HIGHLAND TECHNOLOGY

MODEL T240

SINGLE-CHANNEL USB-

PROGRAMMABLE PULSE GENERATOR

Technical Manual

March 24, 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.

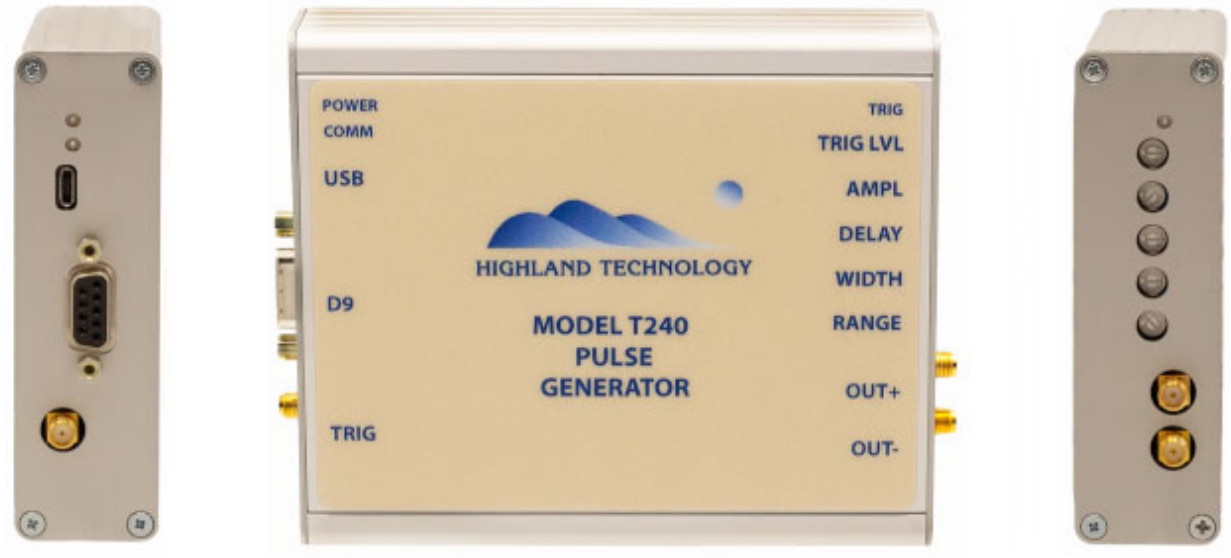
(Disclaimer of expressed or implied warranties in certain transactions is not allowed in some states. Therefore, the above statement may not apply to you.)

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 T240 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 T240 Pulse Generator.

The T240 is an externally-triggered pulse generator with complementary outputs.

Features of the T240 include:

- Generation of fast complementary pulse outputs
- Programmable delay and pulse width in two ranges
- Programmable amplitude from 0 to 750 millivolts nominal, 0 to 375 millivolts nominal LVDS
- Risetime / falltime 75 picoseconds typical, 10-90%
- Pulse width down to 100 picoseconds FWHM
- Programmable trigger threshold
- Powered by USB or standard 5-volt micro-USB power supply
- Control via USB, RS-232, or trimpots; optional SPI
- Compact extruded enclosure with optional mounting flange
- The T240 is suited to:
    - Driving electrical/optical modulators through suitable power amplifiers and bias tees
    - Driving 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 complementary-output pulse generator
TRIGGER	Rising-edge trigger, 50 Ω input impedance, DC coupled Threshold is programmable from -2.5 to +2.5 volts Max safe input is ± 3.3 volts
PROPAGATION DELAY	Range 1: 3 ns nominal insertion delay Range 2: 10 ns nominal insertion delay
COMPLEMENTARY OUTPUTS	-dash 1: User adjustable 0 to ± 750 mV (nominal, ± 675 mV, min) peak into 50 Ω loads; AC-coupled 5 Ω nom. source per output -dash 3: User adjustable 0 to 375 mV (nominal, 340 mV, min) peak-peak LVDS into 50 Ω load; DC-coupled 50 Ω nom. source per output V_{OH} = +1.15 V (nominal, fixed) V_{OL} = +1.15 V to +0.75 V (nominal, adjustable)
PULSE RATE	Min pulse rate is 0 Hz Range 1: max 70-125 MHz depending on delay/width settings Range 2: max 20-50 MHz depending on delay/width settings
RISE/FALL TIMES	75 ps nominal, measured at 10/90%
PROGRAMMABLE TIMINGS	Range 1: delay 0 to 2.5 ns, width 100 ps to 2.5 ns, d+w < 2.5 ns Range 2: delay 0 to 25 ns, width 250 ps to 25 ns, d+w < 25 ns
JITTER	Range 1: < 5 ps RMS, typical < 3 ps RMS Range 2: < 10 ps RMS
CONTROL	Standard: trimpots, RS-232, and USB; optional SPI
CALIBRATION INTERVAL	One year
POWER	+5 volts at 500 mA nom via USB connector Highland model J6 power supply furnished
CONNECTORS	TRIG OUT+ OUT- SMA jacks Micro/AB for power and USB control D9 female for optional power/RS-232/SPI
LED INDICATORS	Green POWER Blue TRIGGER Orange COMM
PACKAGING	4.75” (L) x 4.0” (W) x 1.25” (H) extruded aluminum enclosure

3 Architecture

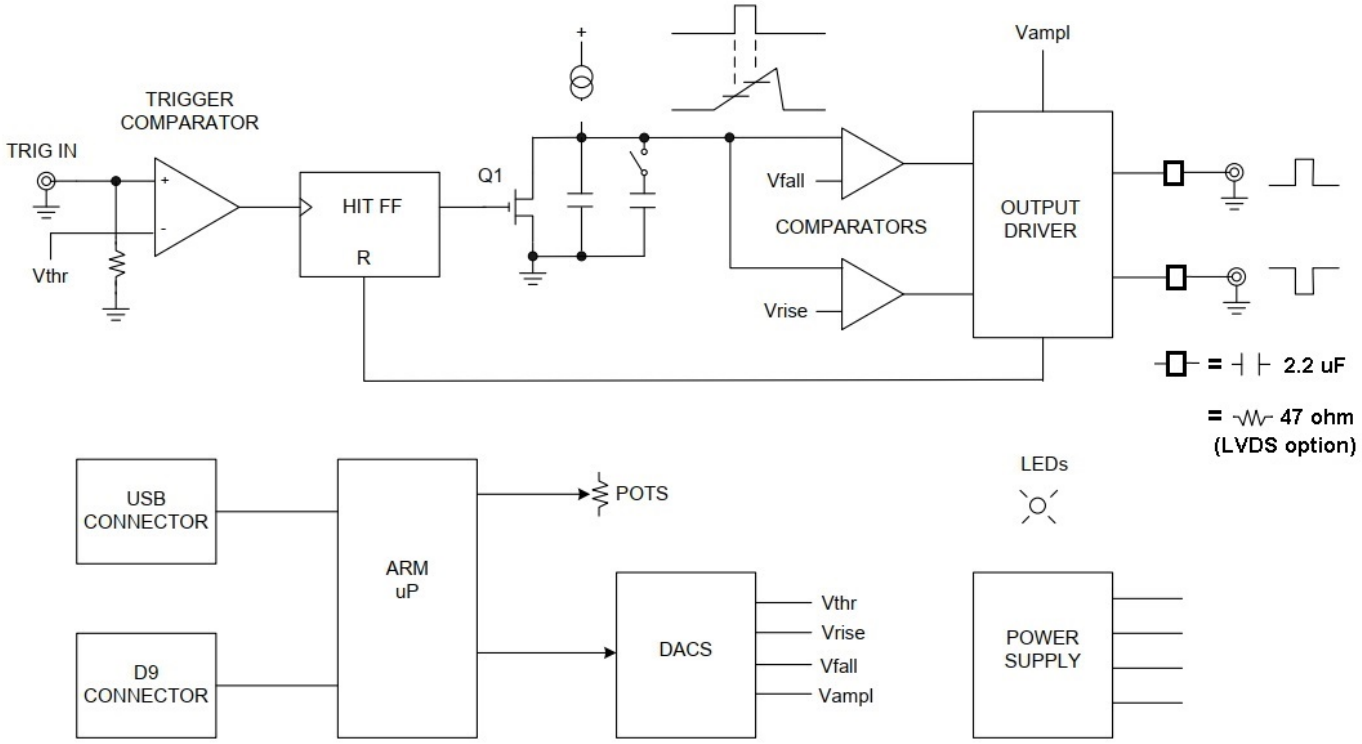


Figure 1: T240 Block Diagram

Refer to

Figure 1 Block diagram above: An input comparator recognizes the rising edge of incoming triggers and sets the HIT flipflop, beginning a timing cycle. The active HIT state turns off transistor Q1, allowing the current source to charge the ramp capacitor.

The resulting linear ramp feeds two comparators, whose threshold voltages determine the rising and falling edge times of the output pulse. The output driver combines the comparator outputs, drives the output connectors, and resets the HIT flipflop.

Two switched range capacitors are provided, with active ramp times of 2.5 and 25 ns respectively. Minimum output pulse widths are 100 ps and 250 ps on the two respective ranges.

Operation is supervised by the ARM microprocessor. At powerup, the uP assumes "pot mode" and digitizes the positions of the trimpots, setting the DACs and the range capacitor selection. A serial command from the USB or RS-232 ports can take over control and allow remote user programming.

The standard T240 gets power from the USB connector and accepts serial commands from both the USB and the RS-232 ports.

4 Connection and Operation

The standard T240 receives power over a Micro-A or Micro-B USB connector. It may be powered by a PC or by a USB hub. If remote control is not needed, it can be powered from a USB-style 5-volt power supply or charger, in which case the local trimpots may be used to set trigger threshold, pulse delay/width, and pulse amplitude.

The T240 is externally triggered on the rising edge of a user-supplied pulse. The trigger input connector terminates the user trigger with 50 Ω to ground, with a maximum safe input of ± 3.3 volts. The trigger level is programmable from -2.5 to +2.5 volts. For minimum jitter, the trigger should have fast, clean edges and be a minimum of 0.25 volts p-p loaded. Because the trigger system is very fast, slow or noisy triggers can cause jitter and possibly trigger on the falling edge.

SMA output connectors must be properly torqued and each complimentary output must be individually terminated with 50 Ω to ground, or differentially terminated with 100 Ω. The equivalent bandwidth of fast-switching output signals require RF coax and terminations rated for 18 GHz or better for optimal performance.

The T240-1 outputs have low, AC-coupled output impedance, each intended to drive a 50 Ω coaxial cable terminated in 50 Ω (see

Figure 2).

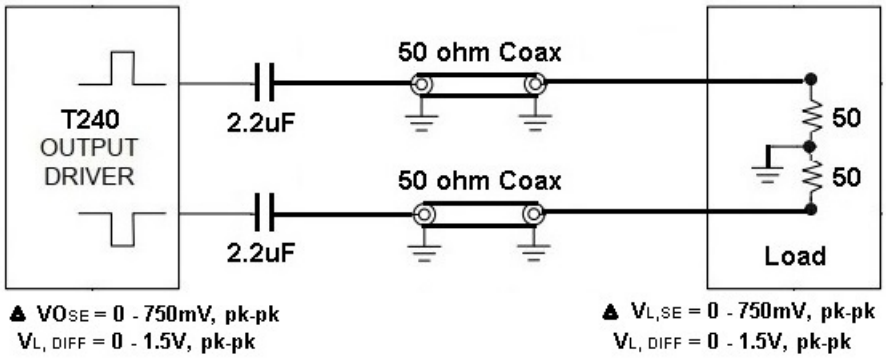


Figure 2: Standard termination configuration (non LVDS version)

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

At powerup, the T240 defaults to working in trimpot-control mode. There are five pots, located adjacent to the output connectors. They are, left to right,

RANGE selects timing ranges 1 or 2: fully CCW selects range 1 (2.5 ns); fully CW selects range 2 (25 ns)

WIDTH sets pulse width from 0 to 100% of range

DELAY sets delay from 0 to 100% of range

AMPL sets output amplitude from 0 to 750 mV into 50 Ω

Note: LVDS version amplitude at terminated receiver is reduced by half

THR sets trigger threshold from -2.5 to +2.5 volts

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

Three LEDs are provided:

POWER lights green when power is available

TRIG flashes blue when the T240 is triggered

COMM flashes orange when USB/RS-232 commands are received

The very high speed components of the T240 are sensitive to electrostatic damage. To maintain picosecond performance, no explicit ESD protection is included.

Discharge coaxial cables before connecting to the T240. Do not apply trigger inputs over ± 3.3 volts, and do not connect outputs to loads terminated at more than ± 3.3 volts.

4.1 LVDS considerations

The T240-3 complimentary outputs are DC-coupled, each providing a 50 Ω nominal source impedance. 50 Ω coax is used to individually transmit signals from the T240-3 to an LVDS receiver. Two methods of termination are recommended, depending on whether or not the LVDS receiver has an internal termination.

4.1.1 Common-ground termination, Hi-Z receiver

A high-impedance (Hi-Z) LVDS receiver won't properly terminate the 50 Ω coax signal lines, requiring placement of external resistors. Each single-ended line may be terminated at the receiver with discrete 50 Ω resistors to ground, or 50 Ω feed-thru RF coax terminations (refer to Figure 3).

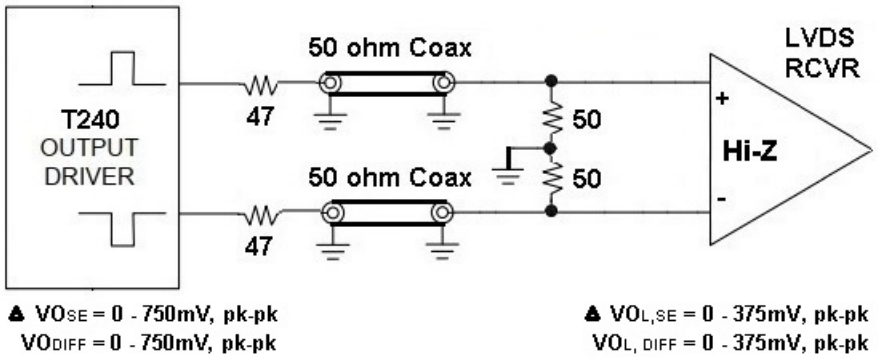


Figure 3: Single-ended external LVDS termination

Alternatively, a Hi-Z receiver may be differentially terminated with a floating 100 Ω resistor across the signal lines (refer to
Figure **4**).

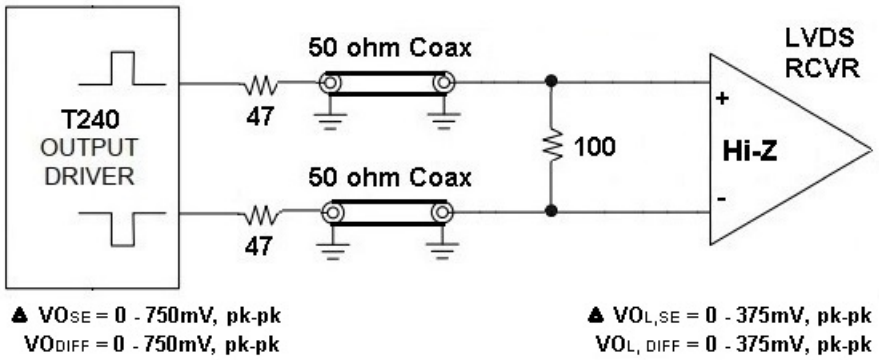


Figure 4: Floating differential LVDS termination

4.1.2 Internal differentially-terminated receiver

Some LVDS receivers include an internal, floating 100 Ω termination resistor between the inputs (refer to
Figure 5). External resistors are not recommended with this arrangement, as the sum of the two individual 50 Ω signal lines optimally matches the receiver's floating 100 Ω input impedance.

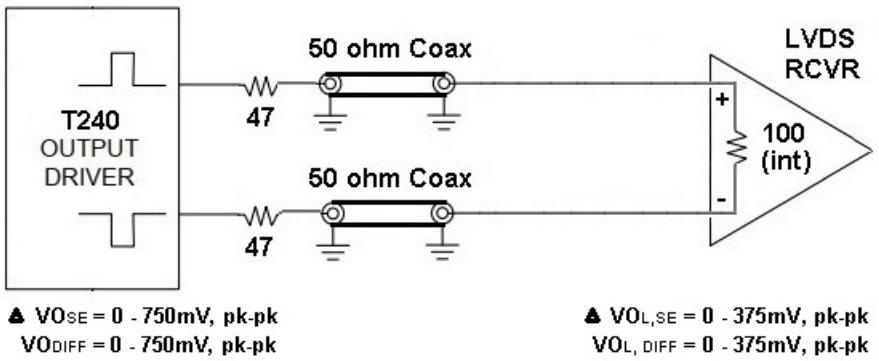


Figure 5: Differential LVDS termination configuration

Adding external 50 Ω resistors to ground, or an external 100 Ω resistor across the input of an internally terminated receiver, will result in reduced signal swing and increases signal reflections in the transmission lines (refer to
Figure 6 and
Figure 7).

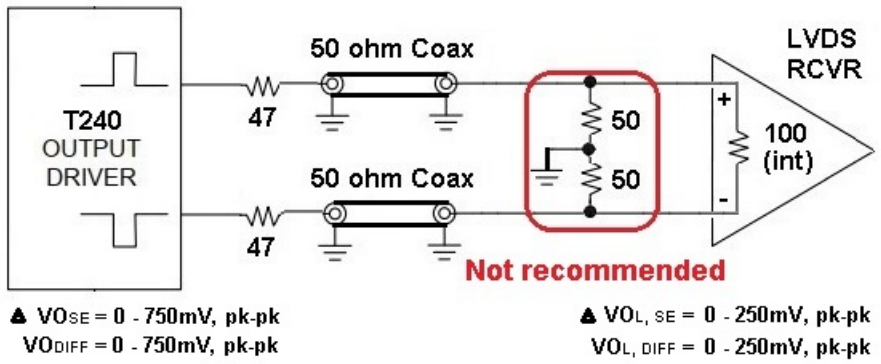


Figure 6: Doubly terminated receiver with external single-ended resistors

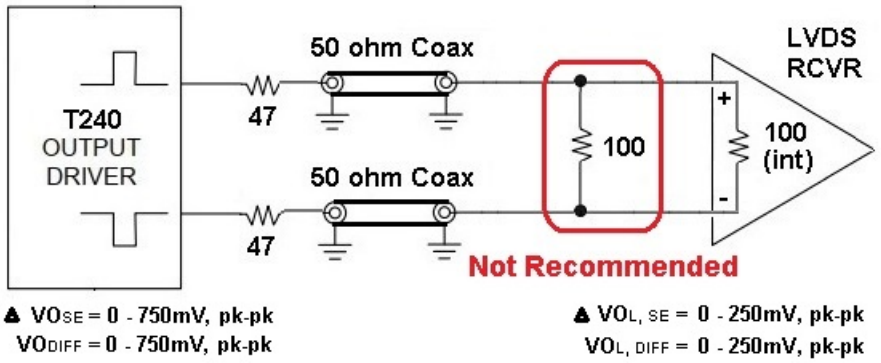


Figure 7: Doubly terminated receiver with external differential resistor

5 Remote Setup and Protocol

5.1 RS-232 Communications

The T240 provides serial RS-232 communications via the D9 connector. Pinout is

PIN	FUNCTION
2	RS-232 reply data from T240
3	RS-232 command data to T240
5	Ground
9	+5v power, factory option

Other pins are reserved for SPI use, but will not be damaged by RS-232 control signals.

The pinout is suitable for connecting to the serial port of a PC using a D9 non-crossover cable. The standard baud rate is 115K, and flow control is not supported.

The RS-232 and USB ports operate concurrently.

5.2 USB Communications

Most newer versions of Windows natively enumerate the T240 as a “USB Serial Device”, and use a simple ASCII command protocol for communicating.

Older versions of Windows may not include the driver to enumerate the T240, and will require installation of the T240.INF script file to establish a COM link. It is recommended to first try connecting the T240 to PC through the USB cable, to determine whether or not a native Windows driver is available. If the T240 isn’t recognized, Install the driver by navigating to “Device Manager”, and locating the device with the warning icon under the “Ports” category. Right-click the device, and select “Browse my computer for driver software”. Browse the directory containing T240.INF, allowing the PC to search for and install the driver.

Once completed, the T240 should logically connect/disconnect as a numbered COM port. Any serial communications program, such as Hyperterminal, or a user application, can be used to send and receive control strings.

5.3 Command Protocol

A command to the T240 is a line of text beginning with a keyword command followed by optional arguments, terminated with a carriage return. Input is case insensitive and does not echo. Linefeeds and commas are ignored. In general, a command without an argument is a query. Any keyword can be truncated to its first two characters.

The T240 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 : text <cr> <lf> to indicate an error.

Inquiry type commands evoke

Requested_data <cr> <lf>

Any queried settings reflect the last data sent over RS-232/USB, not the pot positions. The **STATUS** command will report both the pot and remote settings.

A single received <cr> evokes the response

T240-1 <cr> <lf>

The programmed delay, width, amplitude, and trigger 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.

Commands are

IDENT Unit Identify

This returns a string of the form

T240-1 Pulse Generator sn 0001 Highland Technology Inc

MODE sets local/remote control mode

MODE POTS sets the default trimpot mode
MODE REM sets remote (USB/RS-232) control mode

MODE with no argument is a query. It returns

POTS
or *REM*

TRIG sets the trigger level, -2.5 to +2.5 volts. Syntax is

TRIG 1.25 or **TRIG +1.25** or **TRIG -1.35**

TRIG queries the trigger level. The response looks like

-1.35

RANGE selects one of two timing ranges

RANGE 1 selects the 2.5 ns timing range

RANGE 2 selects the 25 ns timing range

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

2

DELAY sets time delay from trigger

DELAY 12.345n sets time delay in nanoseconds.
DELAY 12.345 sets time delay in nanoseconds. The default unit is ns.
DELAY 456p sets time delay in picoseconds

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

12.345

Note that actual connector-to-connector delay is the sum of the programmed delay and the inherent insertion delay of the T240, about 3 ns and 10 ns on respective ranges 1 and 2.

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 100 ps on range 1, 250 ps on range 2.

AMPL sets output pulse amplitude. The command form is

AMPL 600 sets output amplitude to 600 millivolts. Legal range is 0 to 750 millivolts.

AMPL queries the current amplitude setting. Reply looks like

600

(note: T240-3 amplitude across 100 Ω load is reduced 2:1 [-6dB] rel. AMPL)

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

0003 2154 1904 4095 2108

DACS returns the raw internal 16-bit DAC codes, as four integers from 0 to 65535.

01475 48613 26100 65535

STATUS return status report

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

T240-1 Pulse Generator sn 0001 Highland Technology Inc
Mode REM
Pots: Range 1 Trig level -1.35 Delay 1.454 Width 0.245 Amplitude 720
Rem: Range 1 Trig level 1.20 Delay 0.500 Width 0.700 Amplitude 500

Firmware 28E240-A Cal date: 12/31/2012 OK

The final *OK* indicates that the calibration table is valid.

HELP returns a brief command summary.

6 Typical Waveforms

Unless noted, measurements were taken with a Tektronix 11801/SD-24 sampling system having approximate 17 ps rise time, so actual T240 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.

Picosecond measurements require connections to be short, high-quality hardline coax, and the SMA connectors must be properly torqued to ensure waveform fidelity. If only one output is used, the other should be terminated with a microwave-quality 50 Ω SMA terminator, such as the Highland J48. Refer to Figure 8.

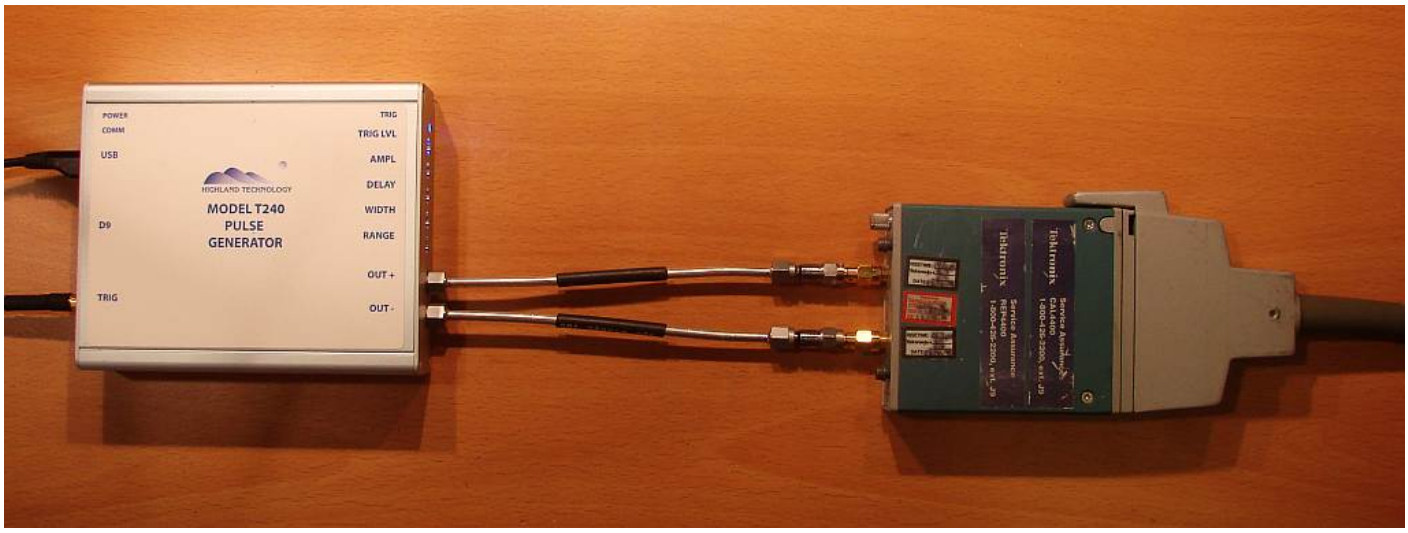


Figure 8: T240 connected to Tektronix SD-24 sampling head with hardline SMA coax

The quality of the T240 pulses challenges most oscilloscopes. Figure 9 shows the minimum usable pulse width on the fastest timing range. Figure 10 shows a typical, narrow square pulse.

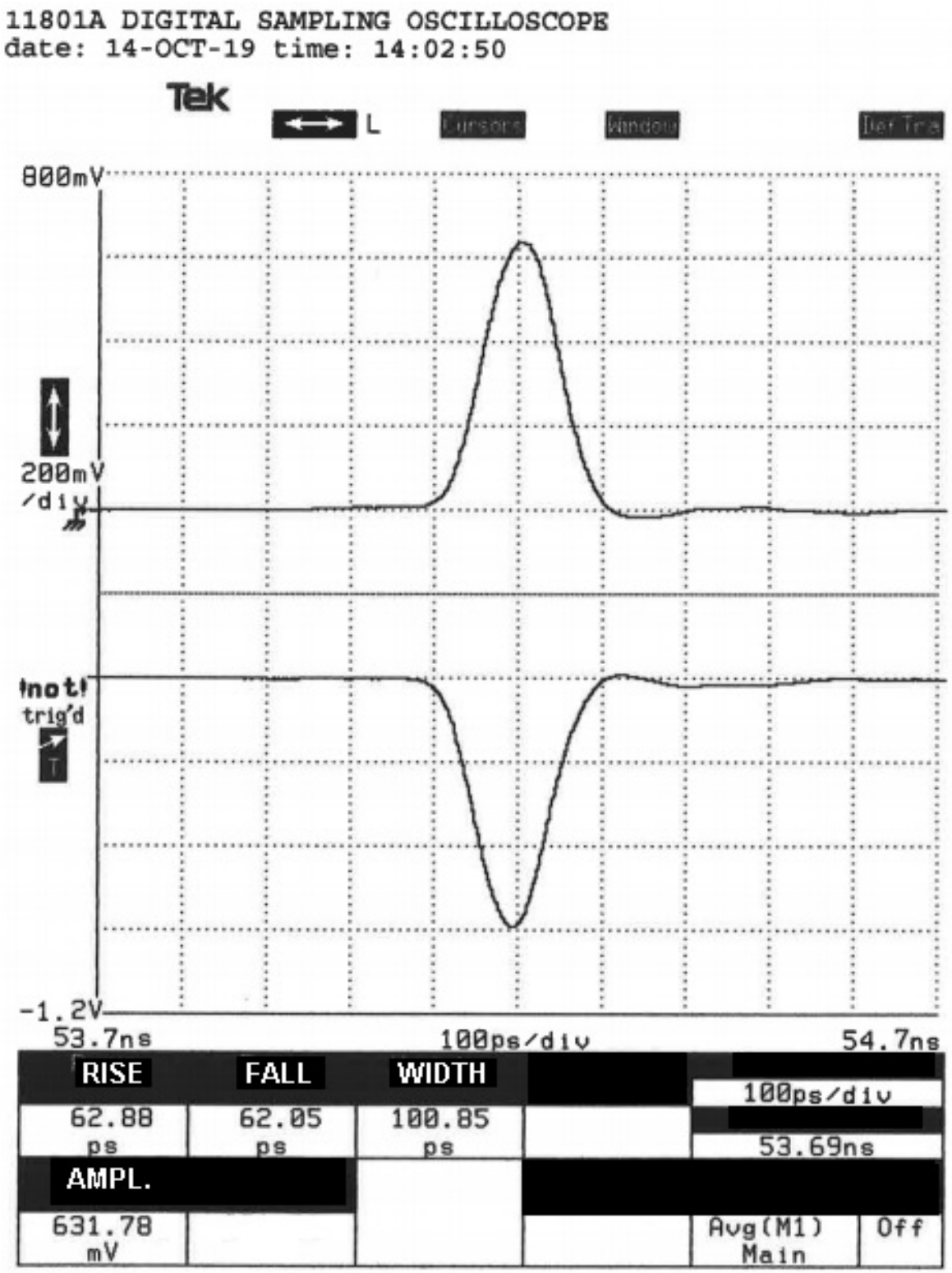


Figure 9: 100 ps FWHM pulses, 10/90 risetime

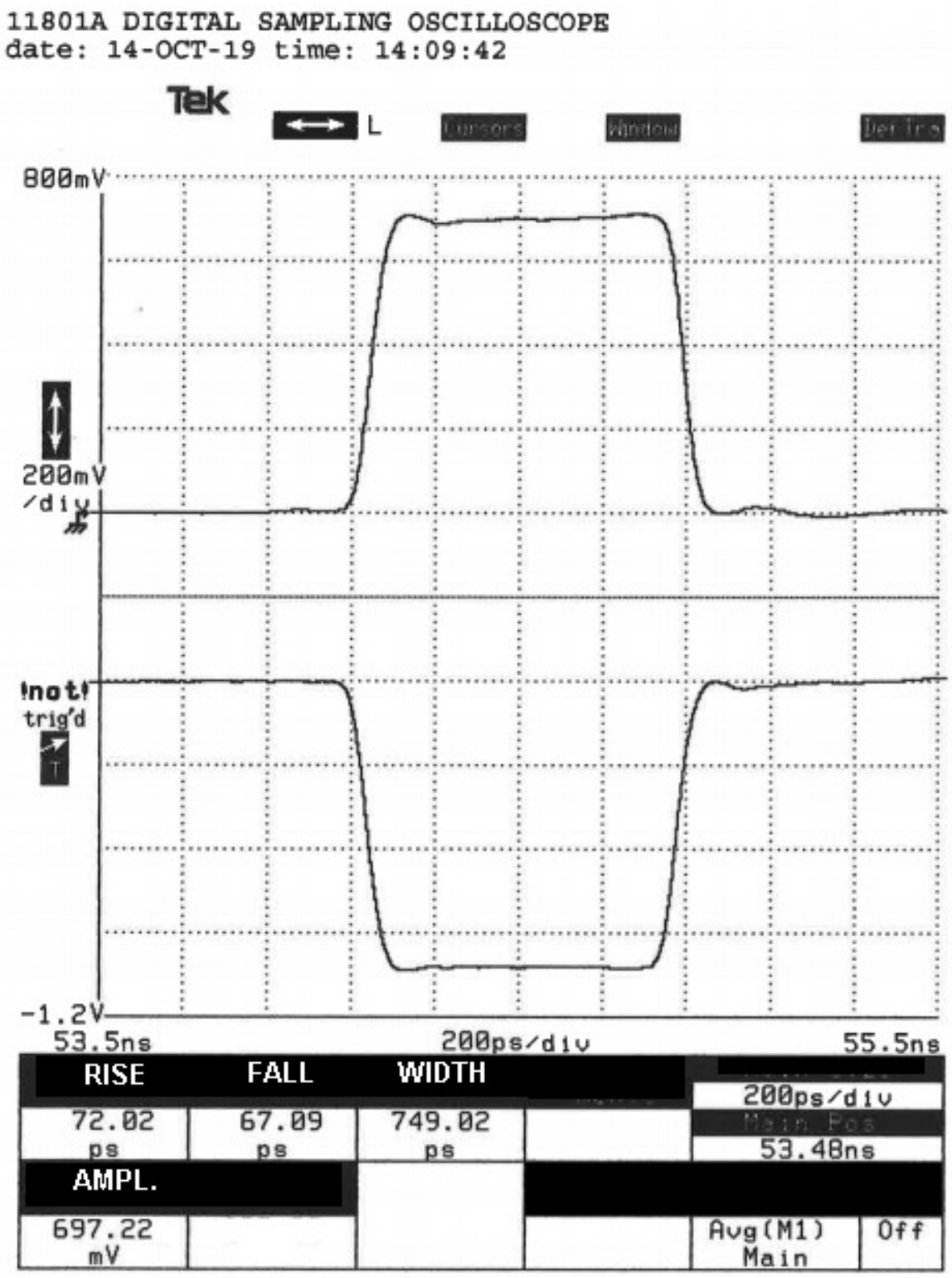


Figure 10: A typical rectangular pulse, 749 ps width, 10/90 risetime

Figure 11Figure 12 shows typical T240-3 output, programmed for 1ns pulse width and typical LVDS amplitude

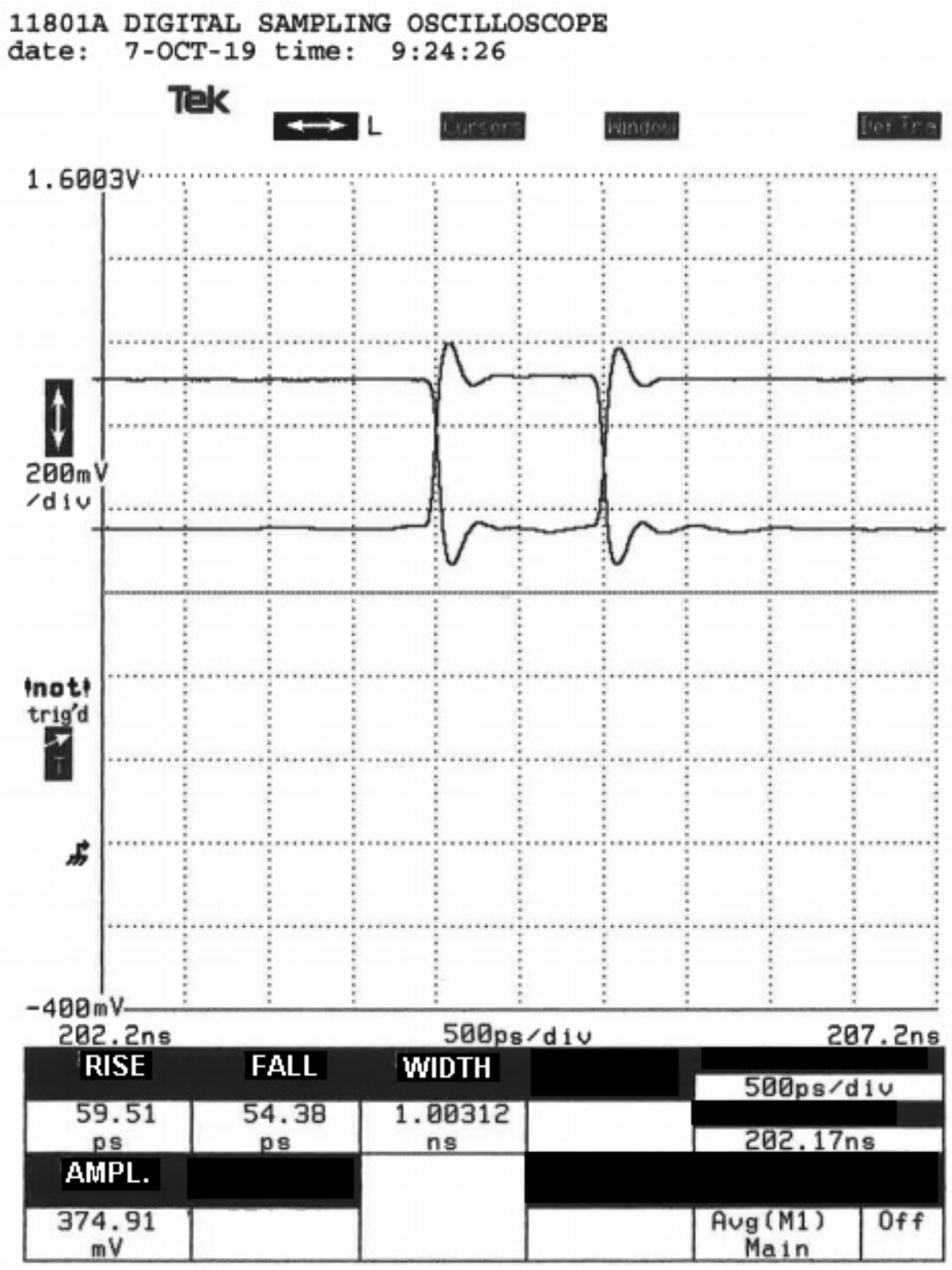


Figure 11: T240-3 typical LVDS output producing 1ns pulses

Typical risetime and falltime transient response is illustrated in Figure 12.

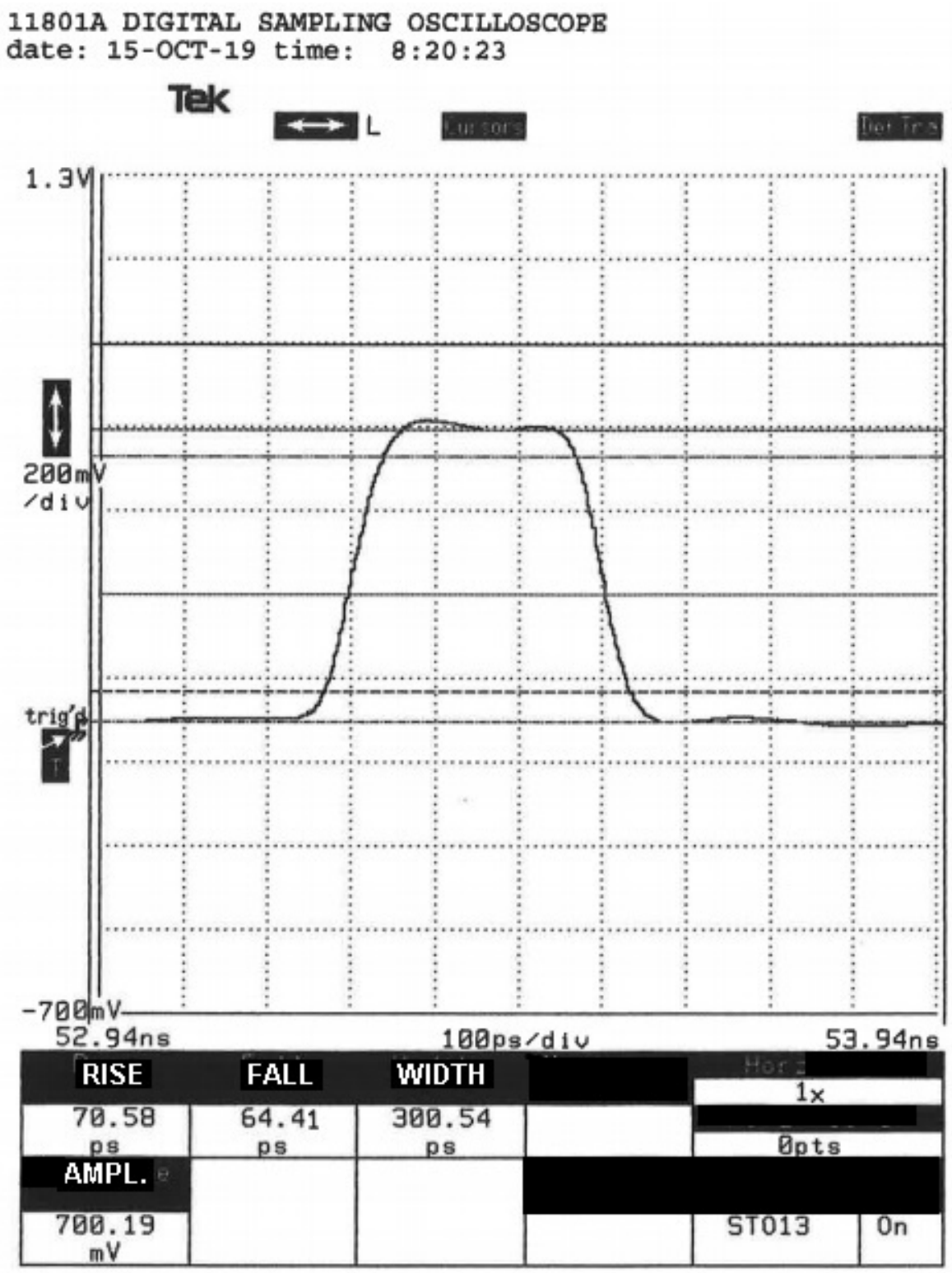


Figure 12: T240-1 typical pulse dynamics

Typical RMS jitter performance on range 1 is illustrated in Figure 13. The T240 was triggered by the 0.25 volt TDR step of a Tektronix 11801 oscilloscope and the T240 output rising edge was displayed on the same scope over a 10-second interval. The net jitter is nearly indistinguishable from the internal jitter of the scope, which is about 3 ps RMS.

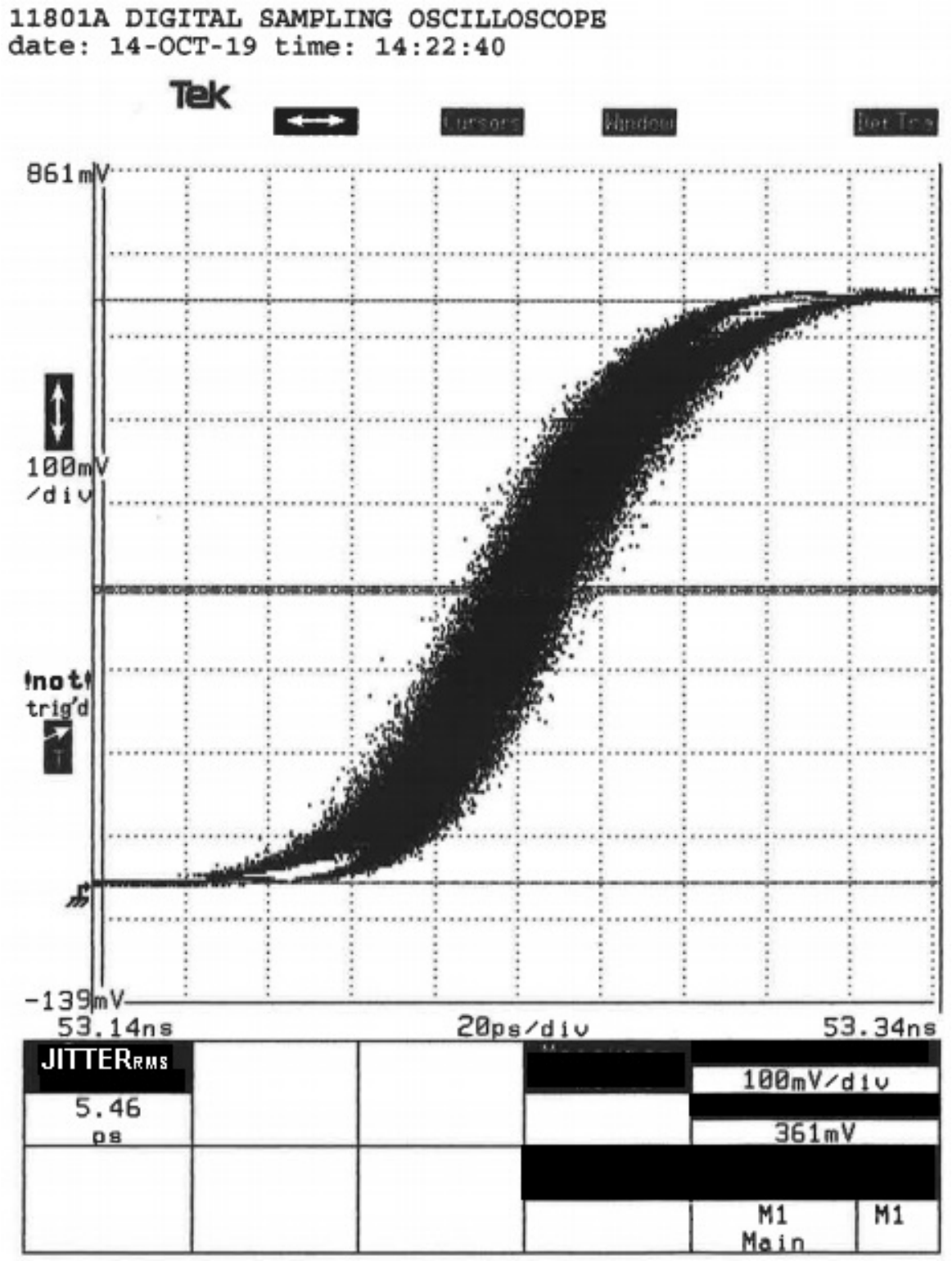


Figure 13: typical jitter of the T240 on range 1.

7 Dimensions

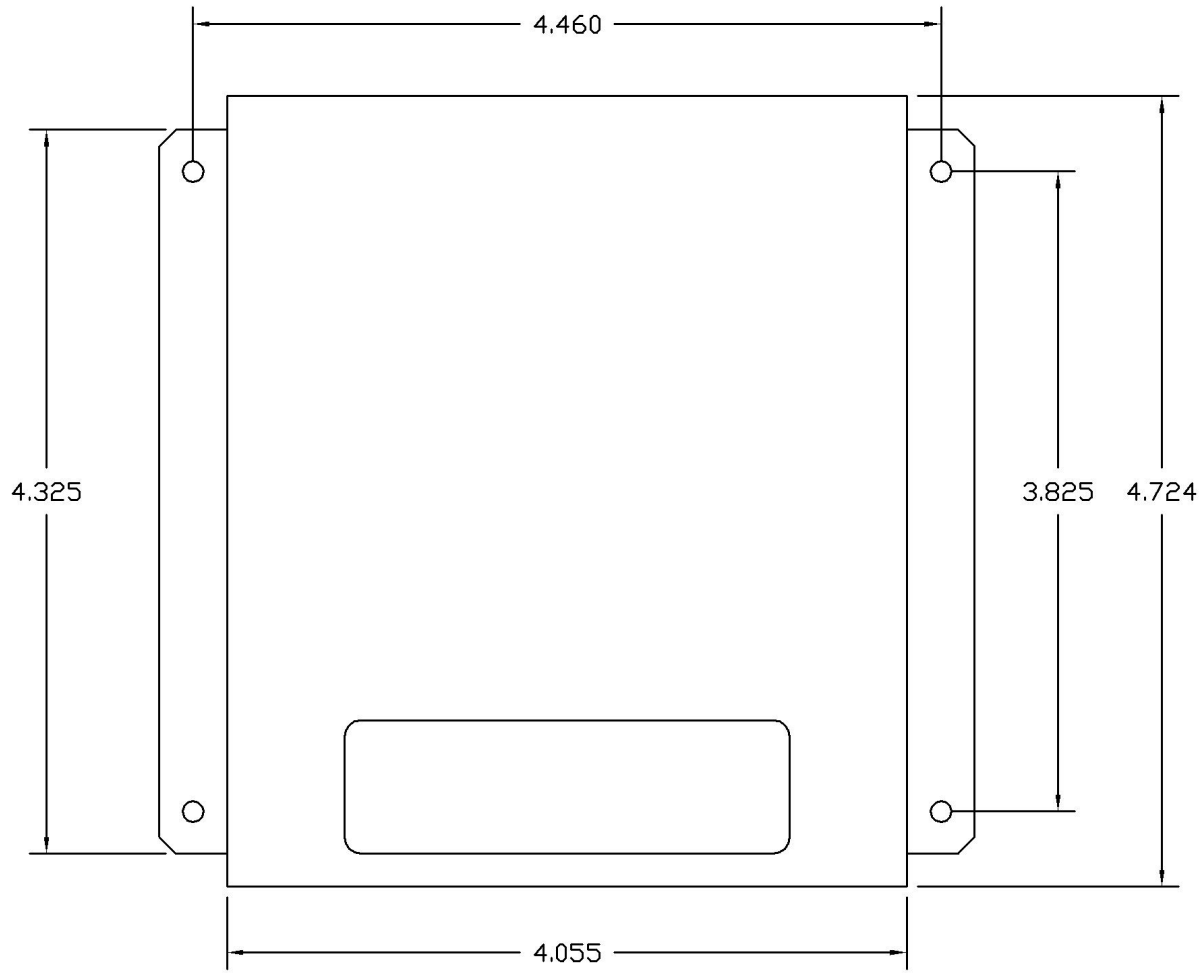


Figure 14: Enclosure, shown with optional mounting flange (inches)

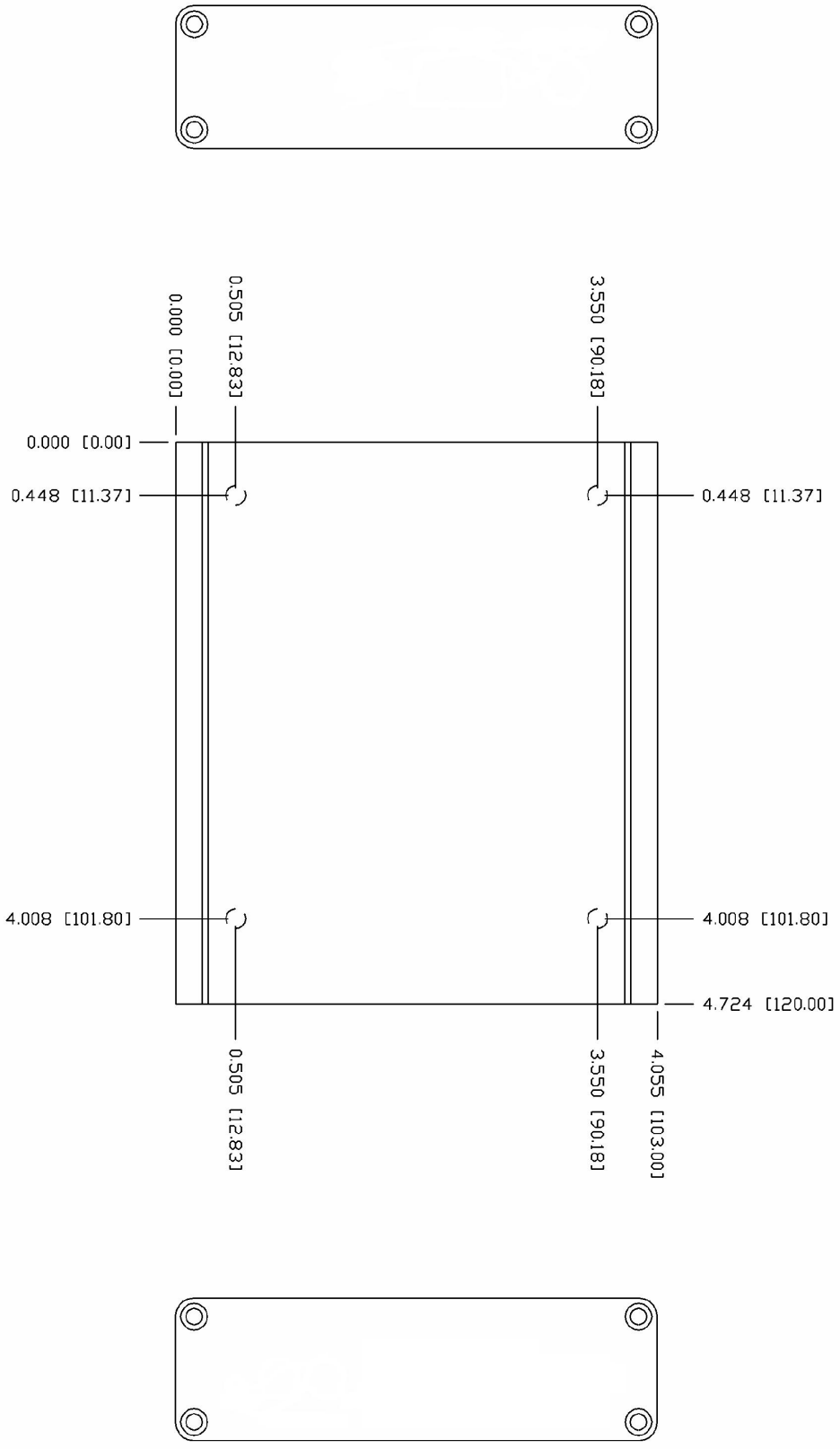


Figure 15: T240 enclosure and mounting locations

8 Versions

Standard versions of the T240 include:

T240-1: single-channel AC-coupled externally-triggered complementary-output pulse generator

T240-3: single-channel DC-coupled externally-triggered complementary LVDS output pulse generator

T240-9: single-channel externally-triggered complementary-output pulse generator evaluation kit (includes T240-1 factory installed on T566-1 mounting flange, J6-1 power supply, and J48-1 SMA terminator)

T240-13: single-channel DC-coupled externally-triggered complementary LVDS output pulse generator evaluation kit (includes T240-3 factory installed on T566-1 mounting flange, J6-1 power supply, and J48-1 SMA terminator)

9 Customization

Consult factory for information on additional custom versions.

10 Hardware and Firmware Revision History

10.1 Hardware Revision History

Revision B Dec 2013
Functionally equivalent to Revision A.

Revision A Apr 2012
Initial PCB release

10.2 Firmware Revision History

Revision B Aug 2012
Makes an RS-232 port available for serial communications with the LPC

Revision A Jul 2012
Initial firmware release

11 Accessories

J6-1: 5 volt USB power supply (furnished with purchase)

J42-1: 3′ SMB to SMA cable

J44-1: 3’ SMA to SMA cable

J48-1: 50 Ω SMA terminator (furnished with evaluation kit purchase)

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

T566-1: mounting flange (furnished with evaluation kit purchase)