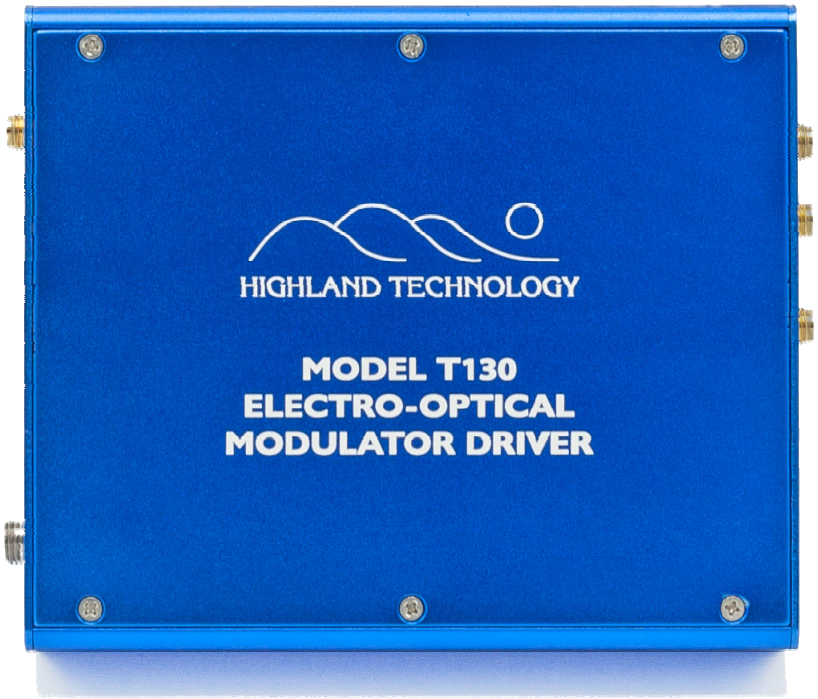
HIGHLAND TECHNOLOGY

MODEL T130

SINGLE-CHANNEL

PICOSECOND EOM DRIVER



Technical Manual

October 17, 2023

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

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

NOTICE

HIGHLAND TECHNOLOGY, INC. PROVIDES THIS PUBLICATION “AS IS” WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

(Disclaimer of expressed or implied warranties in certain transactions is not allowed in some states. Therefore, the above statement may not apply to you.)

This manual may contain technical inaccuracies and/or typographical errors. Changes are periodically made to this manual which are incorporated in later editions. Highland Technology, Inc. may make changes and improvements to the product(s) and/or programs described in this publication at any time without notice.

The T130 has finite failure rates associated with its hardware, firmware, design, and documentation. Do not use the product in applications where a failure or defect in the instrument may result in injury, loss of life, or property damage. This product is not intended for use in medical applications.

IN NO EVENT WILL HIGHLAND TECHNOLOGY, INC. BE LIABLE FOR DAMAGES, INCLUDING LOST PROFITS, LOST SAVINGS OR OTHER INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OF OR INABILITY TO USE SUCH PRODUCT, EVEN IF HIGHLAND TECHNOLOGY, INC. OR AN APPROVED RESELLER HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES, OR FOR ANY CLAIM BY ANY OTHER PARTY

Table of Contents

1 Introduction

This is the technical manual for the Highland Model T130 Pulse Generator.

The T130 is an externally-triggered single-channel pulse generator, suitable for driving 50Ω Mach-Zehnder $LiNBO_3$ electro-optical type devices.

Features include:

- Programmable delay and pulse width in three ranges
- Programmable amplitude from -0.5 volts to -7 volts into 50Ω load
- Risetime / falltime 100 picoseconds, typical (10 – 90%)
- Built in width generator adjustable from 250 picoseconds to 300 nanoseconds, FWHM
- Built in bias supply, adjustable ± 6V
- Powered by +24V DC
- Control via USB, RS-232, or onboard trimpots
- Built-in self-test (BIST)
- Compact extruded enclosure with surface mount flange included

Applications include:

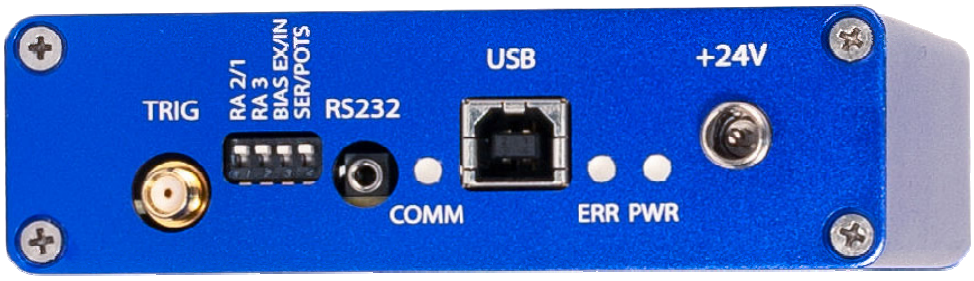
- Driving 50Ω electro-optical phase and amplitude modulators
- Driving 50Ω directly modulated seed lasers in pumped fiber systems
- RF applications: fast-pulse modulation, phase shifting, harmonic generation
- Time-domain device characterization and modeling
- Semiconductor test
- System cable/timing trims

2 Specifications

Specifications are typical unless otherwise noted.

FUNCTION	Externally-triggered single-channel pulse generator and EOM driver
TRIGGER	Rising-edge trigger, 50Ω input impedance, DC coupled Threshold: +0.5 volts Max safe input: -0.6 volts to +6 volts
PROPAGATION DELAY	Range 1: 8ns nominal insertion delay Range 2: 20ns nominal insertion delay Range 3: 70ns nominal insertion delay
RF OUTPUT	User adjustable -0.5 volts to -7 volts peak into 50Ω loads; AC-coupled
PULSE RATE	Min pulse rate is 0 Hz Range 1: max 50 MHz depending on delay/width settings Range 2: max 25 MHz depending on delay/width settings Range 3: max 5 MHz depending on delay/width settings
RISE/FALL TIMES	100ps, typ measured at 10/90%
PROGRAMMABLE TIMINGS	Range 1 : delay 0 to 5ns width 250ps to 5ns d+w < 5ns Range 2 : delay 0 to 50ns width 500ps to 50ns d+w < 50ns Range 3 : delay 0 to 300ns width 1ns to 300ns d+w < 300ns Ranges are selectable by front-panel DIP switch or remotely
JITTER	Range 1: < 3ps RMS typ. Range 2: < 10ps RMS Range 3: < 50ps RMS
BIAS SUPPLY	Internal / External DC bias tee injection at RF OUT Internal BIAS supply adjustable ± 6 volts, 100 mA max BIAS connector serves as Hi-Z voltage monitor when set to INT mode
CONTROL	Trimpots, RS-232, and USB
OPERATING TEMPERATURE	0 to 50°C, non-condensing
CALIBRATION INTERVAL	One year
STORAGE TEMPERATURE	-20 to 80°C

POWER	+24 volts at 250mA, max J24 universal wall-plug power supply furnished
COMMUNICATION	USB, RS-232
CONNECTORS	TRIG RF OUT RF MON BIAS OUT SMA jacks Standard B receptacle for USB control, 2.5mm phono jack for RS-232
LED INDICATORS	Green POWER Blue TRIGGER Orange COMM Red ERROR
PACKAGING	4.84” (L) x 4.06” (W) x 1.20” (H) extruded aluminum enclosure Mounting flange furnished
CONFORMANCE	OEM product has no UL/FCC/CE compliance requirements Designed to meet UL/FCC/CE requirements



3 Architecture

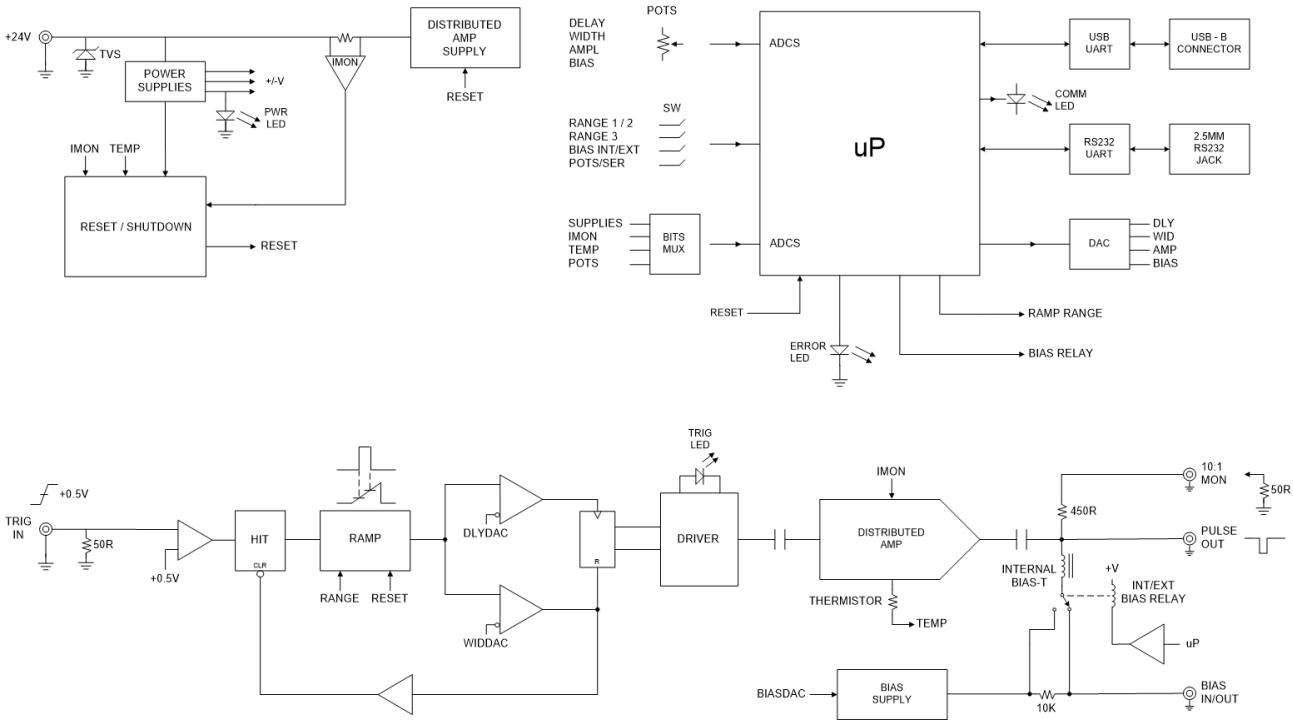


Figure 1: T130 Block Diagram

An input comparator recognizes the rising edge of incoming triggers and sets the HIT flipflop, initiating the timing ramp cycle.

The resulting linear ramp feeds two comparators, with threshold voltages determining rising and falling edge times of the output pulse. The HIT flipflop is reset after the falling edge, in preparation for the next valid trigger.

An output driver combines comparator outputs, forming an adjustable amplitude, adjustable pulse-width, fast square pulse. A wideband GaAs pHEMT distributed amplifier increases pulse amplitude and drives the RF OUT SMA connector and external 50Ω load. The MON signal is generated by a resistor pickoff, forming a 10:1 divider into a 50Ω load.

Range switching provides three selectable time ranges of 5ns, 50ns, and 300ns. Minimum output pulse widths are 250ps, 500ps, and 1ns for each of three respective ranges.

An integral bias supply is included in the T130, providing clean, quiet, user-adjustable DC bias voltage. Output is continuously adjustable from – 6 volts to + 6 volts, providing up to ±100 milliamps of source current. A bias tee is included in the RF pulse signal path, permitting direct DC injection for single-port modulators. A selector switch and relay permits application of externally applied bias through the bias tee inductor. When bias is set to INT mode, the BIAS SMA connector functions as a Hi-Z bias supply voltage monitor. Limit current to 200mA or less when using an external bias source.

Note: The internal bias generator and injection inductor DCR combined have approximately 15Ω of source resistance. For 50Ω resistive loads, the resulting 0.75:1 voltage divider will reduce internal BIAS adjustment range to approximately ±4.5V at the RF port.

The injection inductor DC resistance is approximately 5Ω, resulting in up to 1 volt of drop at max rated 200mA applied external bias current.

A -20dB MON SMA connector allows confirmation of RF pulse for diagnostic purposes. The MON signal must terminate into a 50Ω load for best results. It does not require a termination when not in use. Note that the MON signal is a representation of the RF pulse, not an exact duplicate, and will differ slightly in appearance.

Operation is supervised by the ARM microprocessor. At powerup, the uP digitizes trimpot and DIP switch positions. The uP then loads the DACs, and sets the timing range and bias routing relay. BIST (Built In Self Test) is managed by the uP to verify supply voltages, distributed amp current and temperature are within normal operational limits. When the DIP switch is set to remote mode, a serial command from the USB or RS232 enables remote user programming.

The T130 includes a real-time analog supervisor that monitors internal voltages and de-activates the T130 if the output amplifier overheats or draws excessive current.

A red ERR led illuminates if a fault is detected. The associated error code can be accessed using the serial interface.

4 Applications

The T130 drives high-speed, 50Ω Mach-Zehnder / $LiNbO_3$ electro-optic modulator ‘slicers’ between two optical transmission states, determined by the T130 amplitude setting, bias voltage and the EOM’s $V\pi$. Typical M-Z EOMs respond continuously to the magnitude of applied voltage, and cross zero. The bipolar bias supply can be adjusted ± 6 volts, providing up to 12 volts of bias span for setting the E-O device’s operating point.

The AC-coupled T130 output amplitude baseline is typically zero volts, with an adjustable ON pulse amplitude ranging -0.5 volts to -7 volts typ, lasting the duration of the pulse width setting. Note that the output driver amplitude setting is filtered and not designed to be quickly modulated.

E-O devices, such as Mach-Zehnder $LiNbO_3$ slicers, can have significant thermal coefficients affecting transmission. The bias voltage can be used to manually compensate for an E-O device’s thermal drift. Note that the bias voltage supply provides direct current (DC), it does not include a dithering signal. For automatic bias control, an external method of measuring E-O drift is required, with T130 bias voltage adjusted serially to compensate.

5 Connection and Operation

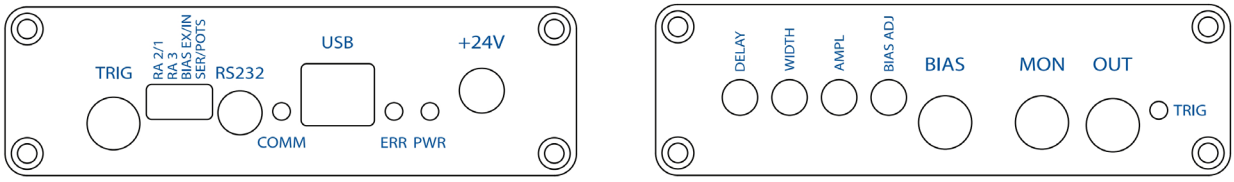


Figure 2: Input and Output panels

A DC power connector is located at the right side of the input panel. The T130 receives +24V DC through a 2.0mm x 5.7mm barrel power jack, compatible with locking 2.1mm x 5.5mm power plugs. A Highland model J24, 24 volt, 1.2 amp universal switching wall supply is included in the T130-9 evaluation kit. An international power supply adapter kit is furnished. The J27 is an optional locking 6ft. pigtail power cable for applications requiring integration into systems with existing +24V DC power.

The T130 is externally triggered on the rising edge of a user-supplied pulse. The trigger input connector terminates the signal with 50Ω to ground, and has a maximum safe input of - 0.6 volts to +6.0 volts. The input trigger threshold level is fixed at +0.5 volts. For minimum jitter, the trigger source should provide fast, clean edges with at least a +1.0 volt amplitude into 50Ω. Suitable logic levels include 1.8 volt to 5 volt TTL / LVTTL / CMOS. Because the trigger system is very fast, slow or noisy triggers can cause jitter, with the possibility to trigger on the falling edge.

SMA connectors must be torqued with a 5/16 inch wrench to 3 – 5 in-lb (0.3 – 0.6 N-m), and must be terminated with 50Ω to ground. The equivalent bandwidth of fast-switching output signals require RF coax and terminations rated for 18 GHz or better for optimal performance:

$$BW_{equiv} = 0.35 / \text{risetime}$$

with risetime measured as 10%-90%

Thus, the 100 picosecond risetime produced by the T130 has equivalent bandwidth components extending up to greater than 3 GHz. Using 18 GHz or better coax, connectors and terminations will minimize losses.

Note that even moderate lengths of low-quality cable can degrade pulse rise and fall times, and affect pulse plateau flatness. Short (less than 6 inch) hardline or semi-hardline cables, such as RG-402/U, are recommended.

A USB-B jack is located to the left of the power jack.

A 2.5mm, 3-conductor stereo type jack is located to the left of the USB jack for RS-232 communication. It can be used with a Highland T565, or other commonly available male 2.5mm plug to female DB9 socket adapter cable. It connects TIP (command from PC) to pin 3 of the DB9, and RING (reply to PC) to pin 2 of the DB9.

A 4-position DIP switch is located at the front panel, adjacent to the TRIG connector. The T130 scans the DIP switch paddle positions at power up and sets Range, Bias routing and trimpot/serial mode. Switch position selections may be made while the T130 is operating.

The first two switch paddles select range time:

RANGE 1: 0 to 5ns 

RANGE 2: 0 to 50ns 

RANGE 3: 0 to 300ns 

Note: The sum of delay + width cannot exceed the maximum range value.

The third DIP switch paddle selects whether the adjustable BIAS voltage is injected at the RF pulse output connector:

Internal BIAS source at RF SMA 

Externally applied BIAS at RF SMA 

Note: To prevent saturating the internal bias-T, limit externally applied bias current to 200mA or less.

When set for INT, the BIAS SMA connector functions as a voltage monitor, suitable for Hi-Z instruments such as a DVM with 1MegΩ or greater input impedance.

The fourth DIP switch paddle selects local trimpot control or remote USB control:

Local trimpot control 

Remote serial control 

There are four trimpots, located adjacent to the output connectors. They are, left to right,

DELAY	sets delay from 0 to 100% of range
WIDTH	sets pulse width from 0 to 100% of range
AMPL	sets output amplitude from -0.5 volts to -7 volts, typ. into 50Ω
BIAS ADJ	sets output bias voltage from -6 volts to +6 volts into Hi-Z load. Offset range is reduced -4.5 volts to +4.5 volts, when set for direct injection into a DC-coupled 50Ω signal path.

Four LEDs are provided. POWER and ERROR are located at the input panel between the USB and power connectors. The COMM LED is located to the left of the USB connector. TRIGGER is located at the output panel, to the right of the RF OUT connector:

PWR Located to the left of the +24V barrel connector. Illuminates GREEN when power is supplied to the T130.

TRIG Located to the right of the OUT SMA jack. Illuminates BLUE when the T130 is triggered.

COMM Located to the left of the USB connector. It is off in POT mode, and flashes ORANGE when serial commands are received.

ERR Located to the right of the USB connector. It is normally off, and illuminates RED if any of the error flags are set.

5.1 Duty factor limitations

The T130 signal path is ac-coupled, resulting in DC baseline shifts as the output pulse duty factor increases. DC shift at internal nodes, limits the pulse repetition rate for a given pulse width. Duty factor is calculated as:

$$DF = [PW / (1/PRR)]$$

where,

DF is duty factor, represented as a number from 0 to 1 (100%)
PW is the T130's programmed pulse width.
PRR is the pulse repetition rate.

Typically, the T130 duty limit is around 2.5%, depending on the selected range and pulse width. Table 1 lists pulse repetition rate (PRR) limits at the limits for each RANGE. Figure 3, Figure 4, and Figure 5 are charts associating maximum pulse repetition rate (PRR) as a function of output pulse width (PW) at maximum amplitude.

RANGE	PW, max	PRR, max	Duty Factor (DF)
1	≤ 500ps	50MHz	0.025
	5ns	5MHz	0.025
2	≤ 1ns	25MHz	0.025
	50ns	500 kHz	0.025
3	≤ 5ns	5MHz	0.025
	300ns	50 kHz	0.015

Table 1: T130 duty factor PW and PRR limits

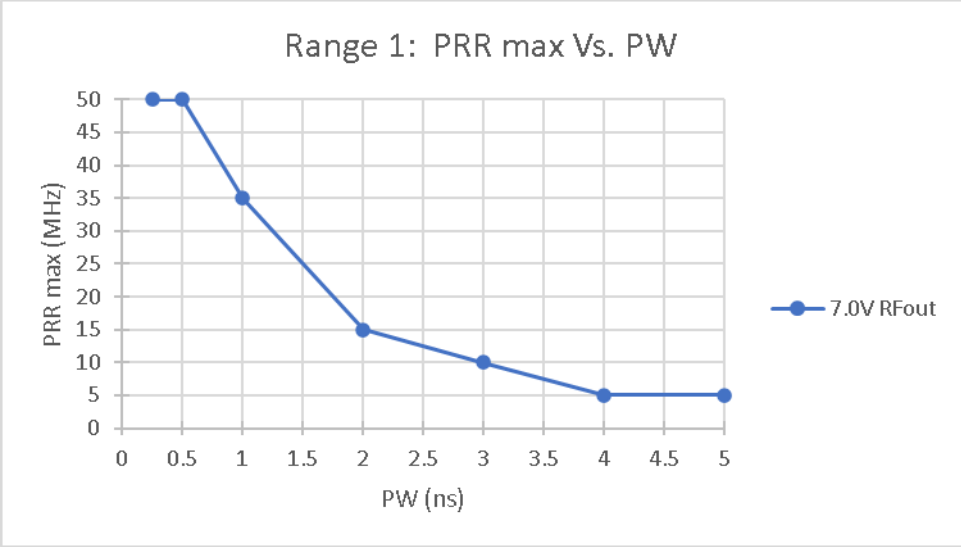


Figure 3: Range 1 maximum pulse repetition rate vs. pulse width

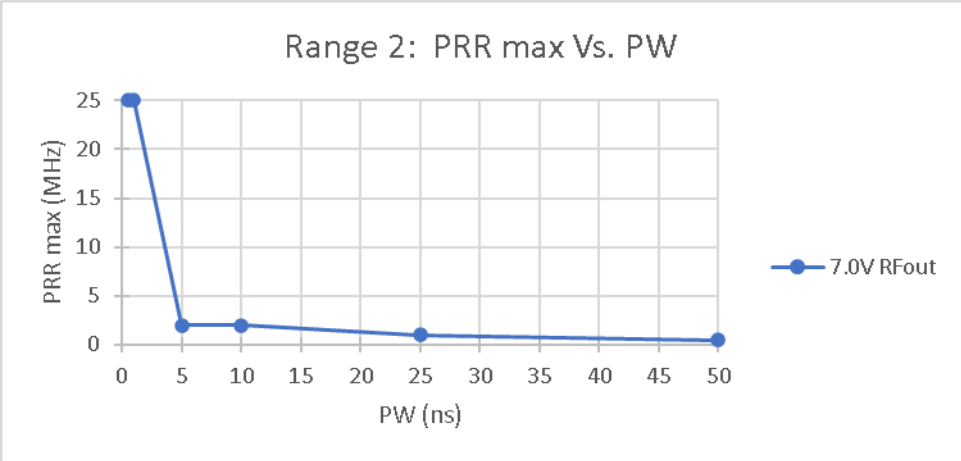


Figure 4: Range 2 maximum pulse repetition rate vs. pulse width

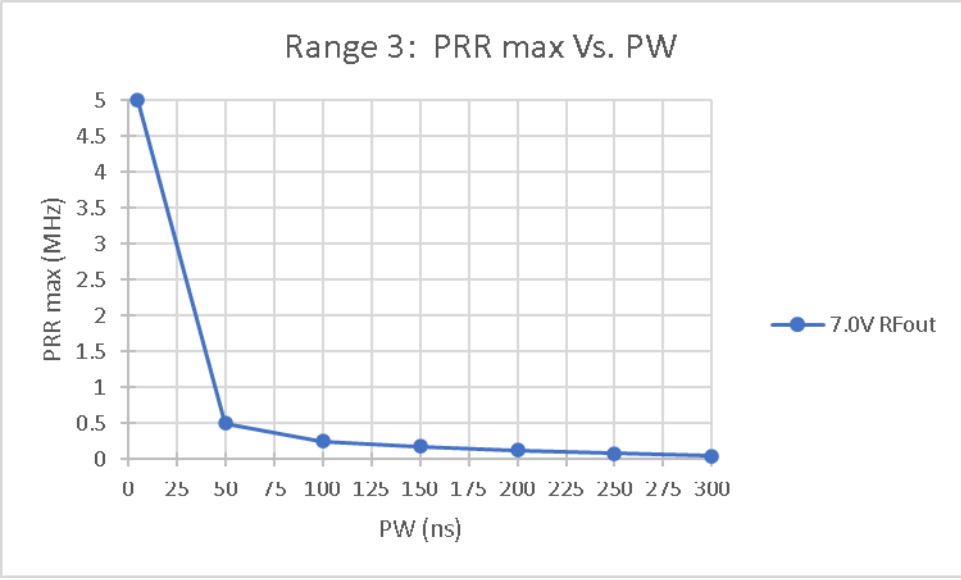


Figure 5: Range 3 maximum pulse repetition rate vs. pulse width

The RF OUT pulse baseline will shift positive at high pulse repetition rates and duty factors. Adjusting the BIAS voltage negative, allows for output signal baseline compensation.

The high speed components of the T130 are sensitive to electrostatic damage. To maintain picosecond performance, no explicit ESD protection is included.

Discharge coaxial cables before connecting to the T130. Do not apply trigger inputs over +6 volts, -0.6 volts. Do not connect RF output to loads terminated at more than ± 6.5 volts. Only operate with RF output connected to 50Ω load. Do not connect BIAS output to loads terminated at more than ± 6.5 volts.

6 Remote Setup and Protocol

6.1 RS232 Communications

The T130 provides serial RS232 communications via the 2.5mm jack. Pinout is:

PIN	FUNCTION
TIP	RS232 command data to T130
RING	RS232 reply data from T130
SLEEVE	Ground

The T565 is available, an optional 6 foot male 2.4mm plug to female DB9 socket adapter cable. It connects TIP (poll) to pin-3 of the DB9, and RING (reply) to pin-2 of the DB9.

The pinout is suitable for connecting to the serial port of a PC using a DB9 non-crossover cable. The standard baud rate is 115.2K, and flow control is not supported.

The T130 should logically connect/disconnect as a numbered COM port. RS232 and USB ports operate concurrently. A serial communications program, such as Hyperterminal, or a user application, can be used to send and receive control strings.

A **`HElp`** command is available, summarizing serial commands and operating modes. The **`STatus`** command will send back a summary of T130 settings.

6.2 USB Communications

Most newer versions of Windows natively enumerate the T130 as a “USB Serial Device” and use a simple ASCII command protocol for communicating.

6.3 Command Protocol

Users send serial ASCII command strings to the T130, to which the T130 immediately replies. A command to the T130 is a line of text beginning with a keyword command, followed with optional arguments and terminated with a carriage return. Input is case insensitive and does not echo. In general, a command without an argument is a query. Any keyword can be truncated to its first two characters.

The T130 only transmits in immediate reply to a serial command. All replies are lines of text terminated by carriage return/linefeed. Commands with arguments evoke the reply

OK <cr> <lf>

or

Enn : <cr> <lf> to indicate an error.

Inquiry type commands evoke

Requested_data <cr> <lf>

Any queried settings reflect the last data sent over USB, not the pot positions. The **STATUS** command will report both the pot and remote settings.

A single received <cr> evokes the response

T130-1 <cr> <lf>

The programmed delay, width, amplitude, and bias levels are accurate to about 5% of range. For critical timings, especially very narrow pulse widths, actual outputs should be verified electrically. If delays, widths, or amplitudes are set beyond allowed values, they will be reasonably clipped before being used to program the hardware.

6.4 Command Strings

One or more spaces are required between a keyword and its argument. Whitespace may not break up a command token or an argument, except where double-quotes escape whitespace in the NAME and RECALL commands.

All commands must be terminated by either an end of line indicator (carriage return, ASCII 13, denoted <cr>) or the semicolon separator ; for multiple commands on a line.

Incoming characters are not echoed. Because serial characters are buffered by both a PC OS and the T130, and because the T130 may spend milliseconds or more to process commands, user software must wait for a response to each command line before sending another command.

Each command consists of a command keyword, followed by an optional second alpha keyword or by a numeric argument. When a full line is received, terminated by the final <cr> character, the buffered line is executed, in the order received.

Keywords may be fully spelled out, or may be sent as their first two characters; only the first two characters are significant. In this documentation, a word that has two possible forms is written with the short form capitalized, and the rest of the word in lower-case letters. The actual T130 protocol is case insensitive.

Examples

`DElay 4.345`	indicates that the short form is "`DE 4.345`", and the long form is…
`DELAY 4.345`	both of which are recognized commands which set the timing of the first edge of the output pulse, relative to insertion delay

Delay and Width units are nanoseconds. Acceptable suffixes are

n
ns
N
NS

All forms are case insensitive. One or more spaces are required to separate keywords from arguments.

RF pulsed signal amplitudes are always negative polarity and set in volts, as

`AMpl 6.500`
shortform `AM 6.500`,

which sets the amplitude to -6.500 at the output.

A negative sign,

-

is an acceptable prefix.

Amplitude is set in volts, with an acceptable suffix:

v
volts
V
Volts
VOLTS

Bias supply amplitude is bipolar, with polarity according to prefix. Setting the bias output negative requires the negative sign as a prefix:

-

Omitting a sign before the bias supply numerical entry is interpreted as a positive voltage.

Most value-setting commands may be sent without an argument, in which case they become queries of the associated value.

`WIdth` (no argument)

evokes the reply

34.500

which represents the output pulse width, in nanoseconds

Certain incoming ASCII characters are treated specially:

Command names and arguments are case-insensitive.

TAB is treated as a space.

Most control characters, and linefeed are ignored.

The T130 does not support hardware or software flow control.

6.5 Reply Strings

Each received command will evoke a reply indicating the execution status of the command. For query commands, the reply is the requested data. For other commands, successful completion will yield a reply of ***OK***. If multiple commands are issued on one line, multiple responses will be sent back on a single line, separated by semicolons. For the command line...

```
BIAS INT; WIDTH; MODE POTS
```

the reply will be of the form

OK;34.500;OK

All reply strings are terminated with carriage return/linefeed.

Numerical replies to queries will be in fixed-point decimal numeric form.

If an error occurs while processing a command, the reply of the form Enn will be replied, where “nn” is an error number (see table below). If multiple commands are present on a command line, and any command produces an error, the erroneous command will respond

with the error indicator and no remaining commands will be processed. Invalid-argument or invalid-command errors will not be saved and will not affect the result of the ERRORS command.

Command Line Errors

Reply	Explanation
E01	Command not found
E02	Invalid argument or command not permitted in currently configured state
E04	Hardware error

6.6 Realtime Issues

User command lines are stored in a buffer until the <cr> character is received, at which time the entire command line is parsed and executed in the order received. Each command sends its reply characters, typically a requested value or the ***OK*** response, as the command is executed. Any additional incoming characters following the command-line <cr> are ignored until the entire command line is processed and the final response-line <cr> <lf> is returned.

Most simple commands execute in hundreds of microseconds, and their realtime execution rate is dominated by the serial communications rate. Shortform commands reduce communications overhead. Long reports are baud rate limited.

6.7 Command Summary

Selection Commands

Long Form	Short Form	Function
RAnge 1	**RA 1**	Sets 5ns range
RAnge 2	**RA 2**	Sets 50ns range
RAnge 3	**RA 3**	Sets 300ns range
BIas INt	**BI IN**	Selects internal bias mode
BIas EXt	**BI EX**	Selects external bias mode

Parameter Commands

Long Form	Short Form	Function
DElay 2.345n **DElay 2.345** **DElay .456**	**DE 2.345n** **DE 2.345** **DE .456**	set first edge output pulse delay relative given range's insertion delay, nanoseconds
WIdth 35.500n **WIdth 35.500** **WIdth .750**	**WI 35.500n** **WI 35.500** **WI .750**	set output pulse width, nanoseconds
AMpl -6.025v **AMpl 6.025**	**AM -6.025v** **AM 6.025**	set output pulse amplitude, volts
BIas -2.352v **BIas +2.352**	**BI -2.352v** **BI +2.352**	set bias generator amplitude, volts

Report Commands

Long Form	Short Form	Function
MOde	**MO**	return operating mode, local trimpot or remote serial
POts	**PO**	return pot wiper position (0-4095)
DAcs	**DA**	return delay, width, amplitude, bias DAC codes (0-65535)
DIpsw	**DI**	return dip switch paddle positions
DElay	**DE**	return delay setting, nanoseconds
WIdth	**WI**	return width, nanoseconds
AMpl	**AM**	return output pulse amplitude, volts
BIas	**BI**	return bias generator voltage
TEmp	**TE**	return thermistor temperature
SUpplies	**SU**	return regulator voltages
STatus	**ST**	displayT130 status report
IDent	**ID**	return ID string
ERrors	**ER**	return error flags

Save / Recall Commands

Long Form	Short Form	Function
CFg NAme text	**CF NA text**	save name of current remote setup
CFg SAve	**CF SA**	save current remote setup
CFg REcall	**CF RE**	recall last remote setup
CFg LIst	**CF LI**	Lists all saved remote setups

Help Commands

Long Form	Short Form	Function
HElp	**HE**	return help command topics

6.8 Commands

IDENT Unit Identify.

This returns a string of the form

T130-1B Pulse Generator sn 0001 Highland Technology Inc

MODE Queries control mode DIP switch setting, local trimpot or remote serial.

MODE returns

POTS

or *REM*

RANGE selects one of three timing ranges.

RANGE 1	selects the 5ns timing range
RANGE 2	selects the 50ns timing range
RANGE 3	selects the 300ns timing range

RANGE queries the range setting. Reply format is a single digit, as

```
2
```

If the T130 is in REM mode and the current delay or width setting is outside of the new range, then a configuration error will be set in the error word replied from the ERRORS command.

DELAY sets time delay relative the range's insertion delay.

DELAY 2.345n	sets time delay in nanoseconds.
DELAY 2.345	sets time delay in nanoseconds. The default unit is ns.
DELAY .750	sets time delay in picoseconds

DELAY queries the time delay setting. The reply is in ns...

```
0.750
```

Note that actual connector-to-connector delay is the sum of the programmed delay and the inherent insertion delay of the T130, about 8ns, 20ns and 70ns at respective ranges 1 through 3.

WIDTH sets output pulse width, with same syntax as **DELAY**
If the requested delay + width exceeds the limit of the current range, the actual width will be reduced. The minimum usable pulse width is 250 ps on range 1, 500 ps on range 2, and 1ns on range 3.

WIDTH queries the current width setting. Reply looks like

```
34.500
```

AMPL sets output pulse amplitude. The command form is

AMPL 6.0	sets output amplitude to -6.0 volts. Legal range is -0.25 to -7.2 volts.

AMPL queries the current amplitude setting. Reply looks like

```
-6.00
```

BIAS sets RF BIAS injection source as internal or external, and sets the internal dc bias generator voltage. The command form is

BIAS INT selects internal source for RF BIAS injection.

BIAS EXT selects external source applied at BIAS SMA connector for RF BIAS injection.

BIAS -2.500 sets bias voltage to -2.500 volts. Legal range is -6.000 volts to +6.000 volts.

BIAS queries the current bias relay routing. Reply looks like

```
INT -2.500
```

POTS returns the physical pot positions, as raw ADC values from 0 (CCW) to 4095 (CW). Reply is values of the four pots, left to right, starting with the Delay pot.

```
0003 2154 1904 4095
```

DIPSW returns the physical DIP switch paddle positions, as binary values, 0 (paddle position not asserted) or 1 (paddle position asserted). Reply is values of the four DIP switch positions, left to right, starting with the Range 1 and Range 2 selection paddles, Bias Int./Ext., and Pots/USB.
Note: RS-232 is enabled simultaneously in USB mode.

```
0 1 1 0
```

DACS returns the raw internal 16-bit DAC codes, as four integers from 0 to 65535, in the same order as the POTS command..

```
01475 48613 26100 65535
```

TEMP returns temperature of onboard thermistor in degrees centigrade.

```
45.1
```

STATUS return status report.

This command returns a multi-line status report of the form....

T130-1 Pulse Generator sn 0001 Highland Technology Inc
Mode: REM
Pots: Delay 0.245 Width 0.455 Amplitude -6.50 Bias +3.100 INT
Dipsw: Range 1 Bias INT
Rem: Range 2 Delay 7.500 Width 9.700 Amplitude -5.00 Bias -4.000 EXT

Firmware: 28E130-A Err: 0 Cal date: 04/30/2021 OK

The final “Err 0” and “OK” indicate that there are no errors and that the calibration table is valid.

SUPPLIES returns a report of critical internal node voltages.

This command returns a multi-line power report of the form....

```
+10: 10.022
+9: 9.001
+6.5: 6.563
+5: 5.103
+3.3: 3.312
+3: 3.027
+2.5R: 2.504
-5: -5.081
-6.5: -6.530
GND: 0.010
IDA: 1.952
```

Note IDA is proportional to output amplifier operating current. Scaling is approximately 80mV/mA.

NAME Prompts for text entry for name of saved T130 configuration.

NAME “t130eom1” names current remote configuration. Single or double quotes are optional; they can be used for escaping spaces, but not carriage returns or semicolons.

NAME queries the current name of remote configuration. Reply looks like:

```
"t130eom1"
```

If the current configuration is not yet named, then an empty pair of double quotes will be replied:

“”

SAVE saves current remote configuration settings. Behavior varies depending on the state:

- If the current configuration has not yet been named, an invalid-argument error will be replied. 16 configurations may be saved.

- If the current configuration's name has not changed since recall, then the old configuration with the same name will be overwritten.
- If the name has changed from a recalled configuration, then the T130 will attempt to save the new configuration to an unused slot. If all configuration slots have been filled, then the current configuration will overwrite the last-recalled configuration.

SAVE "name" is a shortcut for **NAME "name"; SAVE**

LIST List all saved configurations by name, delimited by comma. The last configuration will be the active configuration, whether it has been saved or not. If the reply is a single empty pair of double quotes, this indicates that there are no saved configurations and the active configuration has not been named.

RECALL Recalls last saved remote configuration settings file.

RECALL "t130eom1" recalls the remote configuration settings file named T130eom1. Optional quotation marks follow same rules as with the NAME command.

RECALL without an argument will recall the last-saved setting. If none have been saved yet, then the default configuration will be recalled.

The default remote configuration is:

RANGE:	1
DELAY:	0ns
WIDTH:	2.5ns
AMPLITUDE:	-3.5V
BIAS:	0.0V
NAME:	""

HELP Returns a brief help command summary.

ERRORS The ERrors command returns an integer which identifies any errors. The returned form is...

0 for no errors
8 or a non-zero numeric value if errors are present

where the integer value represents the error flags word. Bits are...

bit	0	configuration error
bit	1	calibration table lost; default cals are used
bit	2	overtemperature error
bit	3	internal hardware error
bit	4	power supply error

7 Typical Waveforms

Unless noted, measurements were taken with a Tektronix 11801/SD-24 sampling system having approximate 17ps rise time, so actual T130 timings are slightly faster than indicated.

Note that rise/fall measurements below at taken at the 10/90 per-cent points. Picosecond-range measurements are sometimes quoted at the 20/80 points, which would result in faster reported rise and fall times. EOMs with $\sin^2$ transfer functions will have faster optical rise times than their electrical drive.

Picosecond measurements require connections to be short, high-quality hardline coax, and the SMA connectors must be properly torqued to ensure waveform fidelity.

Figure 6 shows the minimum usable pulse width on the fastest timing range. Figure 7 shows a 5ns square pulse on Range 1. Figure 8 is of a 50ns pulse on Range 2. Figure 9 is of a 300ns pulse on Range 3. Figure 10 shows amplitude linearity of a 300ns pulse.

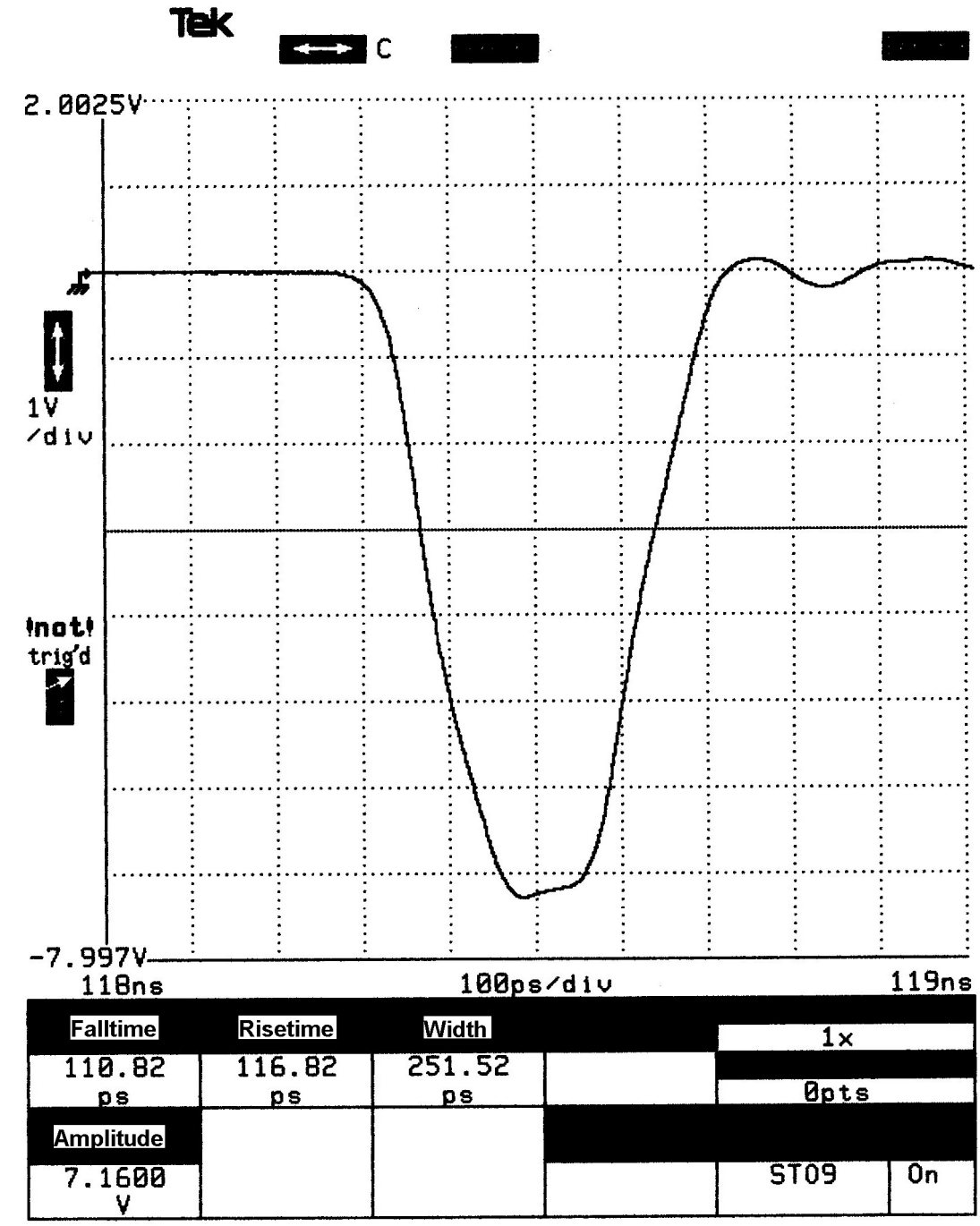


Figure 6: 250ps FWHM pulse, Range 1, 10/90 risetime

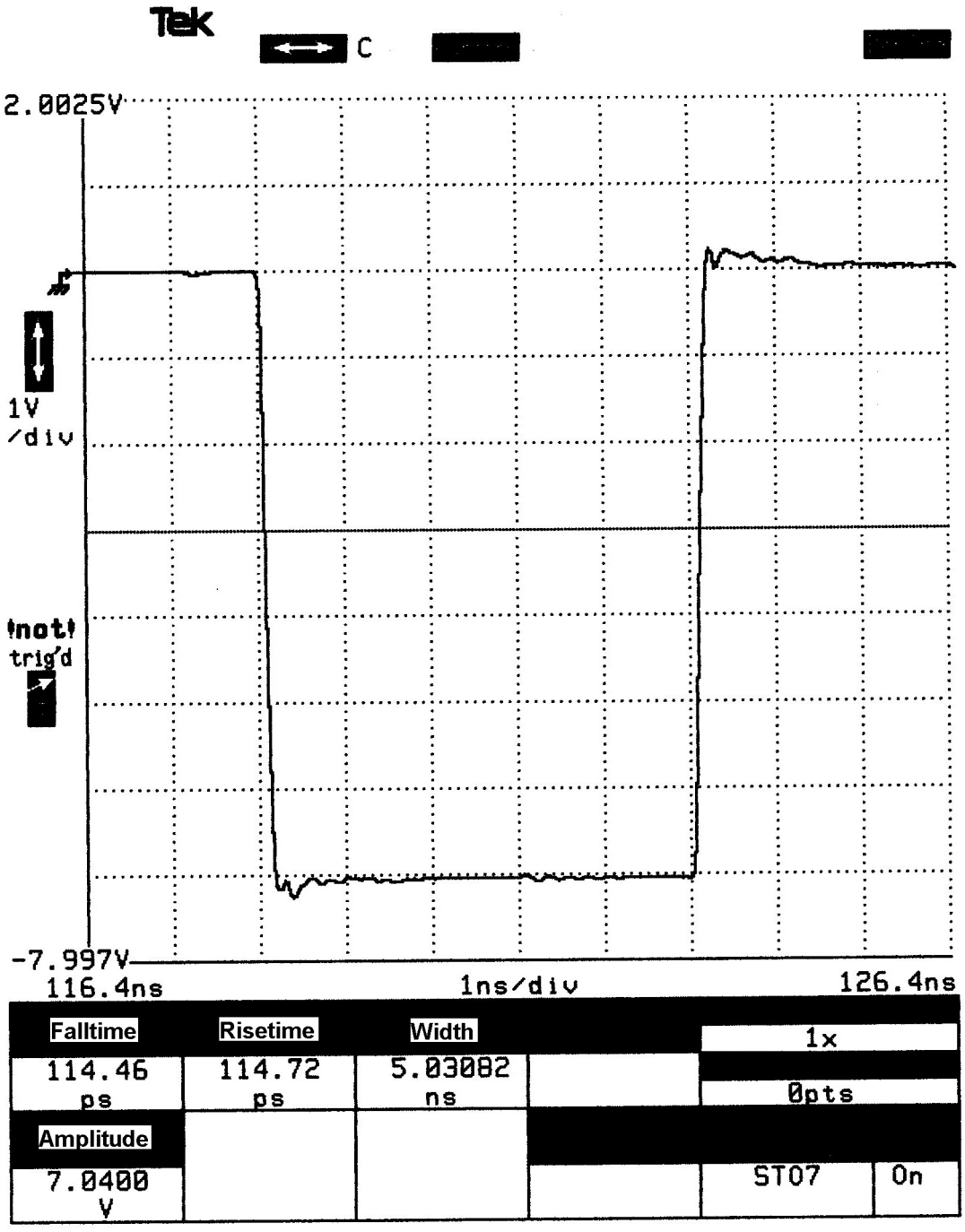


Figure 7: 5ns rectangular pulse, Range 1, 10/90 risetime

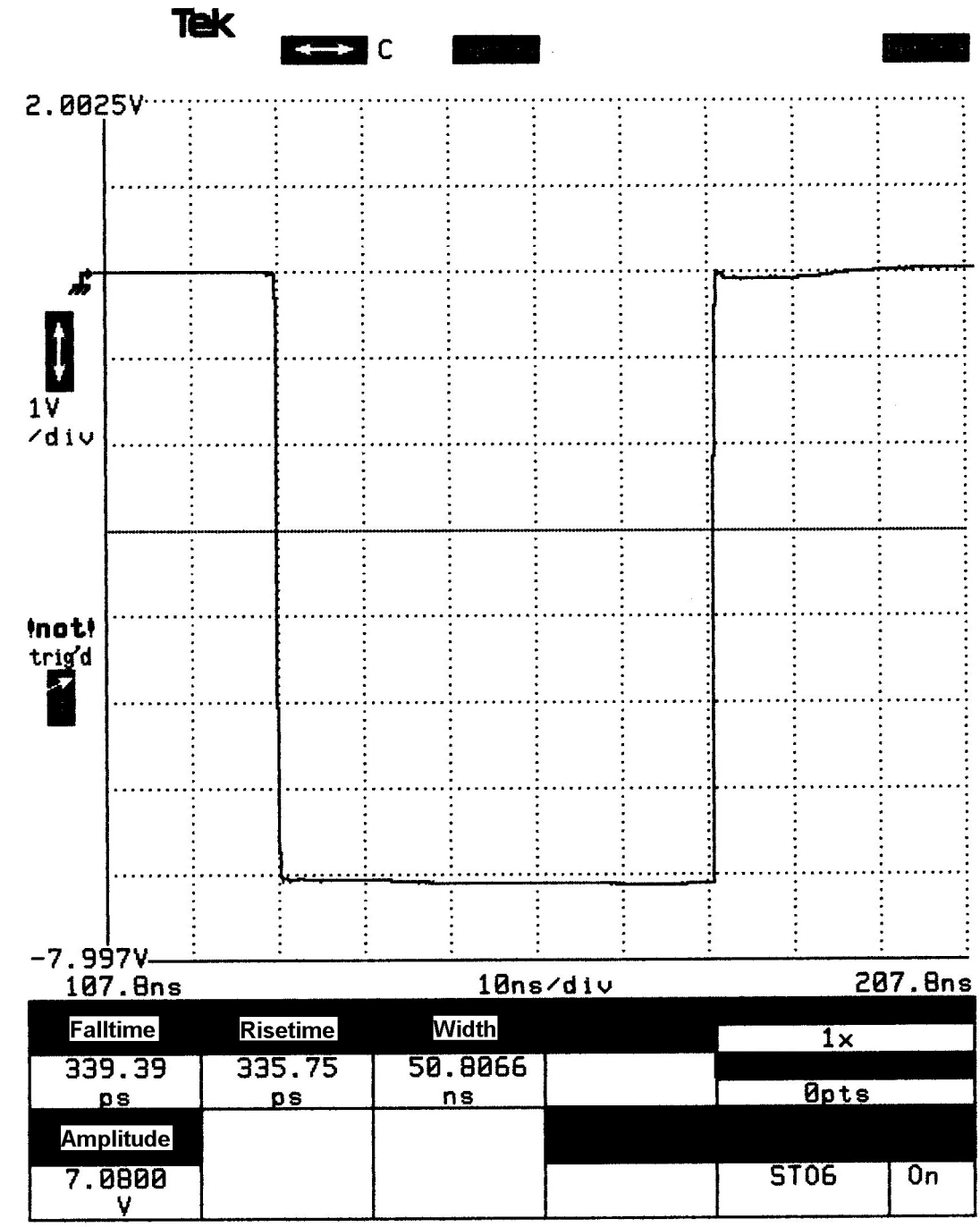


Figure 8: 50ns rectangular pulse, Range 2

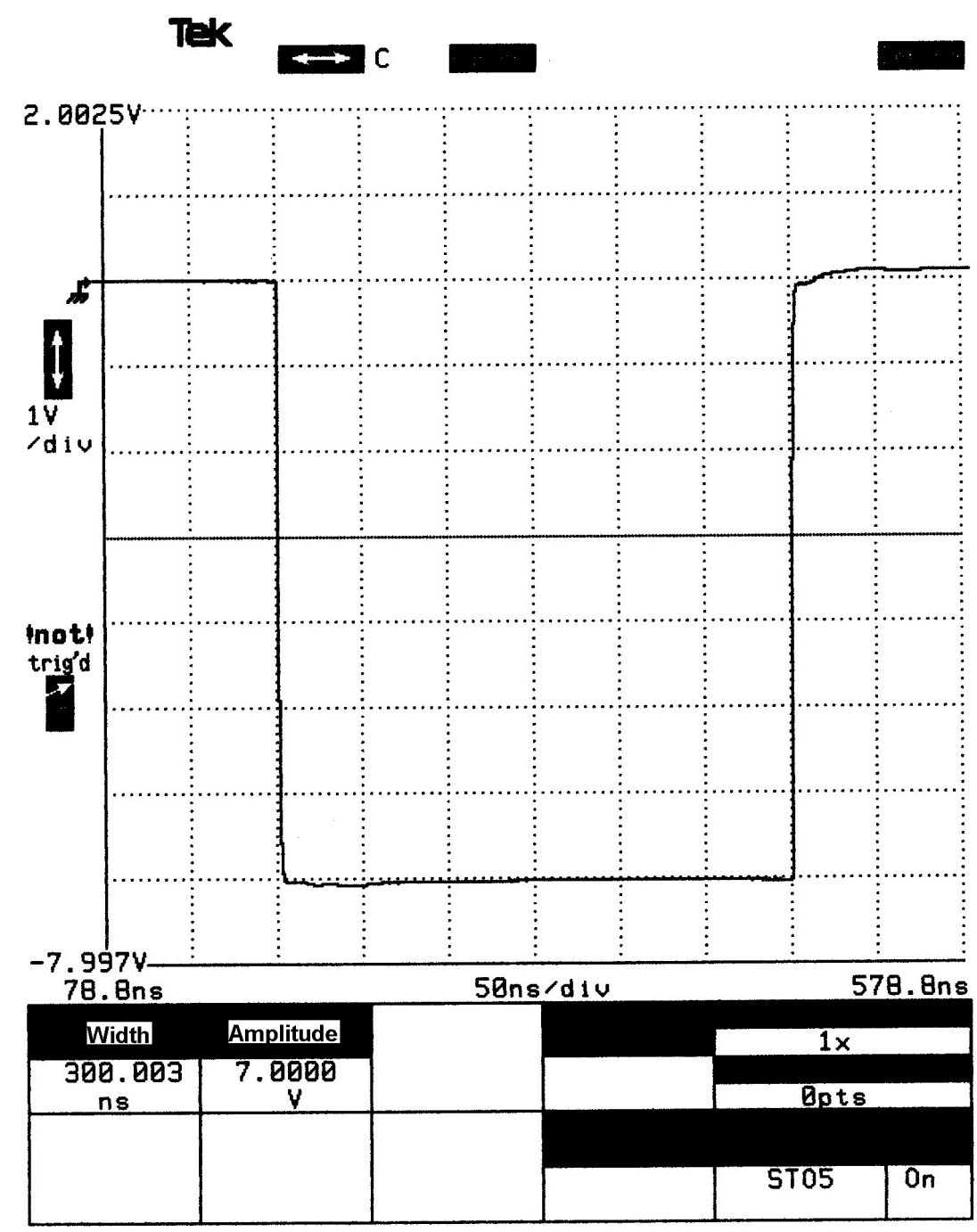


Figure 9: 300ns rectangular pulse, Range 3

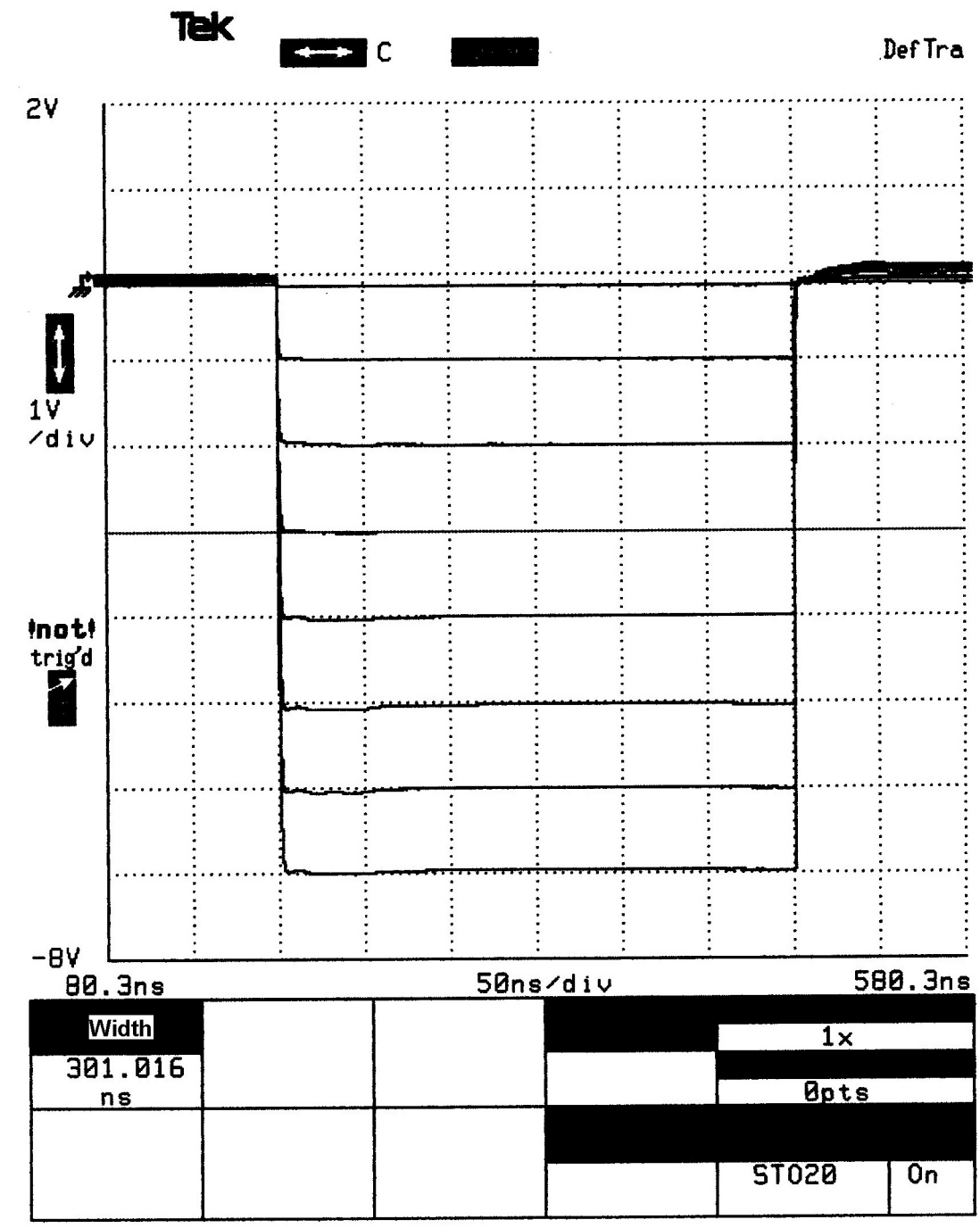


Figure 10: Amplitude Linearity, 300ns rectangular pulse

Typical RMS jitter performance on range 1 is illustrated in Figure 11. The T130 was triggered by a Highland P400 DDG and the T130 output rising edge was displayed on the same scope over a 3-second interval. The net jitter is nearly indistinguishable from the internal jitter of the scope, which is about 3ps RMS.

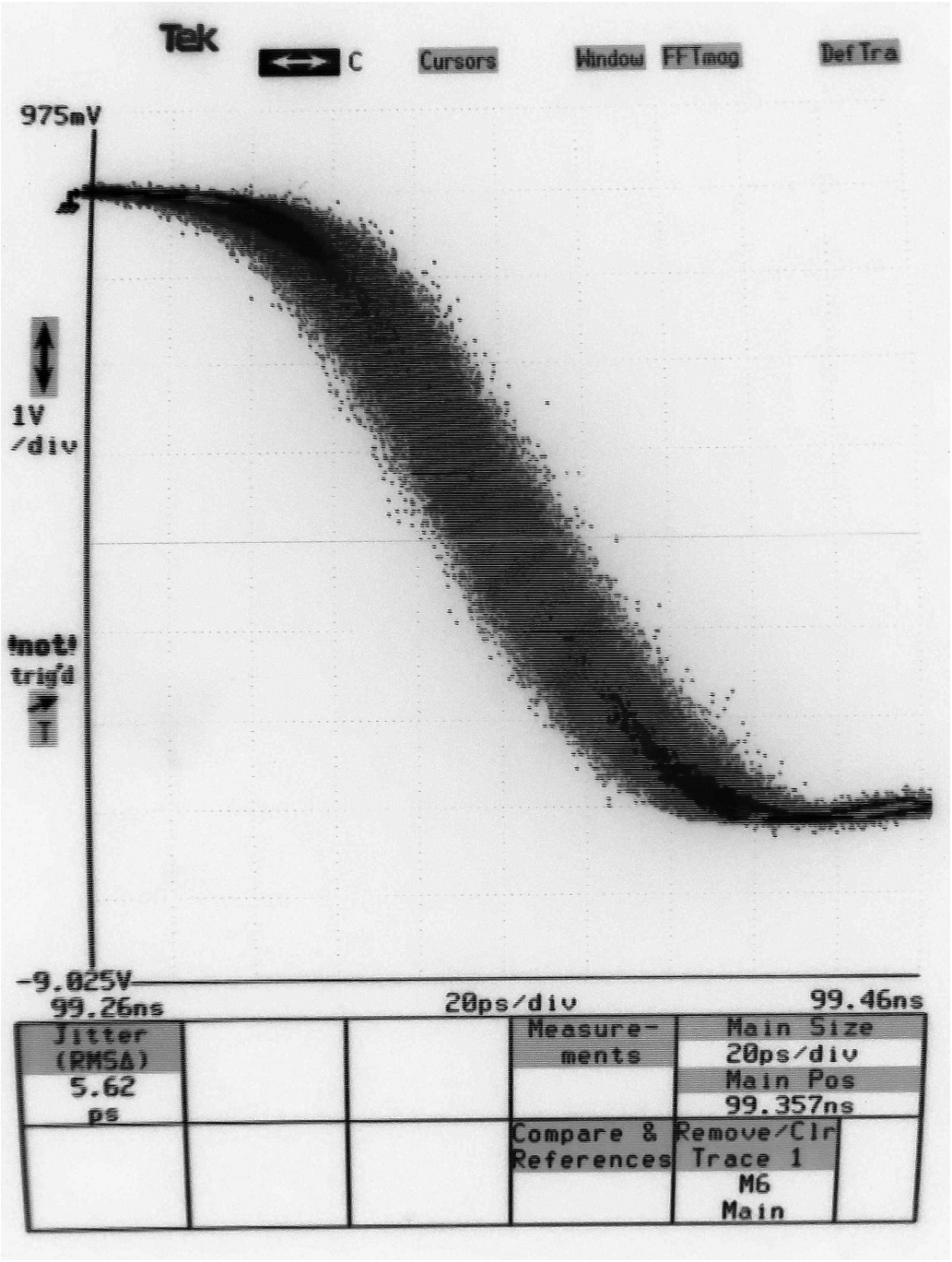


Figure 11: Typical T130 jitter on RANGE 1

8 Dimensions

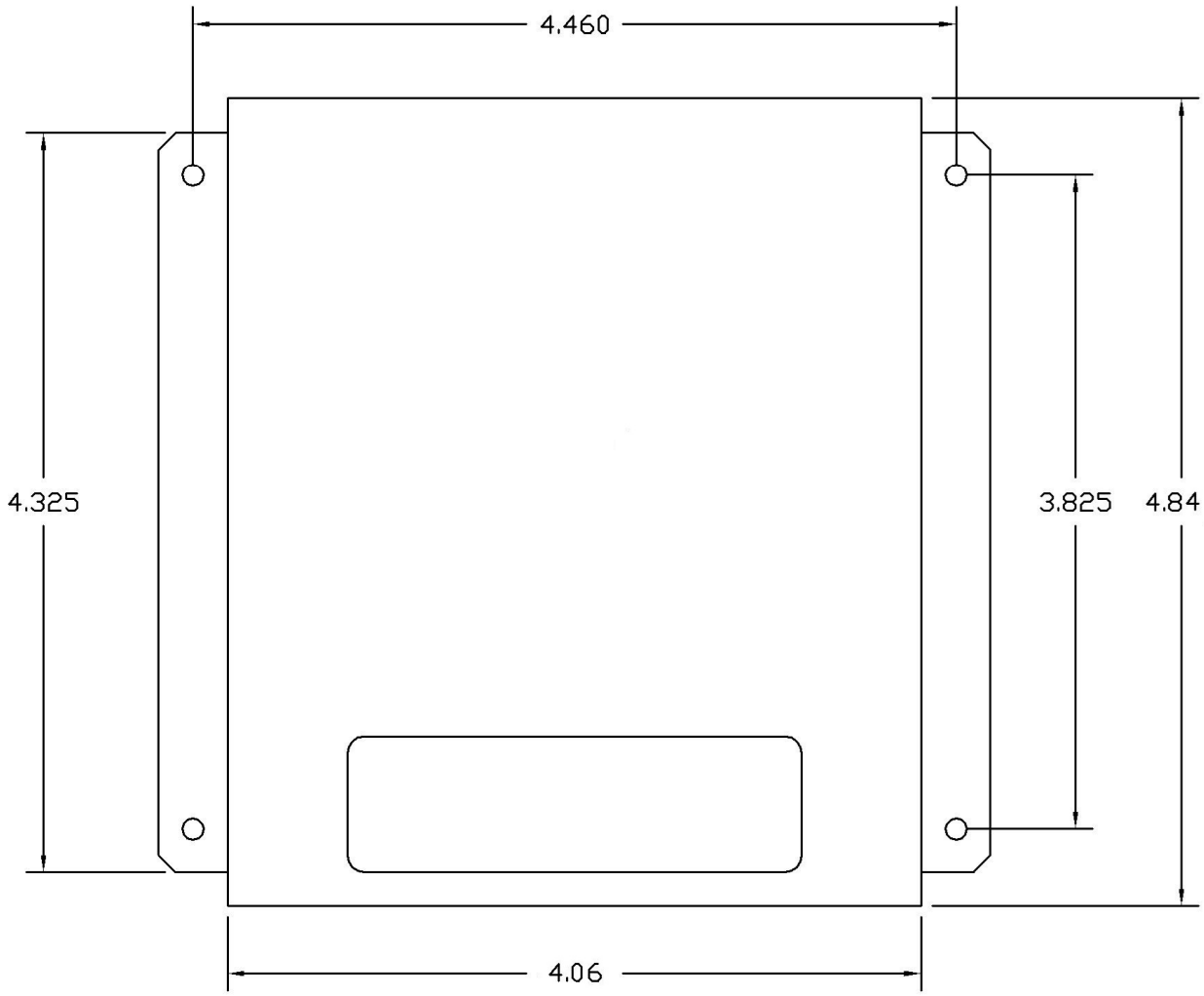


Figure 12: Enclosure, shown with surface mount flange (inches)

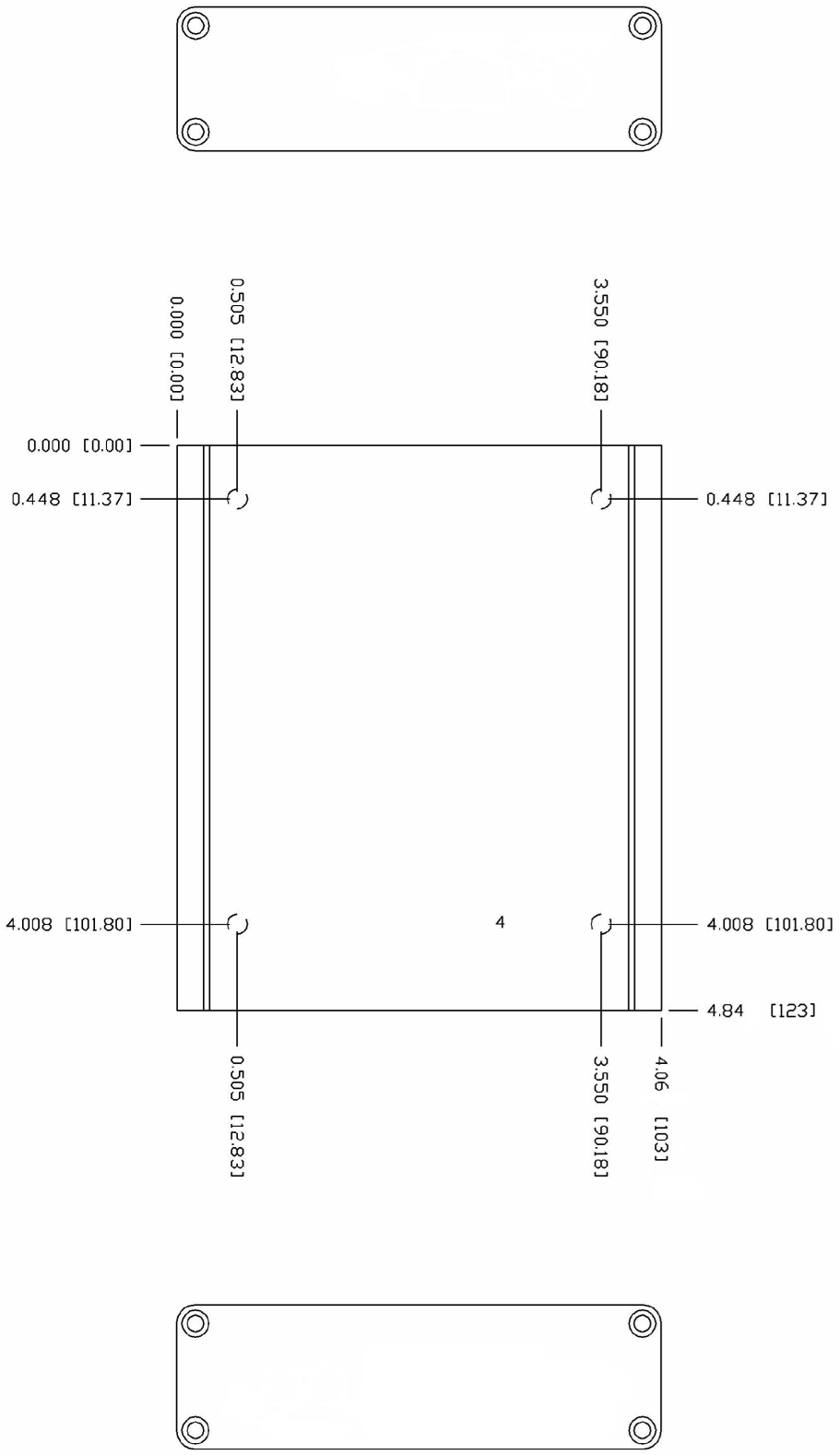


Figure 13: T130 enclosure and mounting locations

9 Versions

T130-9 single-channel picosecond EOM driver evaluation kit (includes T130-1, J24-1 power supply, J62-1 USB cable, and T566-1 mounting flange)

10 Customization

Consult factory for information on additional custom versions.

11 Hardware and Firmware Revision History

11.1 Hardware Revision History

Revision A Apr 2020
Initial PCB release

Revision B February 2021
Performance improvements
Added RS232

Revision C March 2023
Functionally equivalent to Revision B

11.2 Firmware Revision History

Revision A June 2021
Initial firmware release

Revision B October 2023
Eliminate user ability to specify negative delay and width over USB and RS232

Revision C October 2023
Widen BIST limits to prevent spurious failures

12 Accessories

J24-1: 24 volt 1.2 amp power supply (included with purchase)

J27-1: 2.1 x 5.5 mm locking barrel to pigtail power cable

J44-1: 3' SMA to SMA cable

J48-1: 50 ohm SMA terminator

J62-1: 6' male A to male B USB cable (included with purchase)

P10-1: 19" rack mount shelf (four t-boxes per rack)

T565-1: RS-232 cable

T566-1: mounting flange (included with purchase)