

b) Rotate the pulse WIDTH trimpot ('W') fully clockwise. This sets the laser drive pulse for a wide pulse, enabling easier waveform location on the oscilloscope.

c) 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 * $V_{TP8-TP6}$.

d) Activate the pulse generator and locate the optical waveform on the oscilloscope.

e) Begin narrowing the laser drive pulse by ***slowly*** rotating the WIDTH trimpot ('W') counterclockwise until the desired pulse width is obtained.

### 5.2.3 Performance tuning for pulses > 100 ns

The T165-12 and T165-14 are optimized for generating laser drive pulses up to 850 nanoseconds wide. Sub nanosecond laser pulses can be produced by the T165-12, however, the approximate 4 ns per degree of trimpot rotation can make width adjustments extremely difficult. Applications requiring a wide range of pulse width settings are easier to adjust with analog control voltages on the 10-pin header, instead of using trimpot control (refer to section 4.2). The following general adjustment procedure is recommended for generating pulse widths greater than 100 ns :

a) Rotate the BIAS control trimpot ('B') to the 12:00 position. This translates to a measured voltage at TP3 of about 0 volts, and a 0 volt laser 'OFF' bias condition.

b) Rotate the pulse WIDTH trimpot ('W') fully clockwise. This sets the laser drive pulse for a wide pulse, enabling easier waveform location on the oscilloscope.

c) 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 * $V_{TP8-TP6}$.

d) Activate the pulse generator and locate the optical waveform on the oscilloscope.

e) Begin narrowing the laser drive pulse by ***slowly*** rotating the WIDTH trimpot ('W') counterclockwise until the desired pulse width is obtained.

The T165-12 and T165-14 are duty-cycle limited to 40%. Depending on the laser program current setting and pulse repetition rate (PRR), the maximum pulse width is limited according to the chart below:

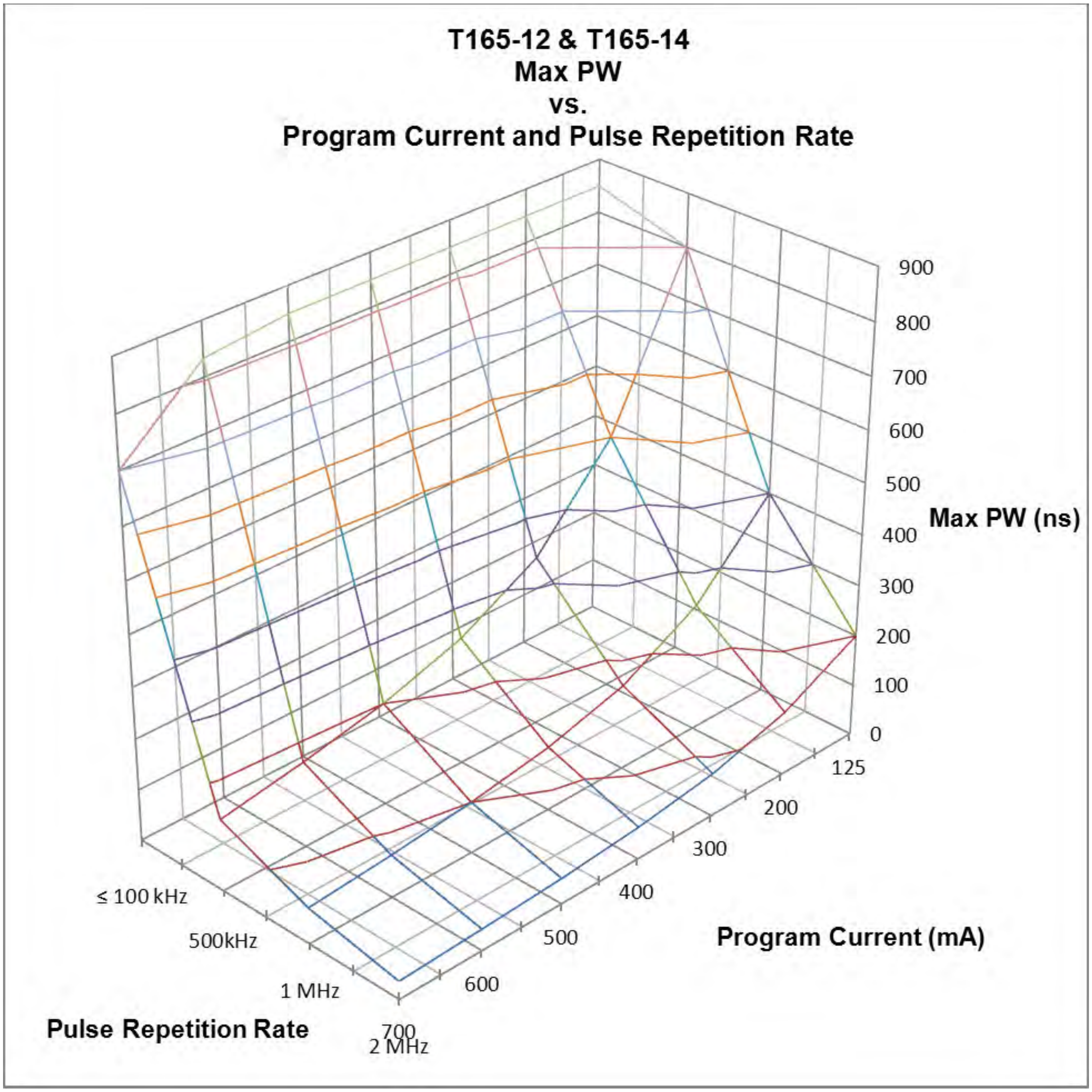



**Chart 3: T165-12 & T165-14 PW$_{max}$ vs. PRR and Program Current**

| | Ipgm (mA) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **125** | **200** | **300** | **400** | **500** | **600** | **700** |
| **PRR (MHz)** | **PW max (ns)** | | | | | | |
| **≤ 0.100** | 850 | 850 | 850 | 850 | 850 | 833 | 700 |
| **1.000** | 800 | 500 | 334 | 250 | 200 | 167 | 140 |
| **0.500** | 400 | 250 | 167 | 125 | 100 | 83 | 70 |
| **1.000** | 200 | 125 | 84 | 63 | 50 | 42 | 35 |
| **2.000** | 850 | 850 | 850 | 850 | 850 | 833 | 700 |

**Table 4: T165-12 & T165-14 $PW_{max}$ (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). Wide rectangular optical pulses can also 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 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 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:

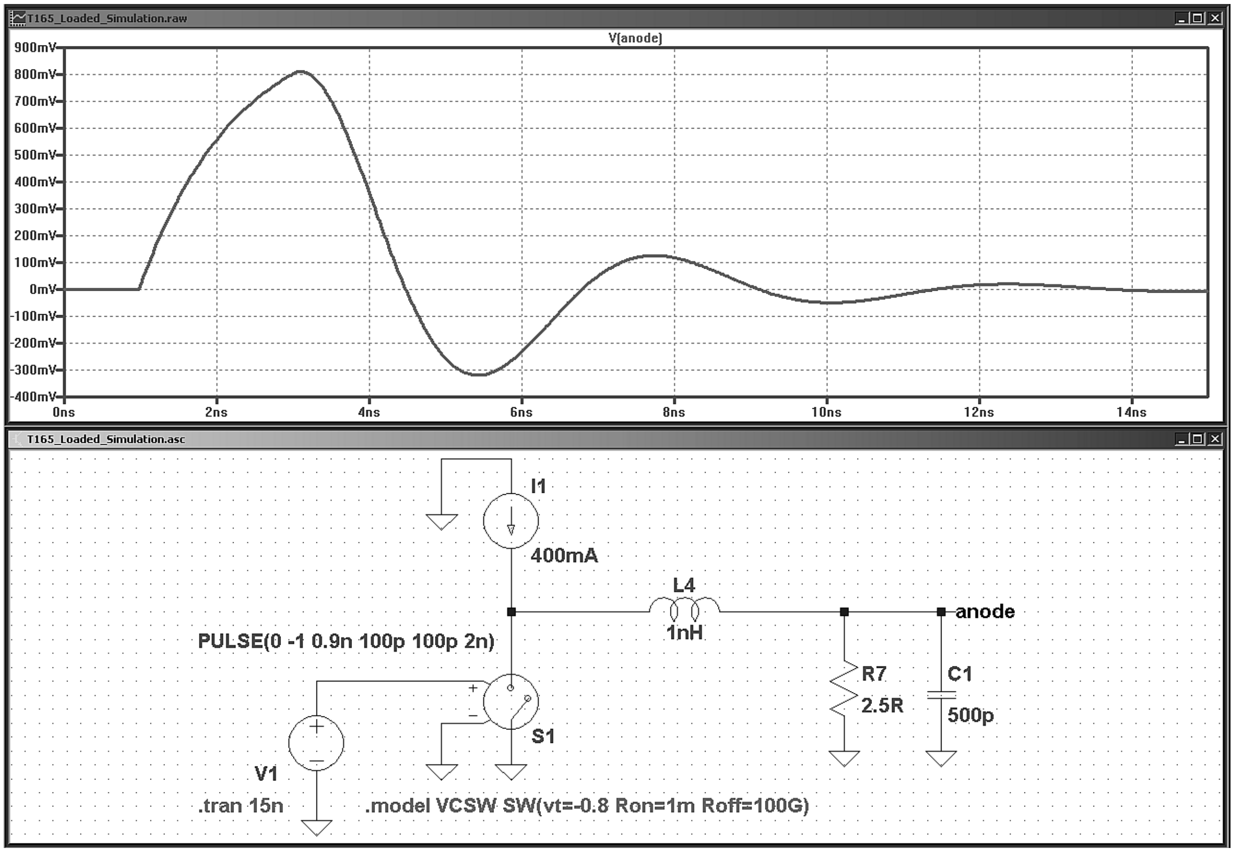
Estimating LC by observing the ringing Period (P): $LC = (P / 2\pi)^2$

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 T165-14 may be more appropriate for the application. The slower ~ 2.5 ns T165-14 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

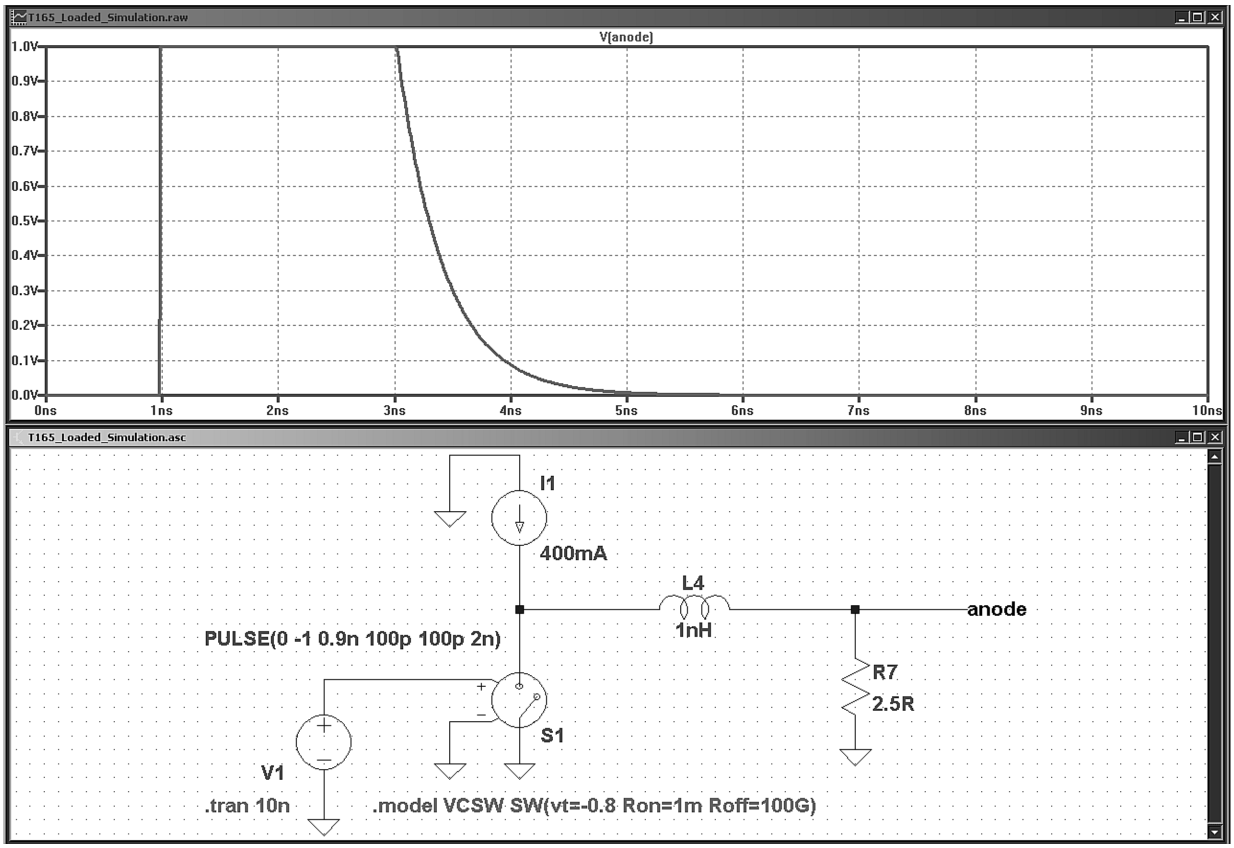
Some laser diodes will produce a dip in optical output amplitude, hundreds of nanoseconds following the rising-edge.

### 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 lengthier 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 T165 (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.

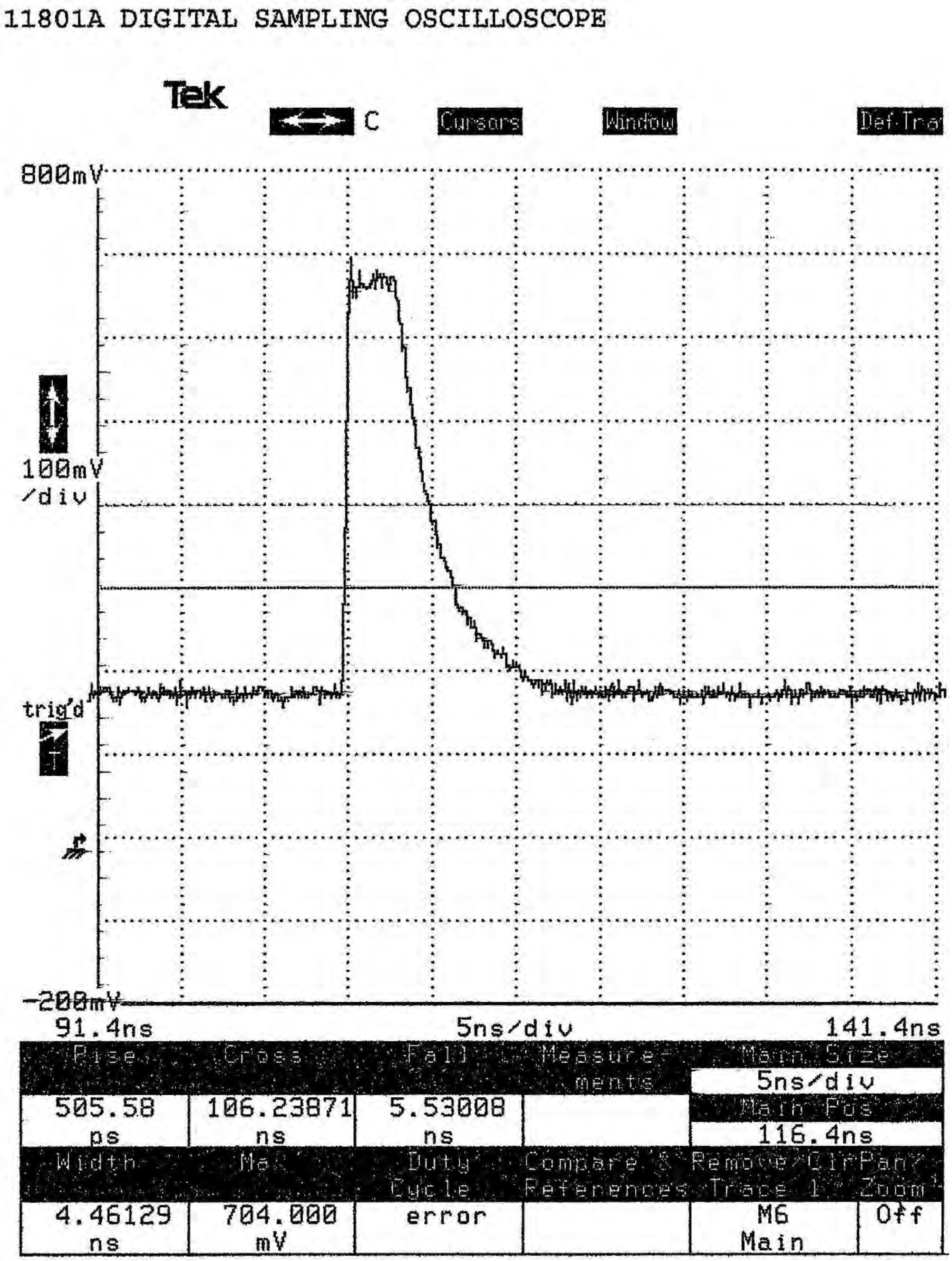



**Waveform 3:  Effects of parasitic inductance on laser drive.**

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 ground (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 waveform 4 below).




**Waveform 4: ~25 % Baseline DC offset while driving 1 Ω resistive load at 700 mA**

The ± 1.2V cathode bias adjustment range provides a means of adjusting out the baseline offset impressed across the laser.

### 5.3.7 Temporal Jitter

Applications requiring minimal temporal jitter, with pulse widths ≤ 2 ns, should utilize the T165-2 or T165-9 version. The extended pulse width versions 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 T165.

The T165 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 T165 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 T165 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.

The T165 requires a trigger pulse at least as long as the desired output pulse + propagation delay. If the T165 receives triggers more frequently than the duration of the programmed output pulse, output pulses won’t form.

The T165 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. If the bias adjustment is adjusted to shift the anode + 1.2 V, relative to the cathode, the quiescent current is nominally limited to ≤ 50 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 a 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 T165, in order to minimize the anode and cathode lead length. The T165 provides a 3-pin male header that connects to pins 12 – 14 of the butterfly. Typically, the negative TEC connection is pin 14 of the butterfly, corresponding to P1-1. The header pins of P1 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 pinsocket. Thermistor and positive TEC connections usually are located on the butterfly leads that don't connect to the T165. 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 T165 base plate. Refer to the example configuration below:

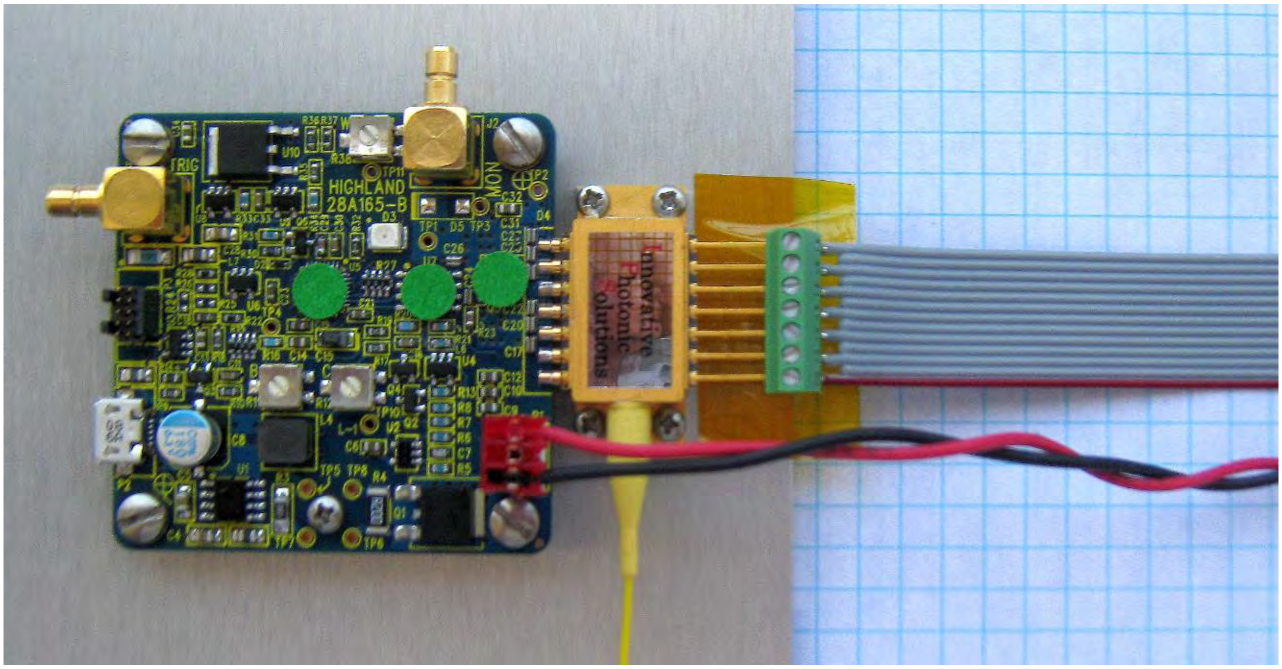



**Photo 1: Example of TEC connections using onboard header P1 and terminal block**

# 6. Dimensions

Dimensions are in inches. The four corner mounting holes are 0.120-inch diameter, with 0.230-inch round copper pads on both sides.

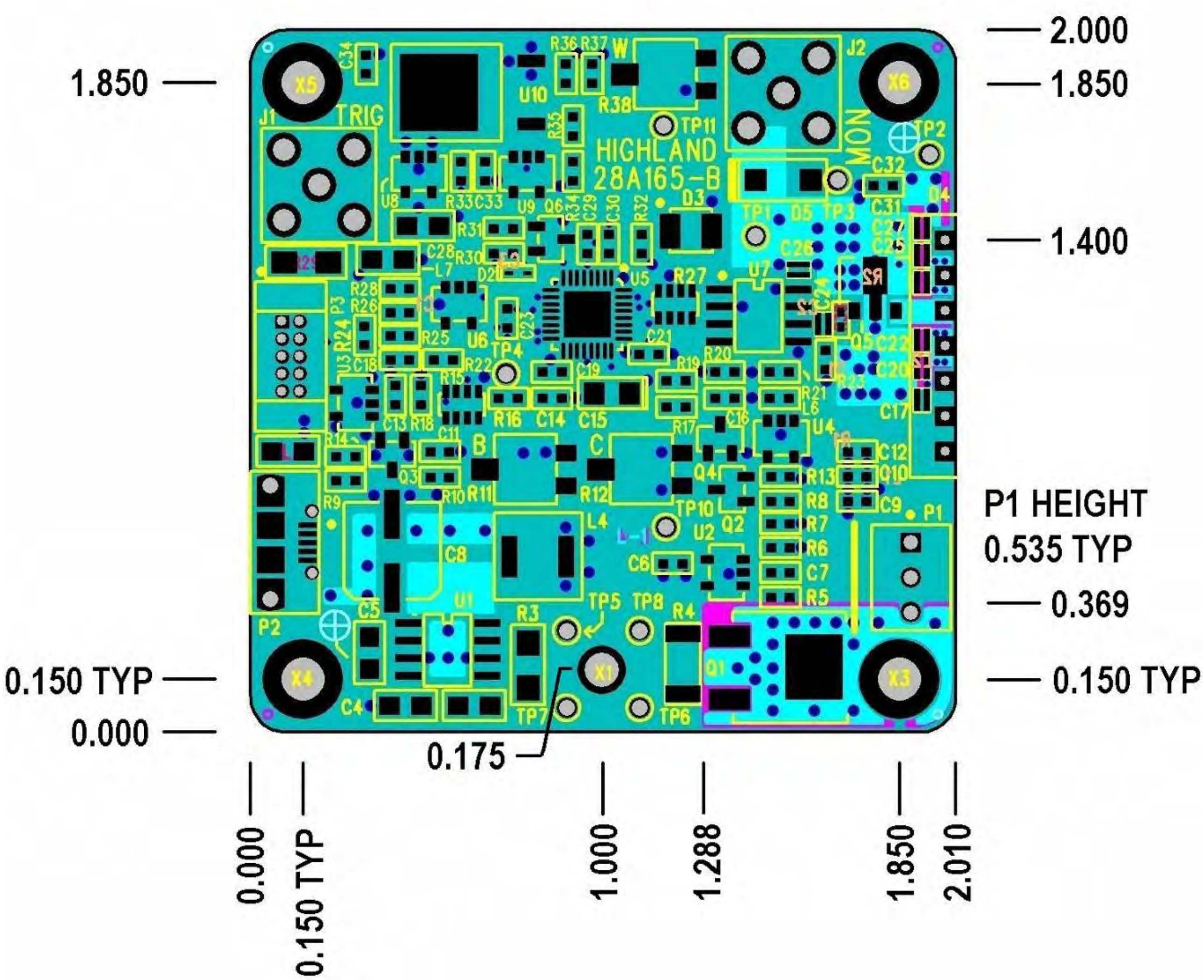



**Diagram 4: T165 layout and dimensions**

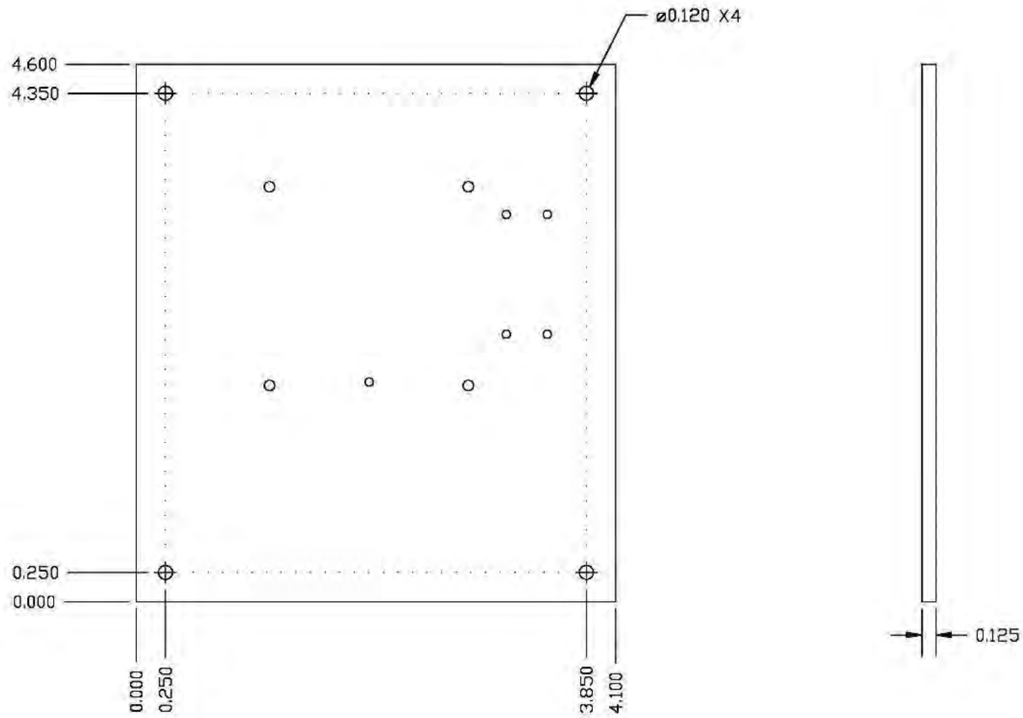



**Diagram 5: T163 mounting flange dimensions**

# 7. Versions

Standard (recommended) evaluation versions of the T165 include:

| | |
|---|---|
| T165-9 | picosecond laser diode pulser evaluation kit (includes T165-2 installed on T163 mounting flange with J6-1 USB power supply and two J53-1 3’ SMB to BNC cables) |
| T165-13 | picosecond laser diode pulser with extended pulse width range evaluation kit (includes T165-12 installed on T163 mounting flange with J6-1 USB power supply and two J53-1 3’ SMB to BNC cables) |
| T165-15 | nanosecond laser diode pulser with extended pulse width range evaluation kit (includes T165-14 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 T165 include:

| | |
|---|---|
| T165-2 | picosecond laser diode pulser |
| T165-12 | picosecond laser diode pulser with LVTTL trigger and output pulse widths extended to 850 nanoseconds |
| T165-14 | nanosecond laser diode pulser with LVTTL trigger and output pulse widths extended to 850 nanoseconds |

Custom versions of the T165 include:

| | |
|---|---|
| T165-22 | picosecond laser diode pulser with output pulse widths extended to 850 nanoseconds, LVTTL trigger, and SMA Trigger and Monitor connectors. Minimum quantities apply, contact factory for details. |
| T165-23 | picosecond laser diode pulser with output pulse widths extended to 150 nanoseconds, LVTTL trigger, and SMA Trigger and Monitor connectors. Minimum quantities apply, contact factory for details. |

# 8. Customization

Consult factory for information about additional custom versions.

# 9. Hardware Revision History

| | | |
|---|---|---|
| Revision E | Nov 2017<br>Functionally equivalent to Revision A<br>Added suppressed output upon power-cycle |
| Revision D | Mar 2016<br>Functionally equivalent to Revision A |
| Revision C | Sep 2014<br>Functionally equivalent to Revision A |
| Revision B | Apr 2013<br>Functionally equivalent to Revision A |
| Revision A | Sep 2012<br>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 T165 evaluation versions (-9, -13, and -15). Accessories must be purchased separately for T165 integration/board-only versions (-2, -12, and -14).