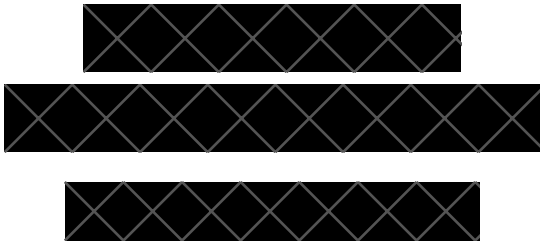
Kentech Instruments Ltd.

Manual for PSP1 Programmable Sub-Nanosecond Pockels Cell Driver

Version Mk2



PLEASE READ THIS MANUAL CAREFULLY BEFORE USING THE EQUIPMENT.

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1. DISCLAIMER

This equipment contains high voltage power supplies. Although the current supply capacity is small, careless use could result in electric shock. It is assumed that this highly specialised equipment will only be used by qualified personnel.

Kentech Instruments Ltd. accept no responsibility for any electric shock or injury arising from use or misuse of this equipment. It is the responsibility of the user to exercise care and common sense with this highly versatile equipment.

2. ABBREVIATIONS

ADC or adc	Analogue to Digital Convertor
CPLD	Complex programmable logic device
CCD	Charge Coupled Device (camera)
cr	carriage return
DPCO	Double Pole Change Over
dv	desired value
EEPROM	Electrically programmable and erasable Read only memory, non-volatile
EHT or eht	Extra High Tension (high voltage)
EPLD	Electrically programmable logic device
EPROM	Electrically programmable read only memory, non-volatile
FET	Field Effect Transistor
hw	hardware
INT	Intensifier
lf	line feed
MCP	Micro Channel Plate
mv	measured value
PSU or psu	power supply unit
RAM	Random access memory, volatile.
ro	read only
rw	read and write
SW	sweep
sw	software
W/E	Write Enable
wo	write only

3. CAUTION

With an appropriate load, this unit is safe for use by an educated user in a laboratory environment. You are warned however that the radiation from the system with an antenna or inappropriate load attached can damage sensitive equipment and corrupt data stored in computer and microprocessor based systems. It can cause terminal failure of vital medical electronic systems such as pacemakers. This equipment is supplied on the understanding that the user will analyse these risks, accept responsibility for them and take appropriate precautions in the use of this instrument.

The output from this pulse generator will destroy many types of power attenuators and electronic test equipment. It is the users responsibility to ensure that any apparatus connected to the output is suitably rated.

Kentech Instruments Ltd. accepts no responsibility for any damage or liabilities incurred in the operation of this equipment.

Please read the manual before applying power.

There are high voltages (4kV) present in this pulser when the unit is operating. Do not remove the covers, return to Kentech Instruments Ltd. or its appointed agent for servicing.

The accessible terminals of this instrument are protected from hazardous voltages by basic insulation and protective grounding via the IEC power input connector. It is essential that the ground terminal of this connector is earthed via the power lead to maintain this protection.

If cleaning is necessary this should be performed with a soft dry cloth or tissue only.

4. RF EMISSIONS AND EC DIRECTIVE 89/336/EEC

This equipment is a research tool that has been intentionally designed to generate short high energy electromagnetic pulses and the EM emissions will be highly sensitive to the load applied by the user, for example the radiation just from some types of output cable may exceed EC permitted levels.

The level of RF radiation generated by the circuit boards within the instrument is inevitably high but the emissions are largely contained by the instrument enclosure. It is therefore very important that all fasteners are secure, do not operate the pulser with the covers removed. The pulser may still interfere with sensitive equipment at short range.

We believe that with this type of unit it has to be the system builder's responsibility to verify that his pulser/load system complies with the EC directive unless the system is used in a screened electromagnetic environment.

We are not able to guarantee compliance with arbitrary loads but to minimise emissions we recommend:-

1) That any load is fully contained within a conductive metal screened box, with all joint surfaces gasketed or fitted with conductive fasteners at less than 5cm intervals.

2) That the load is connected to the pulser output with semi-rigid cable, the cable outer must be carefully connected to the N type output connector at one end, and must be connected directly to the screened box containing the load at the point of entry. Flexible cables should only be used with caution, in particular RG303 type cable will need additional screening to control emissions.

5. DECLARATION OF CONFORMITY

We:-

Kentech Instruments Ltd.
Isis Building, Howbery Park, Wallingford, Oxfordshire, OX10 8BD, U.K

Certify that this apparatus:-

Kentech PSP1 Pulse Generator [redacted]
Conforms with the protection requirements of European Community Directives:-
73/23/EECLow Voltage Directive
89/336/EEC Electromagnetic Compatibility Directive
93/68/EECCE Marking Directive

The following harmonised standards have been applied:-

BS EN55011 Emissions Specification (Group 2 Class A)
Industrial, Scientific and Medical equipment
BS EN50082-2 Generic Immunity Standard
Part 2 Industrial
BS EN 61010-1 Safety Requirements for Electrical
Equipment for Measurement, Control, and Laboratory Use

A L Dymoke-Bradshaw

[redacted]

6. INTRODUCTION

The PSP1 is a pulse generator intended for driving Pockels cells with programmable pulse width, pulse amplitude and trigger enable. Control may be either local via the LCD and keypad on the front panel, or remote via a serial port which can be accessed via RS232 or ethernet interfaces.

Local or remote control is selected by a push button switch on the front panel. It is not possible for the remotely controlling computer to override this selection. The software is multitasking. In remote control mode the trigger and delay settings can be monitored on the LCD. Similarly in local mode the settings can be monitored via the RS232 or ethernet interfaces.

RS232 or ethernet interface is selected based on which interface tries to talk to the unit first after power up.

6.1 CHANGES FOR MK2 UNIT

The electrical specification is unchanged. A terminator is now built into the unit with the return monitor on the front panel. This does not preclude the use of an external terminator. The local remote mode is now a “soft” switch with the option in remote control to determine the boot up state. The choice of remote interface (RS232 or Ethernet) is decided by the first one to be activated after a power up cycle.

The stack voltages are displayed with the trigger inhibited.

It is now possible to use other baud rates on the RS232 port and to change the LCD display brightness. The LCD is bigger and easier to read with more information per page.

6.2 OPERATION OF THE PULSER

The unit requires 110/240V 50/60Hz A.C. power to the fused IEC connector on the rear panel to operate. Power is controlled by a rocker switch which is integral with the rear panel IEC connector.

There is a fan and an air vent on the rear panel which require a free flow of air, though overall power consumption is relatively low (~ 30 W).

On power up there is a second or two delay before text appears on the LCD. The PSP1 first briefly displays a banner page, then stops on the next page, the content of this depends on whether local or remote control has been saved in the “save status” menu. The factor default will be local mode.

There are five user parameters that control operation. These are:-

1) Pulse width - settable in the range 200 ps to 10,000ps in nominal steps of 25ps

2) Trigger enable - either on or off.

Note that this is a trigger enable request. Whether or not the trigger circuit is enabled is determined by a few additional factors, see below.

3) Operating mode - either STANDBY or RUN.

In STANDBY mode, all high voltages are switched off which reduces dielectric stress and power consumption if the pulser is not being used.

In RUN mode, all high voltage power supplies are switched on.

4) Pulse amplitude. The range of amplitude adjustment varies a little between instruments, typically it is from approximately 2.5kV to 3.7kV. Please be aware that the voltage levels shown are very approximate but reproducible.

5) Trigger threshold. The range of adjustment may vary between instruments, typically 1V to 3.5V. These levels are also approximate and will vary a little with the rise time and waveform of the trigger pulse. Initially the trigger threshold should be set to 50% of the amplitude of the trigger pulse, then adjusted to give the best results. To minimise the jitter, find the point at which the trigger delay is least sensitive to the trigger amplitude, this will be on the fastest rising part of the trigger pulse.

The user parameters can be set either locally or remotely. They must be saved explicitly to the EEPROM if required, otherwise they will be lost at power up or reset.

The save command also saves the state for the next power up state with the restriction that in local mode one cannot force the unit to boot up in remote mode. The opposite is not true.

On power up, the PSP1 uses the user parameters saved in EEPROM.

6.2.1 LEDS

There are five LEDs on the front panel:-

1 Local

Illuminated in Local mode. Switch modes with the adjacent push button.

2 Remote

Illuminated in Remote mode. Switch modes with the adjacent push button.

3 Triggered

This will flash momentarily in response to a trigger event in the trigger circuit. There is an additional independent trigger latch provided for remote interrogation.

4 Enabled

This unambiguously reflects the state of the trigger circuit. If the led is ON the trigger circuit is enabled and the PSP1 will produce a pulse if triggered. If the led is off it will not produce a pulse. This information is also available for remote interrogation.

5 Power

This is always illuminated if the PSP1 is switched on and AC power is applied.

6.2.2 FRONT PANEL CONNECTORS AND CONTROLS

There are six front panel connectors, four are BNC:-

1 Trigger input.

This input should be a signal of amplitude 2V to 10V with a rise time < 2ns to maintain optimum jitter performance. Input impedance is approximately 50Ω.

2 Sync. output.

An output taken from an early stage in the trigger circuit, amplitude approximately 2.2V into 50Ω, rise time approximately 0.5ns.

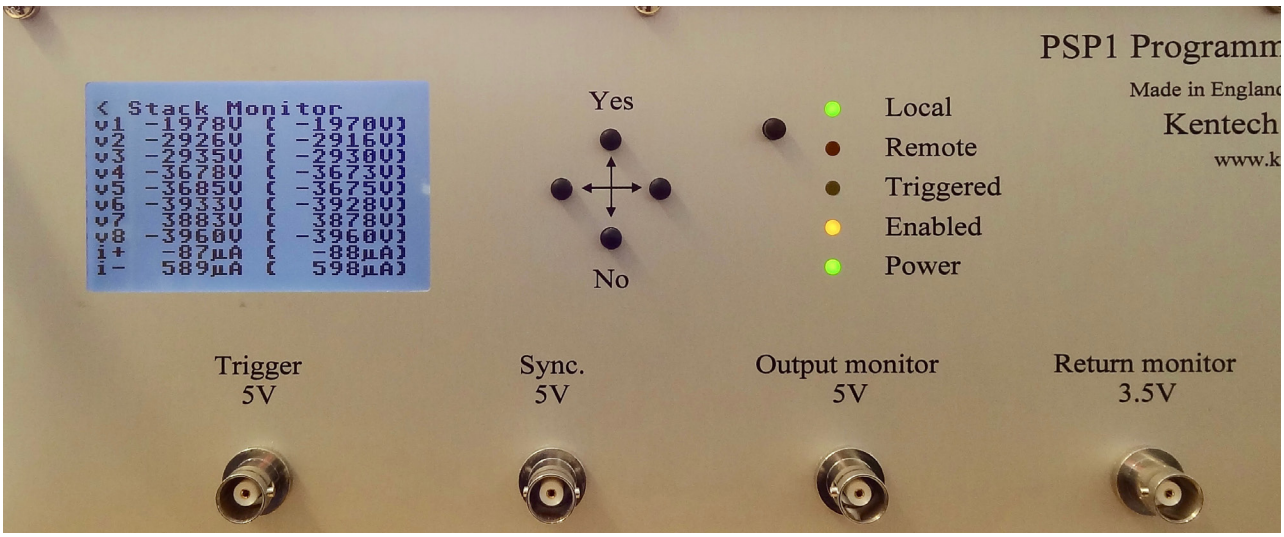
3 Monitor output

A signal divided down (/1000) from the high voltage pulse output, amplitude approximately 4V into 50Ω, rise time approximately 750ps. This has near zero jitter w.r.t. the output pulse.

4 Return monitor

In a typical configuration the output pulse will return to the return input on the front panel. In this case the “Return monitor” will deliver a divided down signal (1000:1) of the returned signal. This has near zero jitter wrt. the output pulse and can be used to trigger other equipment. Note that it is the same polarity as the main pulse (generally negative). Kentech can supply fast pulse inverters if needed.

5 Main output



The pulse output is via an “N” type connector on the front panel. It is important to keep this connector clean and free of metal particulates. Occasional greasing of the connector thread is a good idea if the connector is mated frequently.

6 Return input

The pulse is typically returned to the unit for termination through this front panel N type connector.

Note that it does not have to be, but for a typical through terminated pockels cell the pulse needs terminating to stop reflections return to the cell.

For other loads this may not be relevant.

7 Controls

There are five push buttons on the front panel. Four of these are referred to as UP, DOWN, LEFT and RIGHT in the obvious order. They are used in local mode to control the PSP1 by navigating the cursor around the LCD to select parameters, then the using UP or DOWN to modify them.

The forth button switches between local and remote mode.

Note that the unit can be made to power up in either local or remote mode. Saving the configuration in local mode will make the unit power up in local mode. When saving the configuration from a remote computer in remote mode the boot up mode can be set to either.

Figure 1 The front panel in local mode showing stack voltages

6.2.3 REAR PANEL

There are three signal connectors on the rear panel and the power inlet.:-

1 RS232 comms port

A 9 way D type connector with female contacts.

Pin 2 = data output from PSP1
Pin 3 = data input to the PSP1
Pin 5 = ground.

The default settings are 9600 baud, no stop bits 8 bit word, no flow control. The baud rate can be modified by the software.

2 Ethernet

A standard RJ45 ethernet connector.

3 Hardware inhibit

A Lemo 00 coaxial connector. A short circuit or a TTL low signal will enable the PSP1, an open circuit or TTL high signal will inhibit it.

6.3 THE TRIGGER CIRCUIT

There are a number of conditions and hardware tests that have to be satisfied before the trigger circuit will be enabled. The user trigger enable setting is therefore not a reliable indicator of the state of the trigger circuit. However, the enabled led on the front panel unambiguously indicates the state of the trigger circuit.

There are five main conditions that must be met in order to enable the trigger circuit, the mode set to RUN, the trigger set to enable, the hardware inhibit on the rear panel should be shorted to ground, the

delay circuit for the trailing edge of the pulse must pass a confidence test and neither HV power supply may be “tripped”. An over current condition of either of the two supplies will cause the corresponding trip to activate which will automatically disable the trigger circuit.

The hardware inhibit connector on the rear panel can be used to gate the trigger input.

If a delay error or a HV supply trip occurs then the unit has a fault. For a delay error this may clear on a power recycle but if not it may be possible to circumvent this by choosing an alternative pulse length. The delay error is set when the number of relays in the delay circuit that are in each state (in or out) is not what is expected. This is checked after every change in delay, so in Local mode that means going into the edit delay and out again. In remote mode it would be after a change in pulse width is requested. By using a different delay it may be possible to find a state where the faulty relay is in the correct state. Relay failure is very rare but it can be a cause of concern if the pulser delivers a very different pulse length to that requested. Hence the need for a delay confidence check.

The HV trips can occur due to avalanche transistor failure or other problems in the pulser. If these do not clear on a power up cycle the unit will need to be returned to the factory. A switch to STANDBY and RUN will do the same as a power up cycle.

6.3.1 TRIGGER ENABLE SUMMARY:

The hardware trigger circuit will be enabled if and only if:-
1) the trigger enable is high
AND
2) the mode is set to RUN
AND
3) the inhibit input is TTL low or shorted to ground [rear panel]
AND
4) the positive and negative power supply trips are inactive
AND
5) the relay error flag is low (no DELAY error).

6.4 PULSE WIDTH CONTROL

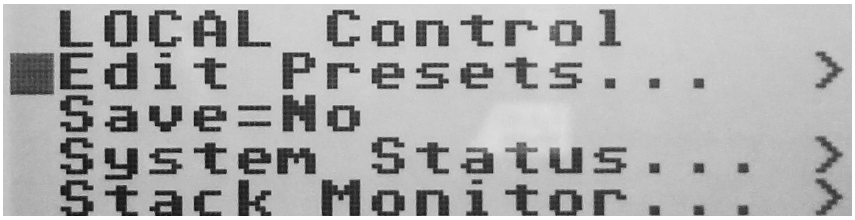
The pulse width can be set to any arbitrary value from 200 ps to 10,000 ps in nominal steps of 25 ps. The hardware uses a relay based switched delay line to delay the trailing pulse edge to produce the different widths. When changing the pulse width, the trigger is automatically disabled by the software before changing the relays, then it attempts to restore the trigger state afterwards. This is done so that relays are never switching significant currents. Whenever the software attempts to enable the trigger circuit, it performs a confidence check on the delay circuit (it checks that the correct number of relay contacts are made). Any discrepancy found causes the relay error flag to be set, which inhibits the trigger circuit.

6.5 LOCAL CONTROL

Local control is implemented using the LCD and 4 front panel push buttons.

At power up into Local control mode the PSP1 will display briefly header page then stop at the Local Control page awaiting input from the user.

6.5.1 THE LOCAL CONTROL MENU



The cursor will initially be adjacent to the E of Edit. The cursor can be moved up or down onto lines 2 to 4 using the UP and DOWN buttons. Pressing the RIGHT key on line one causes the PSP1 to enter the page for the selected option.

Edit Presets is for setting the mode, trigger enable, trigger threshold, pulse amplitude and pulse length

Save is for saving the system state for the next power up cycle.

System Status gives information on the external inhibit input, the delay error status and the trip status of the two HV power supplies.

Stack Monitor will return the voltages on the various Avalanche stacks in the pulser and the power supply currents. Note that this will inhibit the triggering of the unit while these voltages are displayed.

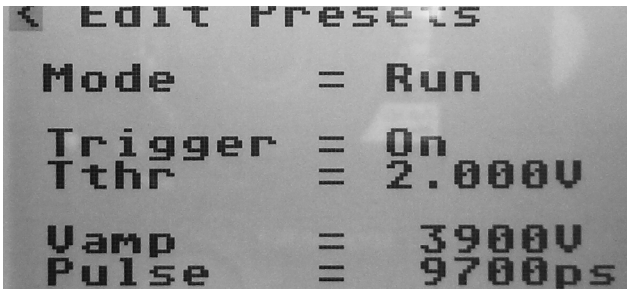
Remember that :-

1) any changes to user parameters are volatile and will be lost on power down or reset unless specifically saved with the save command (local or remote).

2) The values stored in EEPROM are used at power up or reset.

6.5.2 EDIT PRESETS

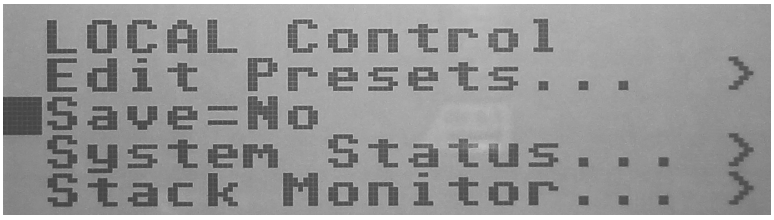
On power up into local mode the cursor will initially be adjacent to the E of Edit on line 1. Moving the cursor to the right will produce the following display.



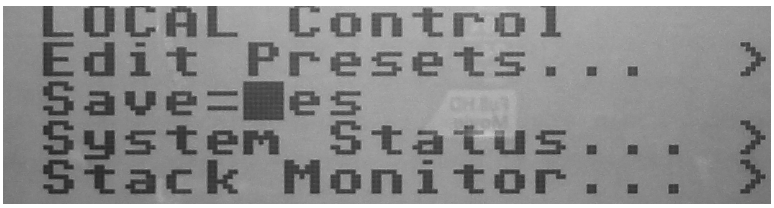
The cursor can be moved up or down using the UP and DOWN buttons. Pressing the RIGHT key on a line one allows editing of that line. For parameters that have numbers to edit the right and left keys will move among the digits. It may be necessary to edit the lower significant digits to reach the maximum or minimum permitted values. The UP and DOWN keys allow changing of the field at the cursor.

The preset values will be lost at power up or reset unless they are explicitly saved to EEPROM - see notes on SAVE. Pressing LEFT with the cursor adjacent to “Edit Presets” will move back to the previous page.

6.5.3 SAVE



There is one editable parameter on the SAVE command. From the above position hit right to move the cursor to the “NO” then the UP/YES button to change the state and then the LEFT button to move out of the SAVE field.



6.5.4 SYSTEM STATUS

There are no editable fields in the System Status page. The parameters shown are discussed at Section 6.3 on page 11.

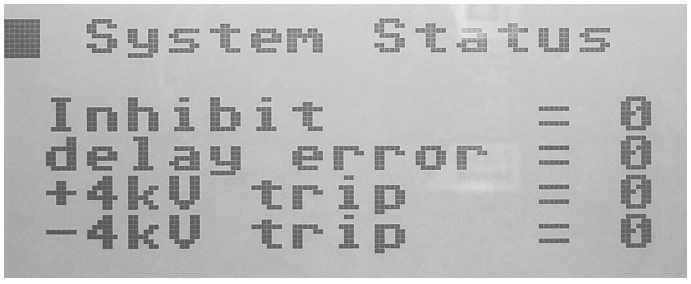


Figure 2 No errors or trips

6.5.5 STACK MONITOR - VOLTAGES.

There are no editable parameters on the STACK page. It gives information on the state of the avalanche stacks and the current drawn by each power supply. The figures inside brackets are expected values with the unit is in RUN mode. In STANDBY mode the values are all near zero. Small changes from the expected values are normal There are eight stacks in the PSP1 number V1 to V8.

If an avalanche stack voltage reads low this will not inhibit the unit. The unit is designed to operate with a few failures of avalanche devices, .ie. graceful failure.

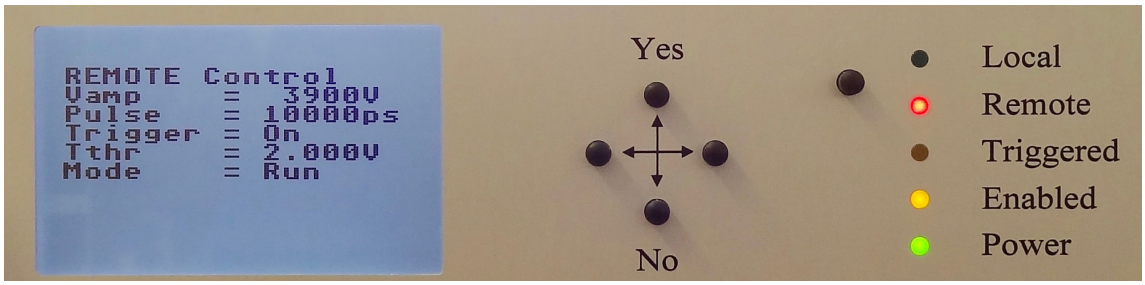
NOTE that if the pulser is being triggered when this page is selected the triggering will be inhibited. This is exactly the same as unenabling the trigger on the EDIT PRESETS page. The trigger enabled state is returned to its previous state when the page is exited.

Note-2 The stack voltages are only available in Local mode.

7. REMOTE CONTROL

At power up the unit will be in either Local or Remote mode depending upon what is saved in the EEPROM. The mode can be switched from local to remote mode with the front panel button. In local mode it is not possible for the software to write to the unit but it can interrogate it. So the commands that are read only will function. All the commands that write will return an error code to indicate that the operation has failed.

In Remote mode the LCD and LED display will show the current value/status of the amplitude, pulse width, trigger status, trigger threshold and run mode.



It is not possible to exit from the REMOTE page, other than by selecting local mode.

7.1 THE SERIAL PROTOCOL

The PSP1 will generate responses to valid commands and will not generate any unsolicited output. Invalid commands will be ignored. All commands and responses will be in ASCII characters. Commands are case sensitive.

In the interest of simplicity all commands are parsed by the PSP1 using the Forth interpreter, so the parameters need to be delimited by spaces and the command line will be terminated by carriage return and line feed characters. The Forth interpreter will not recognise any commands other than those defined in the command set.

The PSP1 will not echo command characters as they are received, no output will be generated until a valid command is recognised.

When a valid command is recognised, the PSP1 will output a response. Responses are preceded with a cr and lf, then an ascii { character and end with an ascii } . The response will be delimited into fields by an ascii ; character. The first field in the response will be a repeat of the command. If the command cannot be completed the PSP1 will return an error code in the second field. The possible error codes are:-

`?stack` - the command interpreter has detected a wrong stack depth error, i.e. the wrong number of parameters have been received.

`?param` - the command interpreter has detected an out of range parameter

After any error, the command is not executed, the stack is cleared and no values are returned other than the error code. Following a stack error, the stack is cleared then dummy parameters (generally -1 or 65536) are added for the purpose of formatting the response only.

All status commands expect and deliver data as decimal numbers and all numeric data should be decimal, no decimal points or other punctuation to be used.

For example

1) to set the desired value of pulse width to 5000 ps, the command would be:-

```
5000   !wid
```

and the response if the command can be completed would be:-

```
{ 5000   !wid;-1 }
```

2) as above but with a missing parameter

```
!wid
```

and the response would be:-

```
{ -1  !wid;?stack}
```

The command interpreter detects the wrong stack depth, corrects this by clearing the stack and adding some dummy parameters then flags the error. No execution will result.

3) as above with invalid parameter

```
100 !wid
```

and the response would be:-

```
{ 100 !wid;?param}
```

Again no execution will result.

4) as above but with the unit in Local mode. In Local mode the unit cannot be written to.

```
500 !wid
```

and the response would be:-

```
{ 500 !wid;0}
```

Again no execution will result.

However, the unit can be read remotely even when in Local mode, e.g. in local mode:

```
@wid
```

and the response could be

```
{ @wid;5000 }
```

7.2 THE STATUS BIT DEFINITIONS

The PSP1 status can be read as one 16 bit number. The status bits are as follows

b0	= user trigger enable	1= trigger enabled, 0= disabled
b1	= hardware trigger circuit state	equivalent to front panel led 1 = illuminated
b2	= triggered flag	1 = triggered, 0 = not triggered this is independent of the triggered led
b3	= mode	1= standby, 0 = run
b4	= control	1= remote, 0 = local
b5	= inhibit	1 = inhibited at rear panel, 0 = enabled at rear panel
b6	= relay error flag	1 = relay error found, 0 = no relay error found
b7	= +4kV tripped	1 = HV supply tripped, 0 = not tripped
b8	= -4kV tripped	1 = HV supply tripped, 0 = not tripped b9 = not used

bits 10 through 15 are not used.

7.3 THE REMOTE CONTROL COMMANDS

Explanatory notes:-

1) In Forth terminology a @ character implies a fetch or read operation, a ! character implies a store or write operation.

2) The commands have a slightly human friendly **name**, but in use they should be truncated as shown on the "format" line.

Name **@width**

Explanation	read pulse width setting in ps
Format	**@wid**
parameter 1	none
parameter 2	none
returned value	pulse width in ps

Name **!width**

Explanation	write desired value for pulse width setting in ps
Format	**x !wid**
parameter 1	x = width, range 200 to 10000 ps
parameter 2	none
returned value	0 = can't adjust, local control set -1 = adjusted, remote control set

Name **@trig**

Explanation	read user trig enable status
Format	**@trg**
parameter 1	none

parameter 2 none
returned value -1 = enabled, 0 = disabled

Name @>trig

Explanation read hardware trig circuit status (reflects front panel led)

Format @>trg

parameter 1 none
parameter 2 none
returned value -1 = enabled, 0 = disabled

Name !trig

Explanation write desired value for user trig enable status

Format x !trg

parameter 1 x = 1 or -1 to enable, 0 to disable
parameter 2 none
returned value 0 = can't adjust, local control set
-1 = adjusted, remote control set

Name @standby

Explanation read mode

Format @sby

parameter 1 none
parameter 2 none
returned value -1 = standby, 0 = run

Name !standby

Explanation write desired mode

Format x !sby

parameter 1 x = 1 or -1 standby, 0 run
parameter 2 none
returned value 0 = can't adjust, local control set
-1 = adjusted, remote control set

Name @remote

Explanation read control method

Format @rem

parameter 1 none
parameter 2 none
returned value -1 = remote, 0 = local

Name **@trigflag**

Explanation read trigger latch

Format **@tgd**

parameter 1 none
parameter 2 none
returned value -1 = triggered, 0 = not triggered

Name **0trigflag**

Explanation reset trigger latch

Format **0tgd**

parameter 1 none
parameter 2 none
returned value none - works in local or remote

Name **@status**

Explanation read psp1 status

Format **@sts**

parameter 1 none
parameter 2 none
returned value status, see above

Name **@version#**

Explanation read version number

Format **@ver**

parameter 1 none
returned value version number in the format x ;y, currently 2 ;0

Name **@Vamp**

Explanation read amplitude setting in volts

Format **@amp**

parameter 1 none
parameter 2 none
returned value amplitude in volts

Name **!Vamp**

Explanation write desired value for amplitude setting in V

Format **x !amp**

parameter 1 x = width, approximate range 2500 to 3700 V
parameter 2 none
returned value 0 = can't adjust, local control set
-1 = adjusted, remote control set

Name **@Tthr**

Explanation read trigger threshold setting in mV

Format **@thr**

parameter 1 none
parameter 2 none
returned value Current trigger threshold in mV

Name **!Tthr**

Explanation write trigger threshold setting in mV

Format **x !thr**

parameter 1 x = threshold, approximately range 1000 to 3500 mV
parameter 2 none
returned value 0 = can't adjust, local control set
-1 = adjusted, remote control set

Name **!lcd**

Explanation Saves the brightness of the LCD backlight

Format **x !lcd**

parameter 1 x = brightness as percentage 0 through 100
parameter 2 none
returned value 0 = can't adjust, local control set
-1 = adjusted, remote control set

Name **!baud**

Explanation Saves the baud rate for the RS232 coms port.
Requires the execution of **Save** command to store this for the next reboot.

Format **x !baud**

parameter 1 x = 9600, 19200 or 115200
parameter 2 none
returned value 0 = can't adjust, local control set
-1 = adjusted, remote control set

Name **Save**

Explanation Saves the current machine state for next reboot

Format **x save**

parameter 1 x = 1 (boot in remote mode); = 0 (boot in local mode)
parameter 2 none
returned value 0 = can't adjust, local control set
-1 = adjusted, remote control set

Note: This is the only way to save the machine state in Remote Mode.
In local mode one may only save the mode as local.

8. SPECIFICATION

Pulse output	N type connector on front panel
Pulse amplitude	≥ 3.5kV adjustable approximately 60 to 100% into 50Ω
Pulse polarity	Positive or negative set during manufacture
Pulse length	200ps to 10ns f.w.h.m. in approximately 25ps steps
Rise time	≤ 150 ps (10 to 90%)
Fall time	200ps + Pulse length / 10 (80 to 25%)
Trigger input	BNC connector
Trigger requirement	4V to 10V pulse amplitude into 50 Ohms,
	<2ns rise time
Trigger threshold	approximately 1V to 3.5V adjustable
Trigger delay	approximately 35ns fixed
Maximum rep rate	≥ 100Hz (small changes to amplitude may occur at high rates)
Trigger to pulse output	
Jitter	<20ps peak to peak
Monitor output	BNC connector
	~ x1000 attenuation of pulse output into 50Ω
	~0.75ns rise time
Sync output	BNC connector
	~2.2V amplitude into 50Ω
	~0.5ns rise time
Inhibit input	Lemo 00 coaxial connector
	TTL compatible with integral 10k pull up
Local display/control	Led indicating power
	Led indicating trig circuit enabled
	Led indicating momentary triggered condition
	2 LED indicating local or remote control active
	Power On/Off by switch on rear panel;
	Local/remote control push button
	LCD and 4 key keyboard allowing local control and/or monitoring of:-
	Pulse width setting
	Trigger enable/disable
	Mode standby/run
	Pulse amplitude

	Trigger threshold and monitoring of:- Inhibit input Power supply trips Delay circuit faults Stack voltages
Remote control	Ethernet/RS232 selectable by first to active. Remote control and/or monitoring of:- Pulse width setting Trigger enable/disable Mode standby/run Trigger latch Pulse amplitude Trigger threshold and monitoring of:- Inhibit input Power supply trips Delay circuit faults
Power	110/240V AC 50/60Hz via fused IEC connector <60W power consumption
Terminator/monitor	
Terminator:	
Input pulse	<4kV for 10ns typical at 100Hz.
Input connector	N type.
Input impedance	50Ω.
Monitor:	
Output	Input voltage divided by approximately x100.
Output connector	BNC type.
Output impedance	50Ω
Rise time	<150ps.

9. TEST DATA FOR PSP1 PULSE GENERATOR

Oscilloscope: Agilent DSO 81004A

Trigger source: Highland P400 digital delay generator

1) Barth 142-NMFP-20B serial no. 561
2) Barth 142-NMFP-20B serial no. 226N
3) Radiall 18GHz 20dB SMA or similar.

All waveforms shown were measured at the output of the pulser except sync. and monitors.

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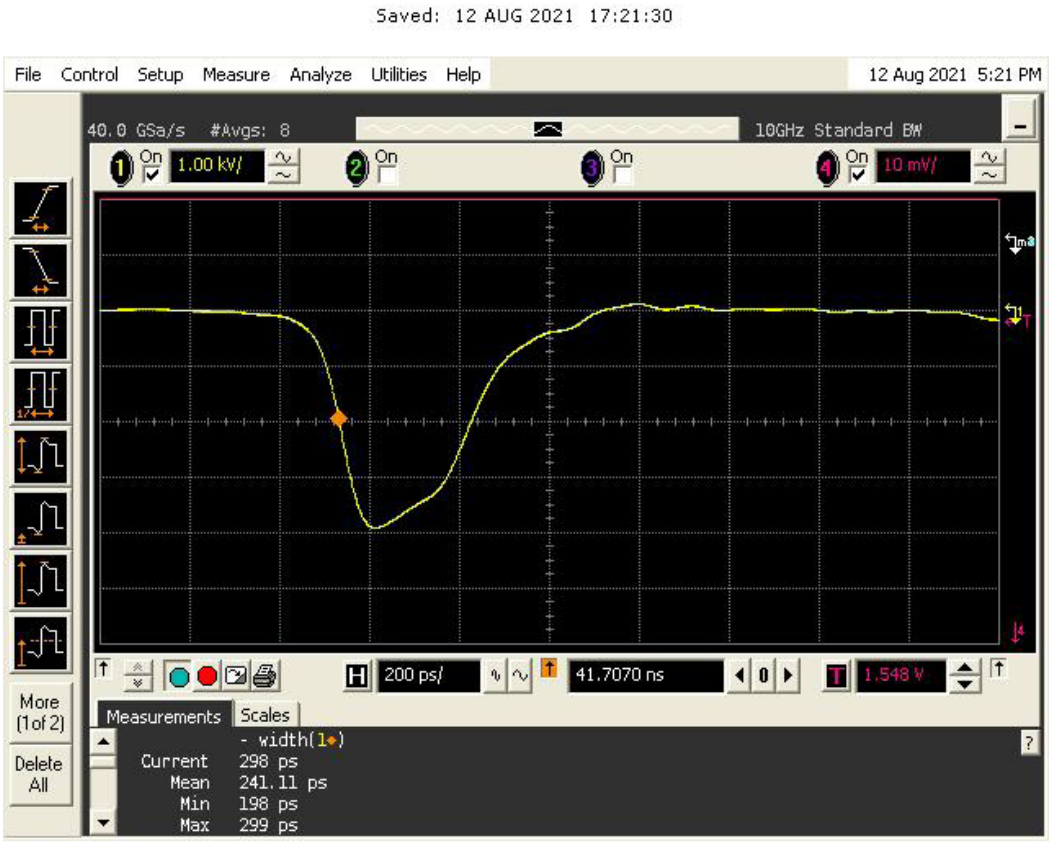
Acquisition	Sampling mode real time Hi resolution Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 200 ps/ Position 41.7070 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.707000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.707000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.707000000000 ns

Measure

	- width(1♦)
Current	202 ps
Mean	200.7 ps
Min	198 ps
Max	203 ps
Range	5 ps
Std Dev	800 fs
# of Meas	870

Figure 3 Width 200ps maximum amplitude



Acquisition	Sampling mode real time Hi resolution Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 200 ps/ Position 41.7070 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.707000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.707000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.707000000000 ns

Measure

	- width(1)
Current	298 ps
Mean	241.11 ps
Min	198 ps
Max	299 ps
Range	101 ps
Std Dev	47.27 ps
# of Meas	1.794 k

Figure 4 Width 300ps maximum and minimum amplitude

Figure 5 Width 400ps maximum and minimum amplitude

Acquisition	Sampling mode real time Hi resolution Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 200 ps/ Position 41.8030 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.803000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.803000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.803000000000 ns

Measure

	- width(1)
Current	508 ps
Mean	456.79 ps
Min	398 ps
Max	519 ps
Range	121 ps
Std Dev	53.65 ps
# of Meas	1.244 k

Figure 6 Width 500ps maximum and minimum amplitude

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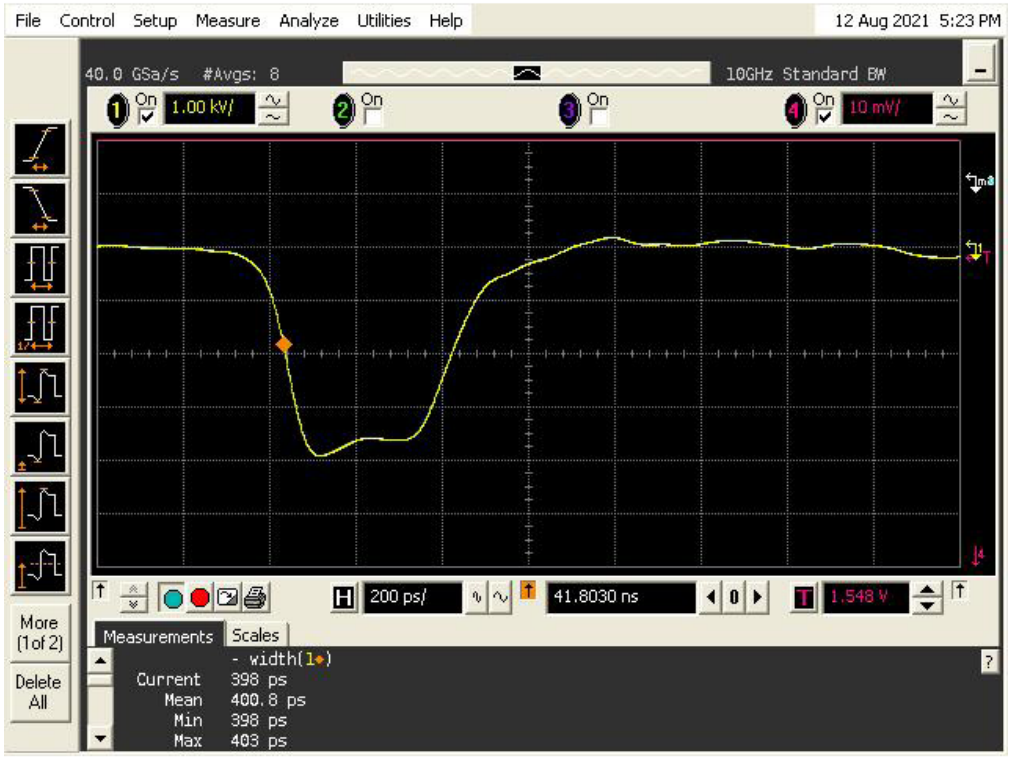

Acquisition	Sampling mode real time Hi resolution Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 200 ps/ Position 41.8030 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.803000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.803000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.803000000000 ns

Measure

	- width(1♦)
Current	398 ps
Mean	400.8 ps
Min	398 ps
Max	403 ps
Range	5 ps
Std Dev	1.1 ps
# of Meas	590

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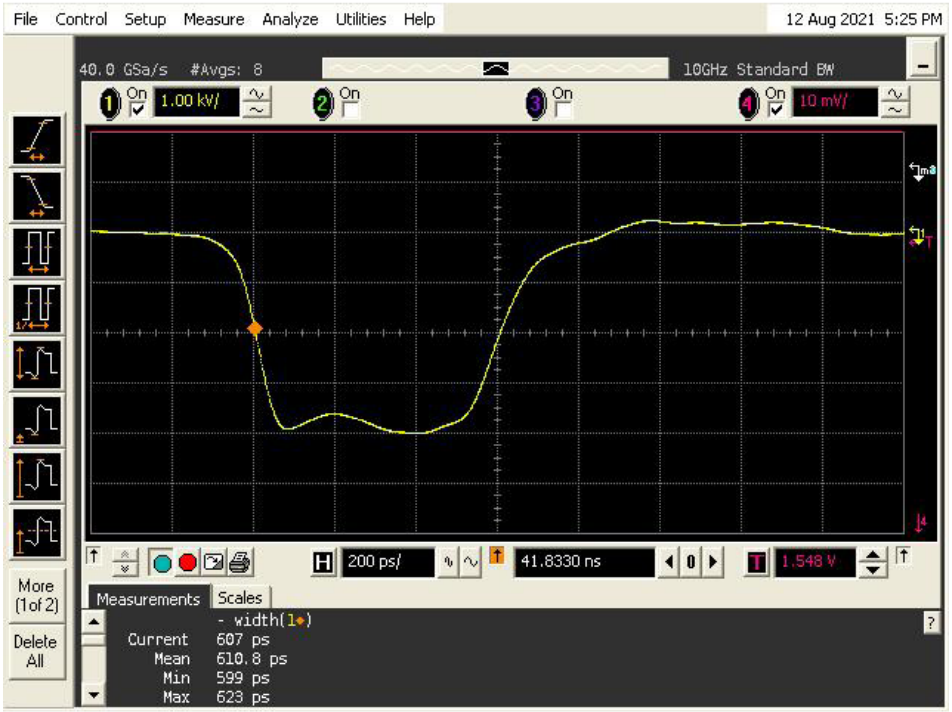

Acquisition	Sampling mode real time Hi resolution Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 200 ps/ Position 41.8330 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.833000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.833000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.833000000000 ns

Measure

	- width(1)
Current	607 ps
Mean	610.8 ps
Min	599 ps
Max	623 ps
Range	25 ps
Std Dev	7.1 ps
# of Meas	719

Figure 7 Width 600ps maximum and minimum amplitude

Acquisition	Sampling mode real time Hi resolution Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 200 ps/ Position 41.8330 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.833000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.833000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 200 ps/ Position 41.833000000000 ns

Measure

	- width(1)
Current	708 ps
Mean	657.78 ps
Min	599 ps
Max	716 ps
Range	118 ps
Std Dev	49.38 ps
# of Meas	1.451 k

Figure 8 Width 700ps maximum and minimum amplitude

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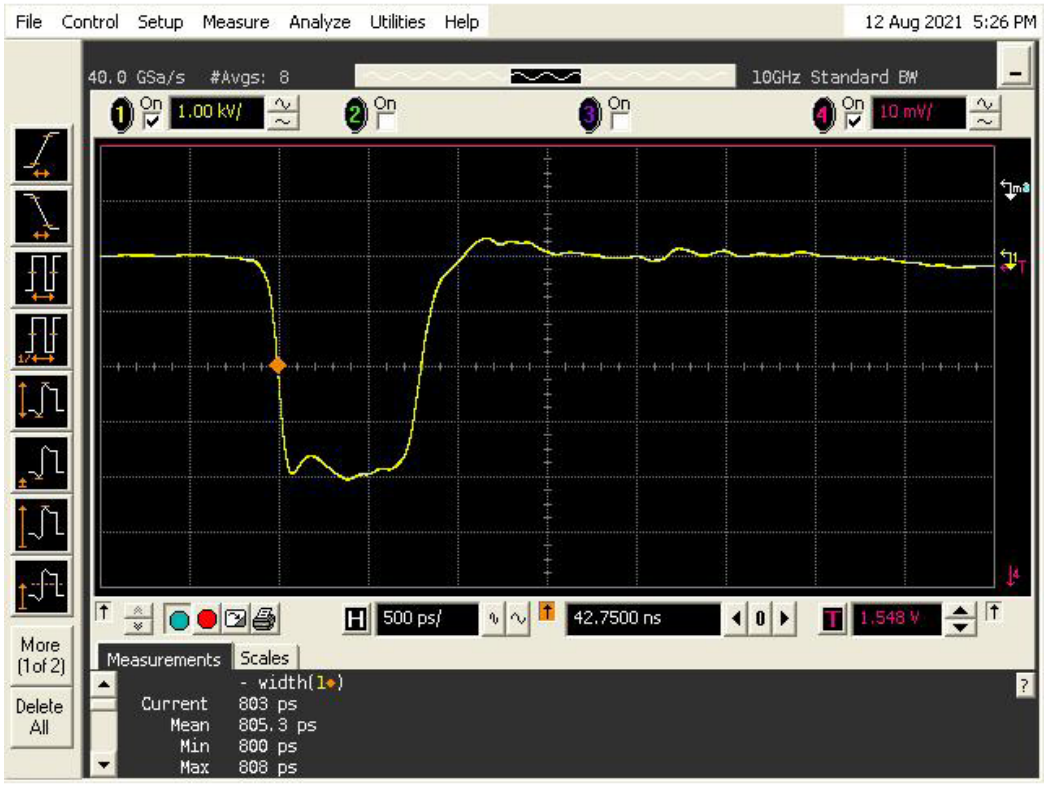

Acquisition	Sampling mode real time Hi resolution Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 500 ps/ Position 42.7500 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 500 ps/ Position 42.750000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 500 ps/ Position 42.750000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 500 ps/ Position 42.750000000000 ns

Measure

	- width(1◆)
Current	803 ps
Mean	805.3 ps
Min	800 ps
Max	808 ps
Range	8 ps
Std Dev	1.7 ps
# of Meas	613

Figure 9 Width 800ps maximum and minimum amplitude

Acquisition Sampling mode real time Hi resolution
Memory depth automatic 1000 pts
Sampling rate automatic Sampling rate 40.0 GSa/s
Averaging on # of averages 8 Interpolation on

Channel 1 Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms

Channel 4 Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms

Time base Scale 500 ps/ Position 42.7500 ns Reference center

Trigger Mode edge Sweep triggered
Sensitivity low Holdoff time 100 ns
Source channel 4 Trigger level 1.5480 V Slope rising

Memory 2 Vertical scale 500 V/ Offset -1.65600 kV
Horizontal scale 500 ps/ Position 42.750000000000 ns

Memory 3 Vertical scale 500 V/ Offset -1.65600 kV
Horizontal scale 500 ps/ Position 42.750000000000 ns

Memory 4 Vertical scale 500 V/ Offset -1.65600 kV
Horizontal scale 500 ps/ Position 42.750000000000 ns

Measure

	- width(1)
Current	898 ps
Mean	852.13 ps
Min	800 ps
Max	902 ps
Range	102 ps
Std Dev	46.62 ps
# of Meas	1.249 k

Figure 10 Width 900ps maximum and minimum amplitude

Acquisition	Sampling mode real time Hi resolution Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 500 ps/ Position 42.7520 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 500 ps/ Position 42.752000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 500 ps/ Position 42.752000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 500 ps/ Position 42.752000000000 ns

Measure

	- width(1)
Current	1.008 ns
Mean	1.0085 ns
Min	1.004 ns
Max	1.012 ns
Range	8 ps
Std Dev	1.6 ps
# of Meas	470

Figure 11 Width 1ns maximum and minimum amplitude

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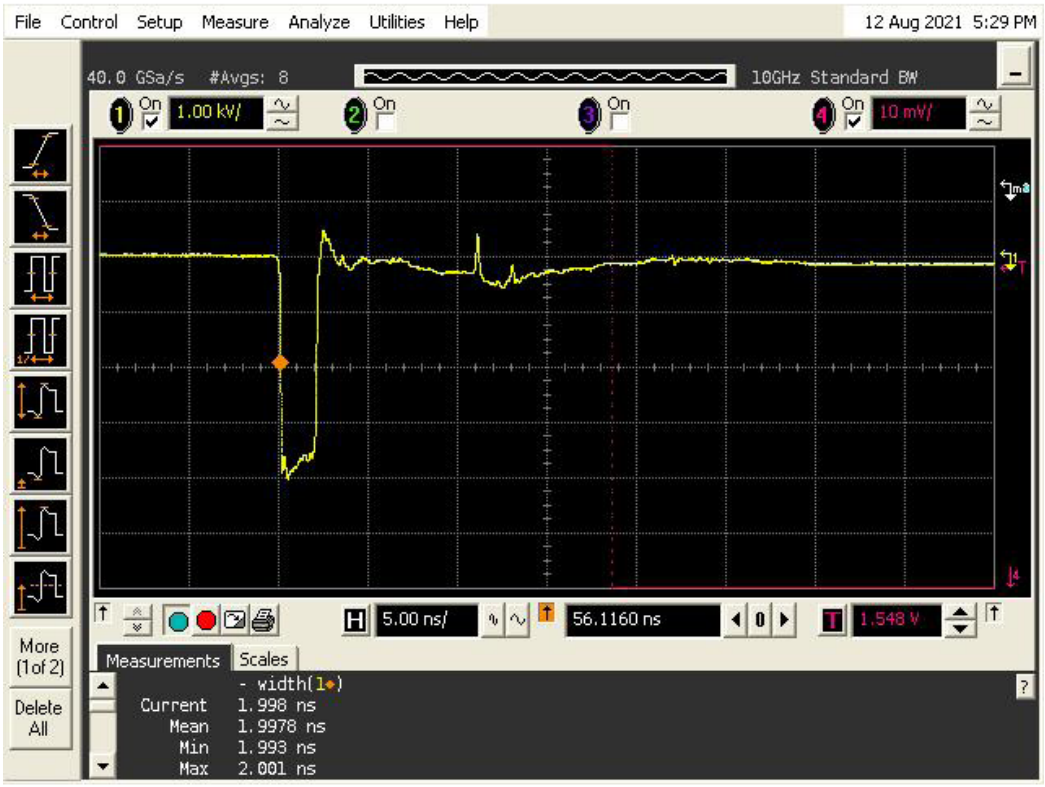
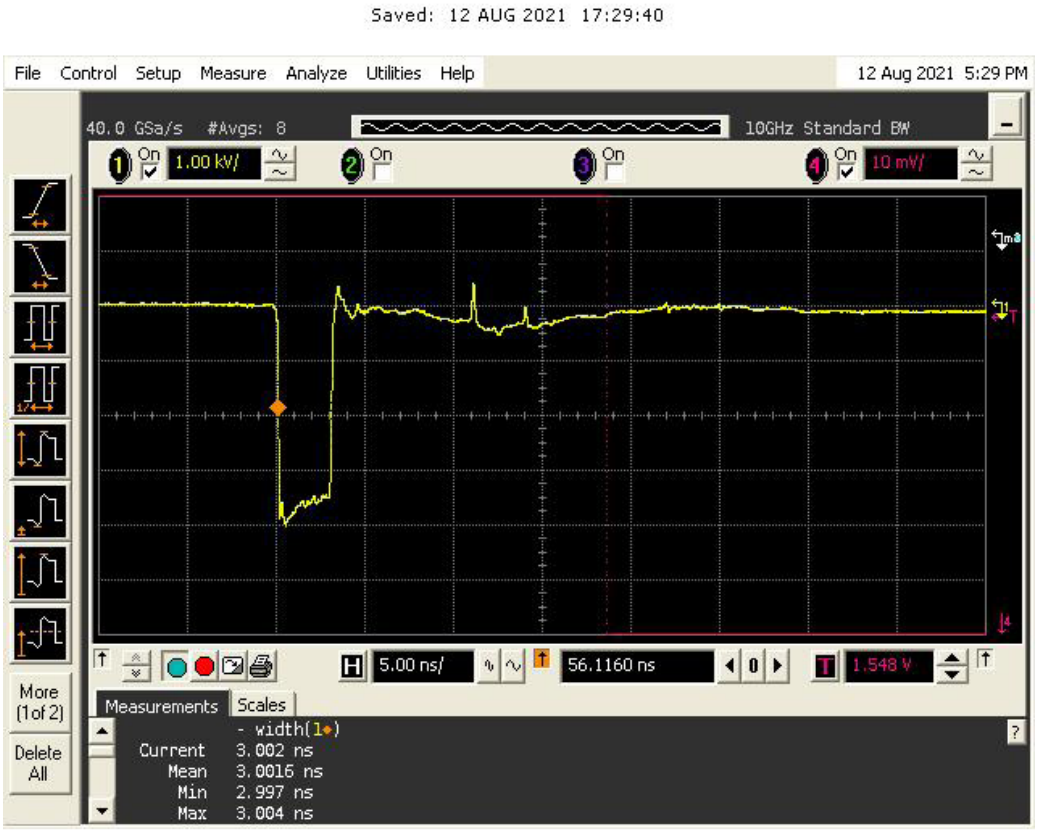


Acquisition	Sampling mode real time Hi resolution Memory depth automatic 2002 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 5.00 ns/ Position 56.1160 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 56.116000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 56.116000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 56.116000000000 ns

Measure

	- width(1)
Current	1.998 ns
Mean	1.9978 ns
Min	1.993 ns
Max	2.001 ns
Range	8 ps
Std Dev	1.3 ps
# of Meas	139

Figure 12 Width 2ns maximum and minimum amplitude



Acquisition	Sampling mode real time Hi resolution Memory depth automatic 2002 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 5.00 ns/ Position 56.1160 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 56.116000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 56.116000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 56.116000000000 ns

Measure	- width(1◆)
Current	3.002 ns
Mean	3.0016 ns
Min	2.997 ns
Max	3.004 ns
Range	7 ps
Std Dev	1.3 ps
# of Meas	119

Figure 13 Width 3ns maximum and minimum amplitude

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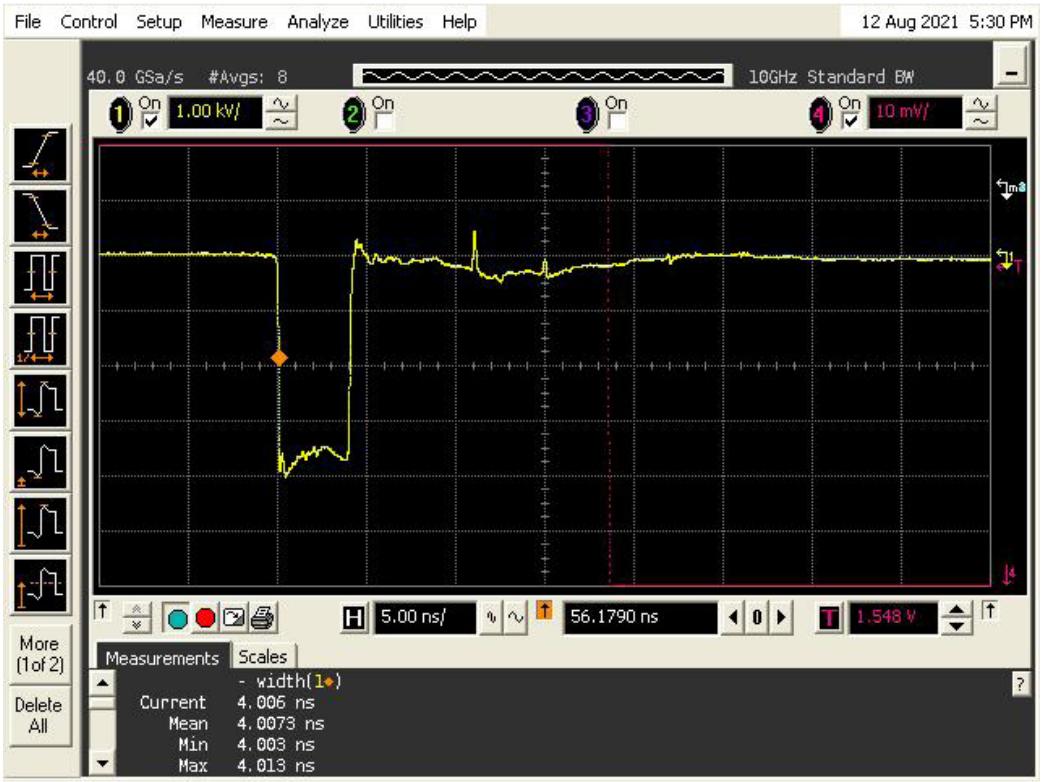
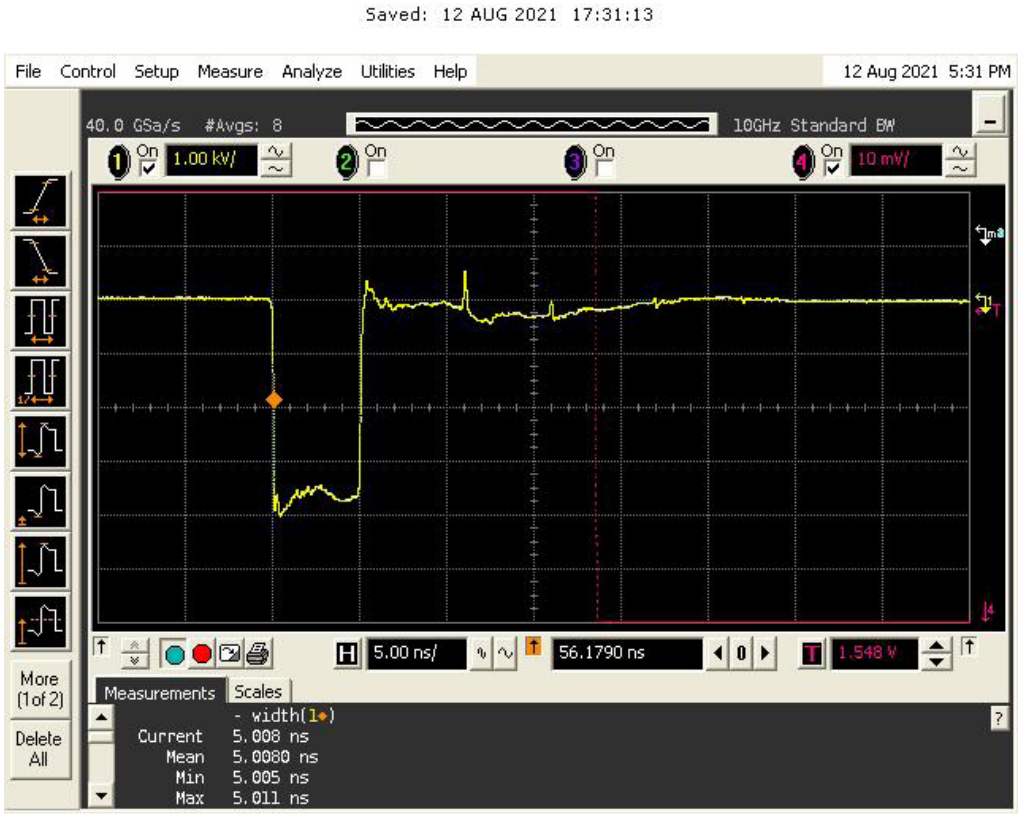


Acquisition	Sampling mode real time Hi resolution Memory depth automatic 2002 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 5.00 ns/ Position 56.1790 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 56.179000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 56.179000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 56.179000000000 ns

Measure

	- width(1)
Current	4.006 ns
Mean	4.0073 ns
Min	4.003 ns
Max	4.013 ns
Range	10 ps
Std Dev	2.5 ps
# of Meas	157

Figure 14 Width 4ns maximum and minimum amplitude



Acquisition	Sampling mode real time Hi resolution Memory depth automatic 2002 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 5.00 ns/ Position 56.1790 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 56.179000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 56.179000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 56.179000000000 ns

Measure

	- width(1)
Current	5.007 ns
Mean	5.0079 ns
Min	5.005 ns
Max	5.011 ns
Range	6 ps
Std Dev	1.1 ps
# of Meas	180

Figure 15 Width 5ns maximum and minimum amplitude.

Acquisition	Sampling mode real time Hi resolution Memory depth automatic 4003 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 10.0 ns/ Position 71.2510 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 10.0 ns/ Position 71.251000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 10.0 ns/ Position 71.251000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 10.0 ns/ Position 71.251000000000 ns

Measure

	- width(1)
Current	6.004 ns
Mean	6.0040 ns
Min	6.003 ns
Max	6.005 ns
Range	2 ps
Std Dev	500 fs
# of Meas	132

Figure 16 Width 6ns maximum and minimum amplitude.

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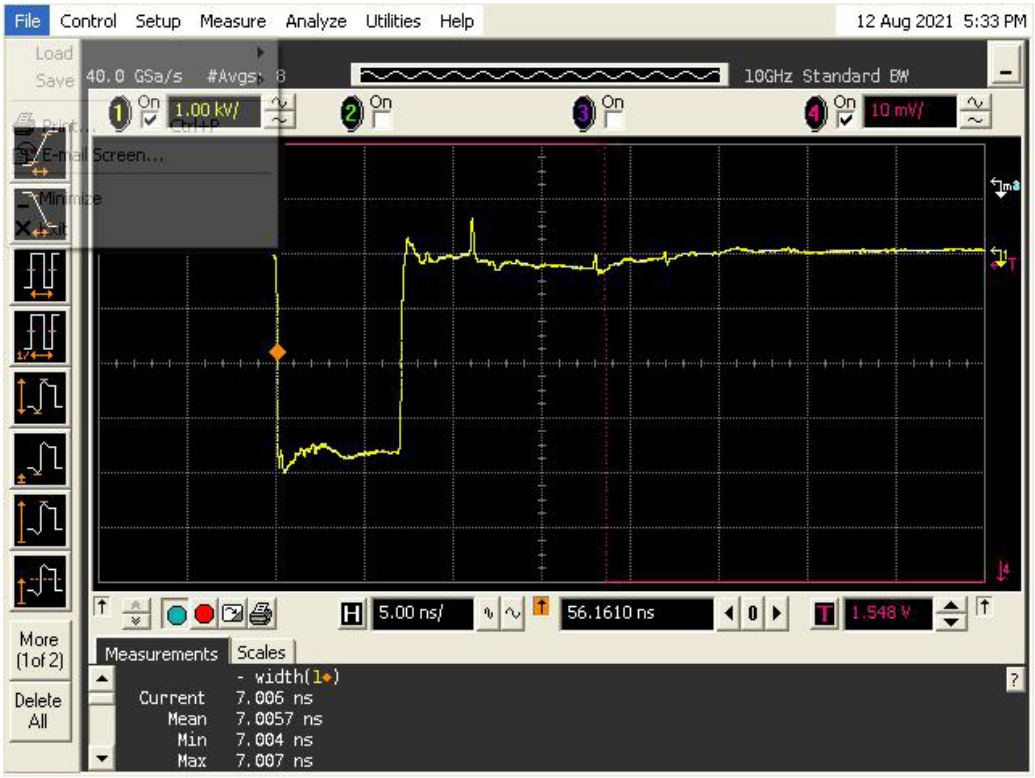

Acquisition	Sampling mode real time Hi resolution Memory depth automatic 2002 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 5.00 ns/ Position 56.1610 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 56.161000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 56.161000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 56.161000000000 ns

Measure	- width(1)
Current	7.006 ns
Mean	7.0057 ns
Min	7.004 ns
Max	7.007 ns
Range	3 ps
Std Dev	600 fs
# of Meas	165

Figure 17 Width 7ns maximum and minimum amplitude.

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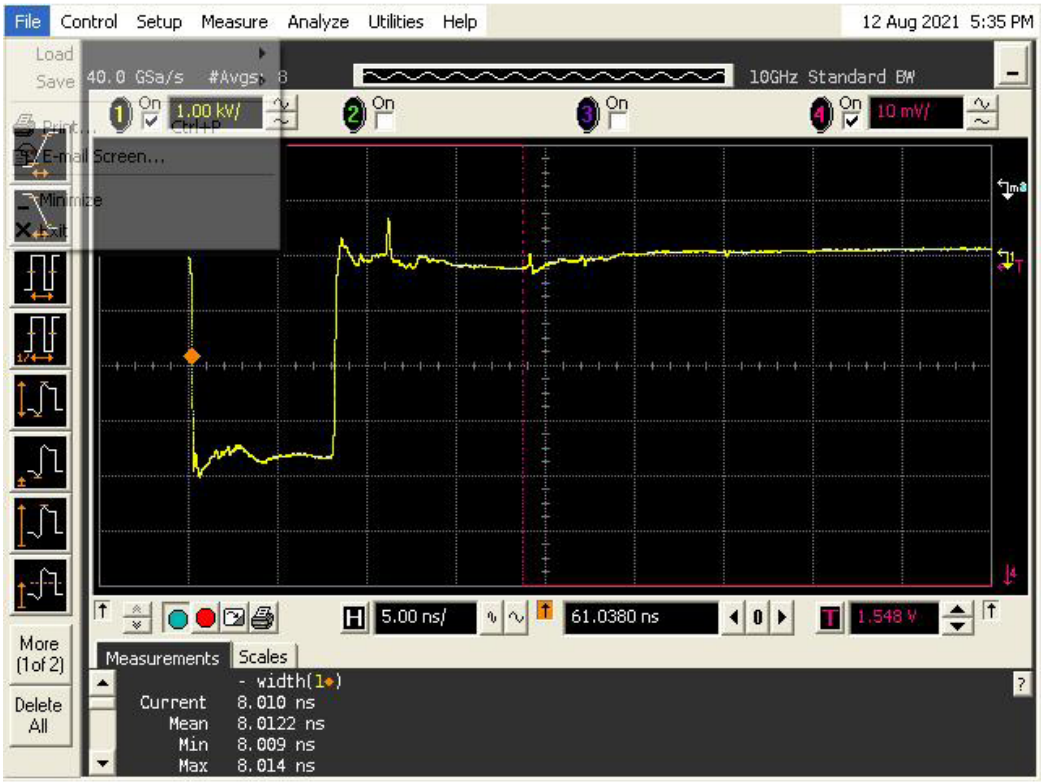
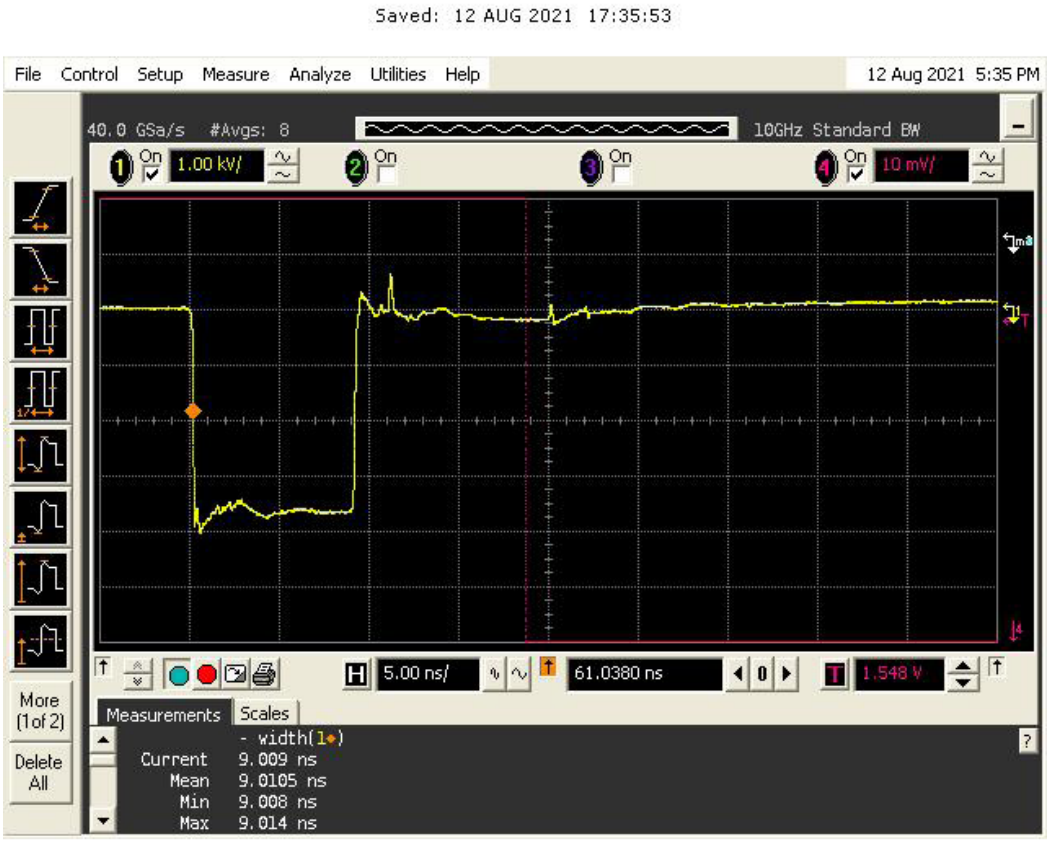


Acquisition	Sampling mode real time Hi resolution Memory depth automatic 2002 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 5.00 ns/ Position 61.0380 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 61.038000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 61.038000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 61.038000000000 ns

Measure

	- width(1)
Current	8.010 ns
Mean	8.0122 ns
Min	8.009 ns
Max	8.014 ns
Range	5 ps
Std Dev	1.2 ps
# of Meas	171

Figure 18 Width 8ns maximum and minimum amplitude.

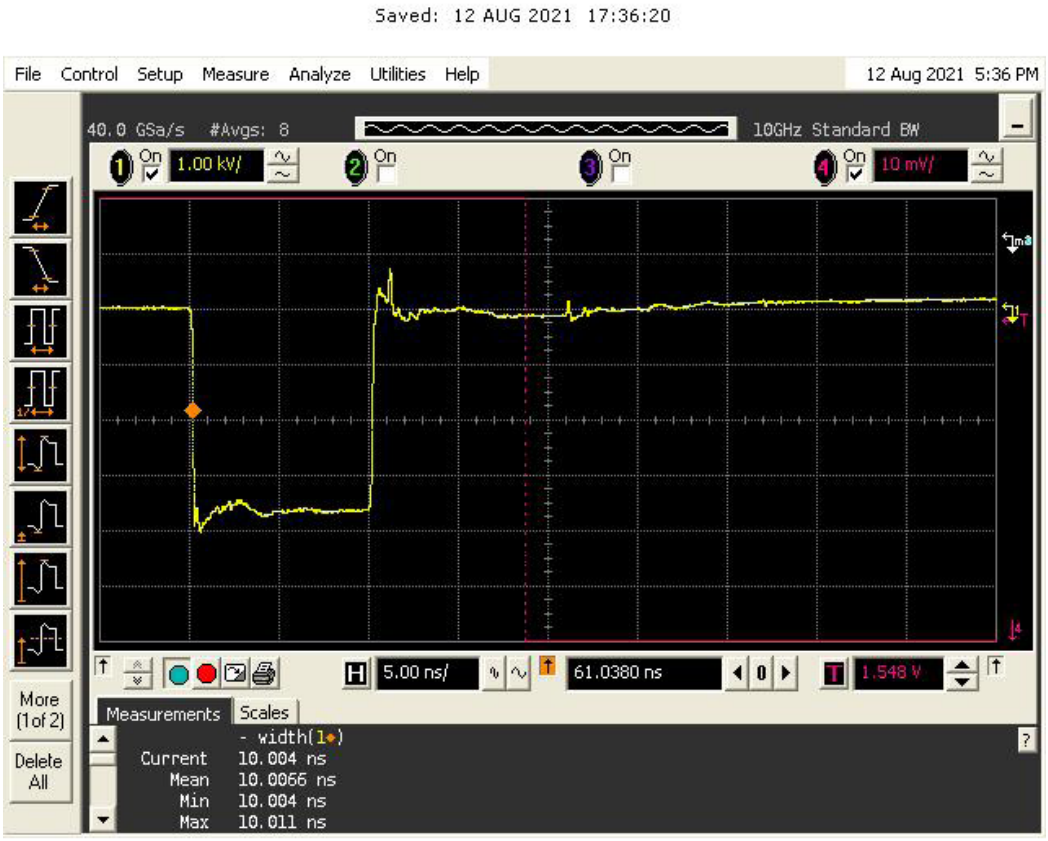


Acquisition	Sampling mode real time Hi resolution Memory depth automatic 2002 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 5.00 ns/ Position 61.0380 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 61.038000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 61.038000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 61.038000000000 ns

Measure

	- width(1)
Current	9.009 ns
Mean	9.0105 ns
Min	9.008 ns
Max	9.014 ns
Range	6 ps
Std Dev	1.9 ps
# of Meas	150

Figure 19 Width 9ns maximum and minimum amplitude.



Acquisition	Sampling mode real time Hi resolution Memory depth automatic 2002 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 5.00 ns/ Position 61.0380 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 61.038000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 61.038000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 61.038000000000 ns

Measure

	- width(1)
Current	10.004 ns
Mean	10.0066 ns
Min	10.004 ns
Max	10.011 ns
Range	7 ps
Std Dev	2.3 ps
# of Meas	369

Figure 20 Width 10ns maximum and minimum amplitude

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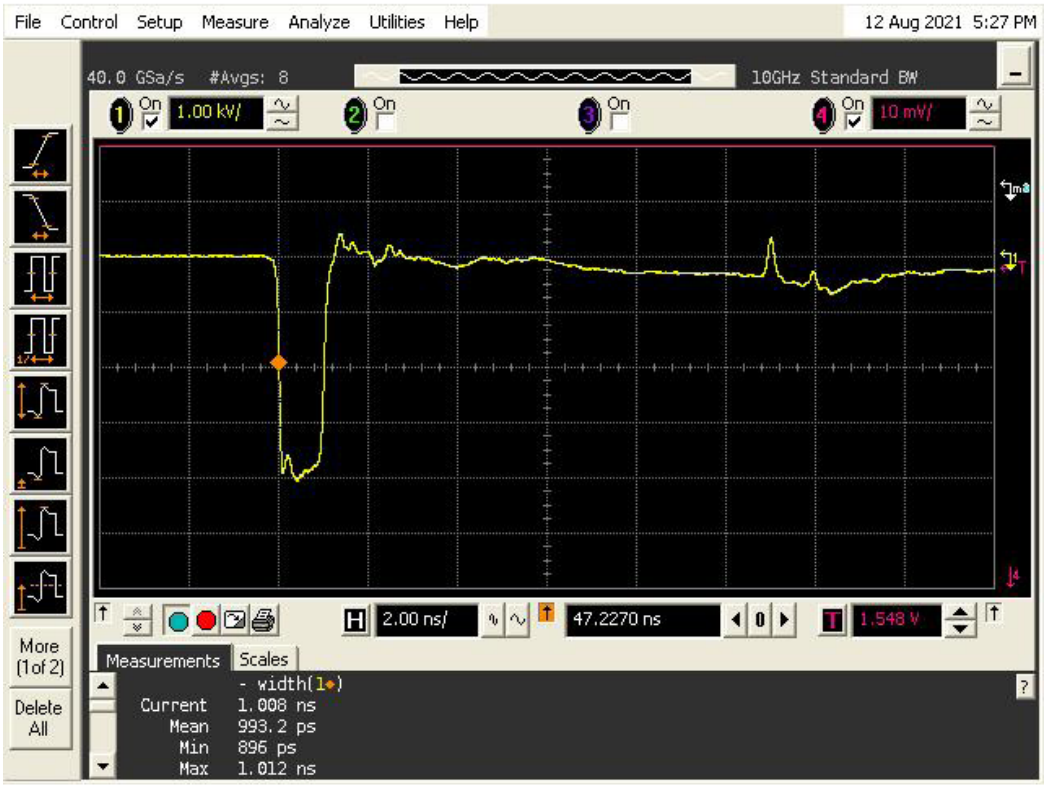
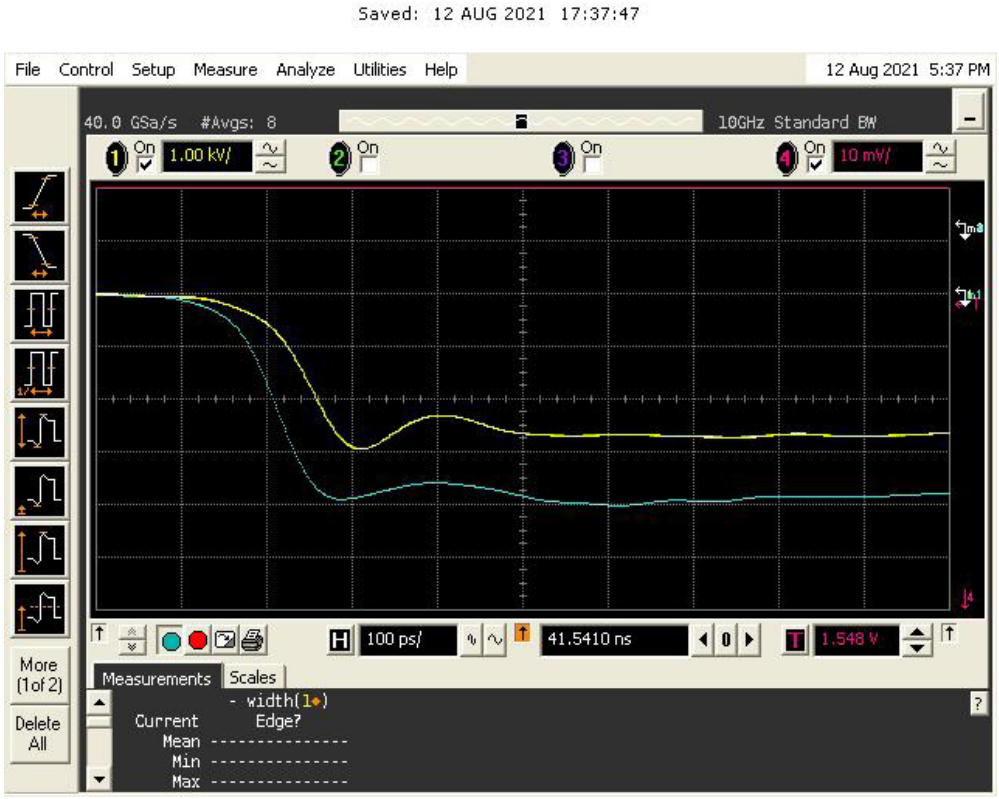


Acquisition	Sampling mode real time Hi resolution Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 2.00 ns/ Position 47.2270 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 2.00 ns/ Position 47.227000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 2.00 ns/ Position 47.227000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 2.00 ns/ Position 47.227000000000 ns

Measure

	- width(1)
Current	1.008 ns
Mean	993.2 ps
Min	896 ps
Max	1.012 ns
Range	116 ps
Std Dev	37.5 ps
# of Meas	482

Figure 21 Post pulse output with 1ns output pulse

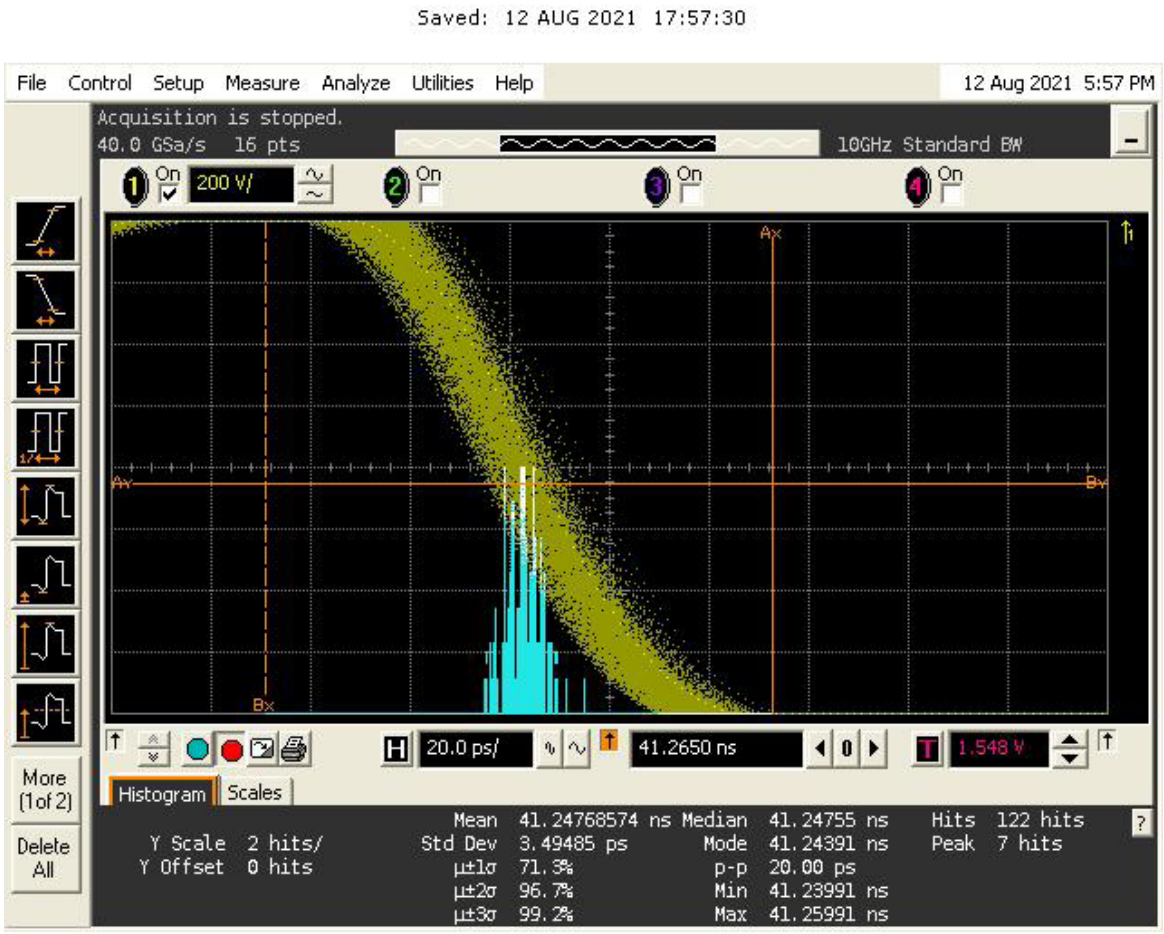


Acquisition	Sampling mode real time Hi resolution Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 100 ps/ Position 41.5410 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 1	Vertical scale 1.00 kV/ Offset -2.05500 kV Horizontal scale 100 ps/ Position 41.541000000000 ns
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 100 ps/ Position 41.541000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 100 ps/ Position 41.541000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 100 ps/ Position 41.541000000000 ns

Measure

- width(1)
Current
Edge?
Mean
Min
Max
Range
Std Dev
# of Meas

Figure 22 First edge transition time maximum and minimum amplitude



Acquisition	Sampling mode real time Hi resolution Memory depth automatic 16 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 200 V/ Offset -1.954 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 20.0 ps/ Position 41.2650 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising

Histogram

Axis horizontal Scale source channel 1
Ax Position 41.29773 ns Bx Position 41.19591 ns
Ay Position -2.0069 kV By Position -2.0069 kV
Scale type linear Size 4.0 div

		Mean	41.24768574 ns	Median 41.24755 ns	Hits 122 hits
Y Scale	2 hits/	Std Dev	3.49485 ps	Mode 41.24391 ns	Peak 7 hits
Y Offset	0 hits	µ±1σ	71.3%	p-p 20.00 ps	
		µ±2σ	96.7%	Min 41.23991 ns	
		µ±3σ	99.2%	Max 41.25991 ns	

Figure 23 1st. edge jitter (~20ps p – p, 3.5ps SD).

Acquisition Sampling mode real time Hi resolution
Memory depth automatic 4003 pts
Sampling rate automatic Sampling rate 40.0 GSa/s
Averaging on # of averages 8 Interpolation on

Channel 1 Scale 2.00 V/ Offset 3.79 V Coupling DC Impedance 50 Ohms

Channel 4 Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms

Time base Scale 10.0 ns/ Position 41.2960 ns Reference center

Trigger Mode edge Sweep triggered
Sensitivity low Holdoff time 100 ns
Source channel 4 Trigger level 1.5480 V Slope rising

Memory 1 Vertical scale 1.00 kV/ Offset -1.58442 kV
Horizontal scale 10.0 ns/ Position 41.296000000000 ns

Measure

	ΔTime(1-m1)	- width(1◆)
Current	35.942 ns	Edge?
Mean	35.9439 ns	----------
Min	35.920 ns	----------
Max	35.954 ns	----------
Range	34 ps	----------
Std Dev	3.7 ps	----------
# of Meas	309	----------
From Num	1	
From Dir	Rising	
From Lvl	Middle	
To Num	1	

Figure 24 Trigger delay 36ns, input BNC to output N type.

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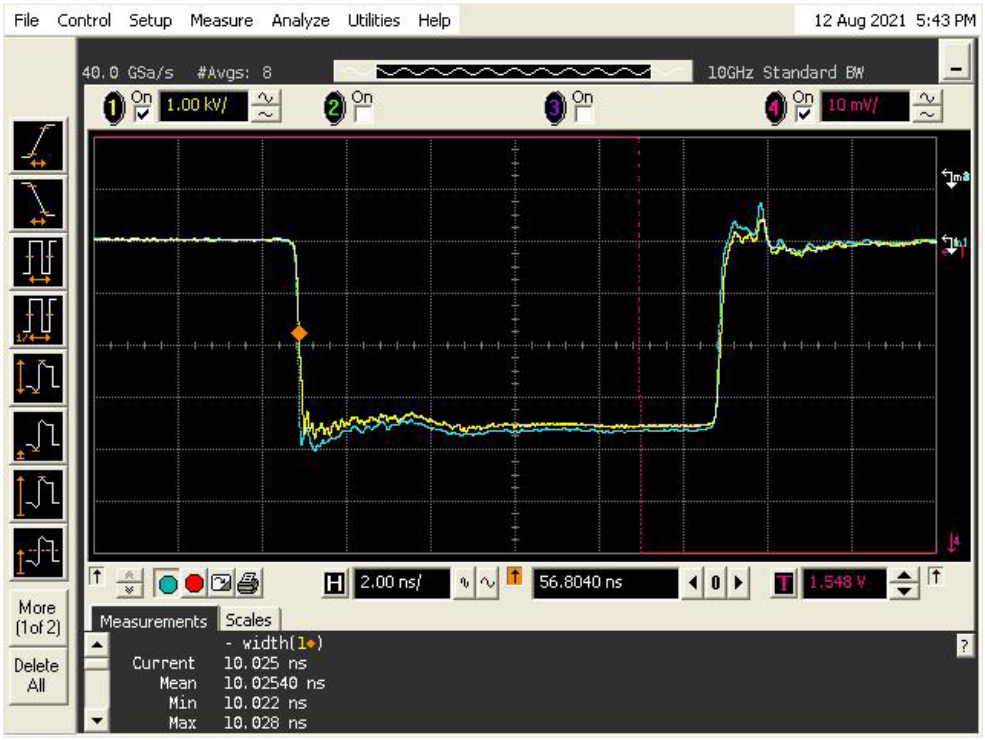
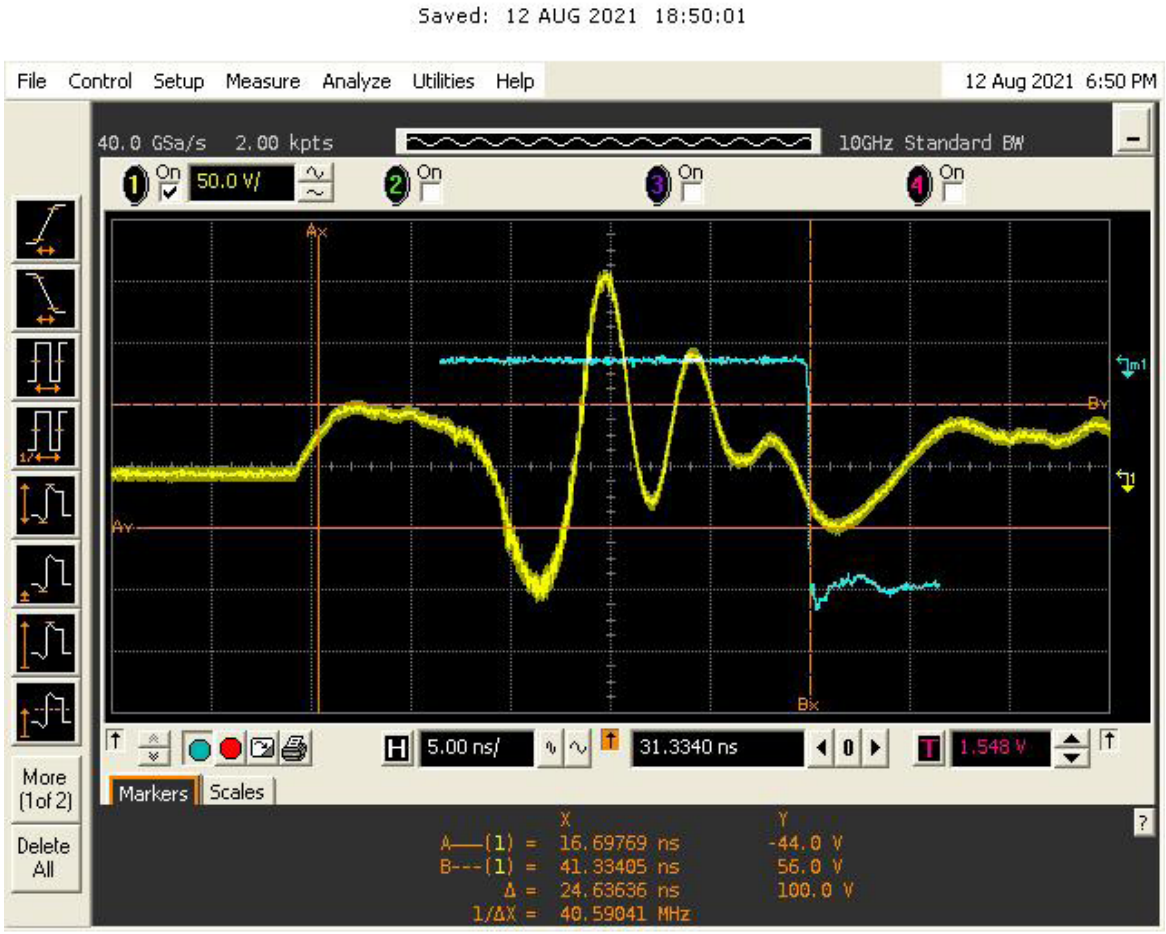


Acquisition	Sampling mode real time Hi resolution Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 kV/ Offset -2.055 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 2.00 ns/ Position 56.8040 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 1	Vertical scale 1.00 kV/ Offset -2.05500 kV Horizontal scale 2.00 ns/ Position 46.399000000000 ns
Memory 2	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 61.171000000000 ns
Memory 3	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 61.171000000000 ns
Memory 4	Vertical scale 500 V/ Offset -1.65600 kV Horizontal scale 5.00 ns/ Position 61.171000000000 ns

Measure

	- width(1)
Current	10.025 ns
Mean	10.02540 ns
Min	10.022 ns
Max	10.028 ns
Range	6 ps
Std Dev	1.20 ps
# of Meas	1.403 k

Figure 25 Comparison of the Return monitor [yellow] against the Barth attenuators. [blue].

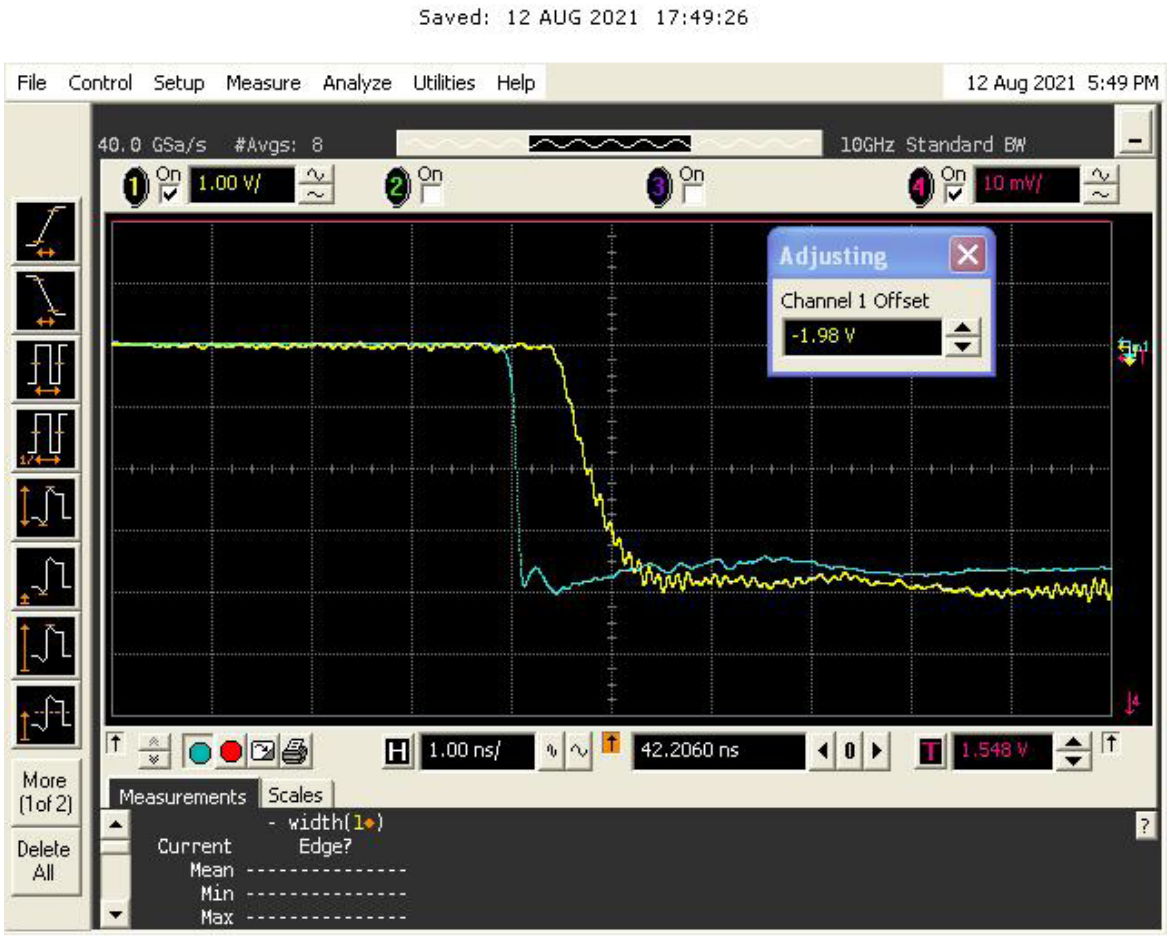


Acquisition	Sampling mode real time Hi resolution Memory depth automatic 2002 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 50.0 V/ Offset 6.0 V Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 5.00 ns/ Position 31.3340 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 1	Vertical scale 1.00 kV/ Offset -1.72800 kV Horizontal scale 5.00 ns/ Position 31.334000000000 ns

Marker

	X	Y
A——(1) =	16.69769 ns	-44.0 V
B---(1) =	41.33405 ns	56.0 V
Δ =	24.63636 ns	100.0 V
1/ΔX =	40.59041 MHz	

Figure 26 Sync output BNC on front panel 24.6 ns before main pulse.



Acquisition	Sampling mode real time Hi resolution Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 8 Interpolation on
Channel 1	Scale 1.00 V/ Offset -1.98 V Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 1.530 V Coupling DC Impedance 50 Ohms
Time base	Scale 1.00 ns/ Position 42.2060 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 1.5480 V Slope rising
Memory 1	Vertical scale 1.00 kV/ Offset -2.05500 kV Horizontal scale 1.00 ns/ Position 42.206000000000 ns

Measure

```
          - width(1♦)
Current      Edge?
   Mean ---------------
    Min ---------------
    Max ---------------
  Range ---------------
Std Dev ---------------
# of Meas ---------------
```

Figure 27 Monitor output BNC on front panel. Monitor has ~750ps rise time.

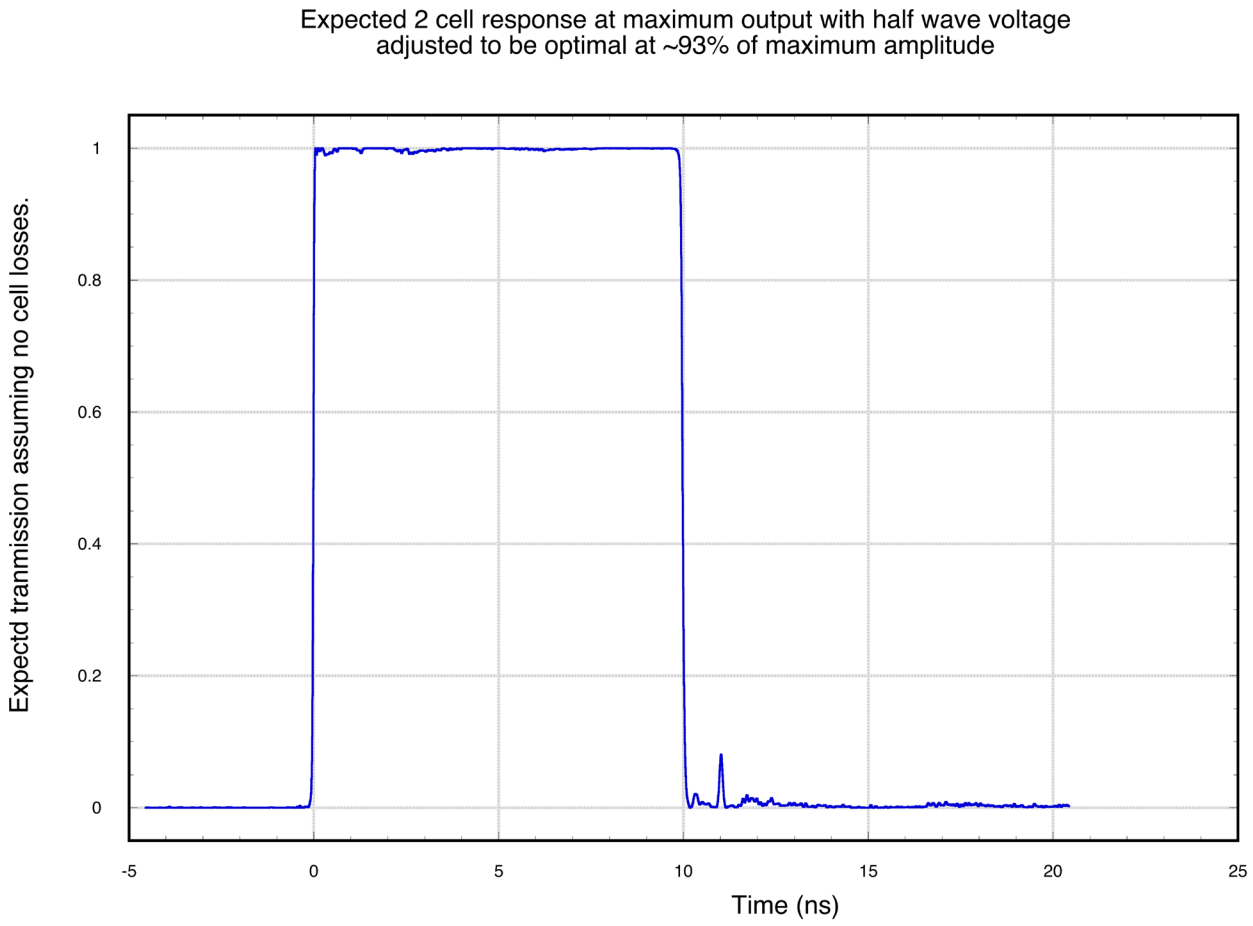


Figure 28 Expected Pockels cell response with pulser.

10. CONFIGURING THE ETHERNET CONTROLLER.

10.1 INTRODUCTION

Ethernet remote control of the PSP1 is available via a Lantronix Xport device within the PSP1. This may need configuring for your system and on your LAN. Generally when supplied the controller is set to acquire its IP address automatically. The serial settings of the device have been preset to communicate with the processor in the PSP1 and normally these should not be changed. If you need to modify the settings follow the next section.

10.2 SETTING UP THE IP ADDRESS OF THE PSP1

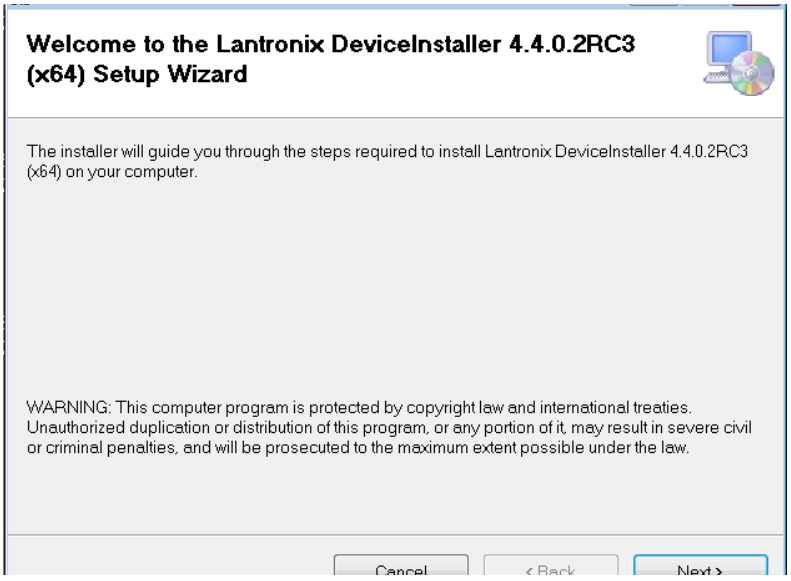
Lantronix supply a piece of software called “Device Installer” to configure the Xport interface. The latest version at the time of writing will be on the CD with this manual. This will run under windows 7 64 bit Pro and probably several other operating systems.

It can also be obtained from

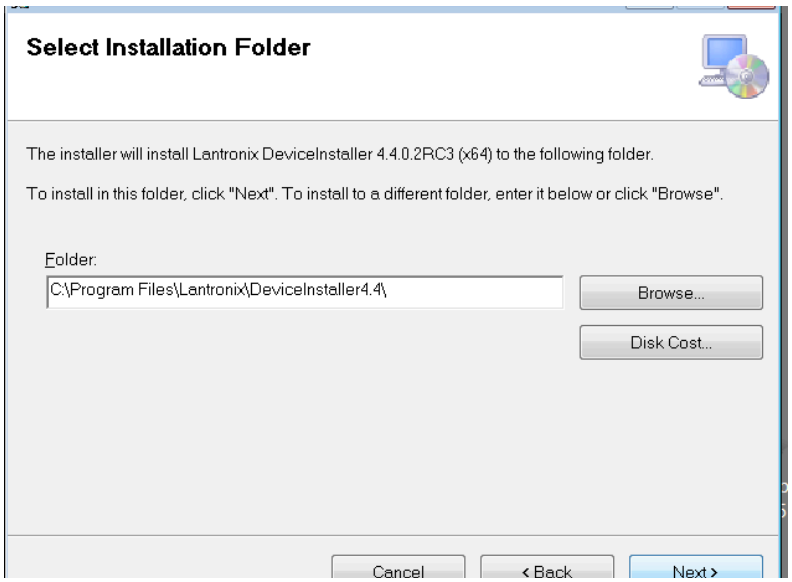
http://ts.lantronix.com/ftp/DeviceInstaller/Lantronix/4.4/4.4.0.7/Installers/SingleInstallFiles/DeviceInstaller-4407-SA.zip

Run this program. You should be presented with a window similar to that below..

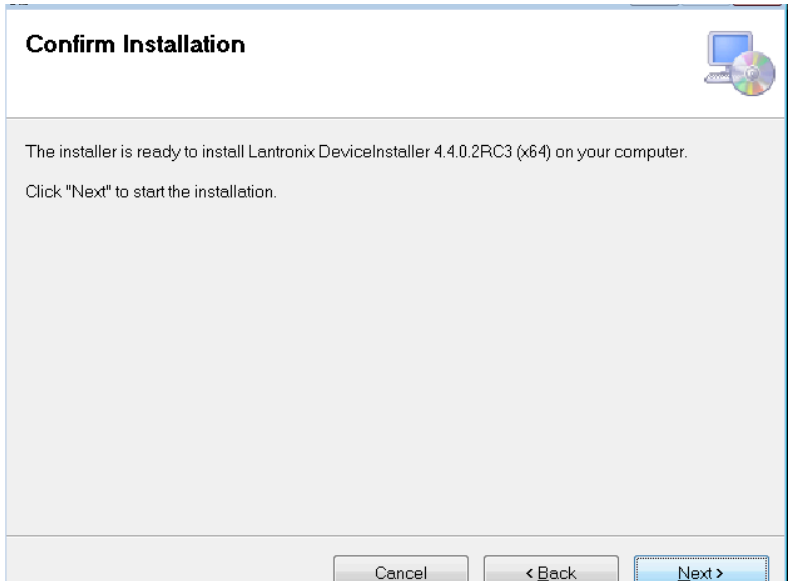
If you have not already installed the .NET software you will have to do so now. This is general software for many applications and may well be installed already. Check the DeviceInstaller box and click “Install”. You should be presented with the following (Note the example is for an earlier version 4.4.0.2RC3) :



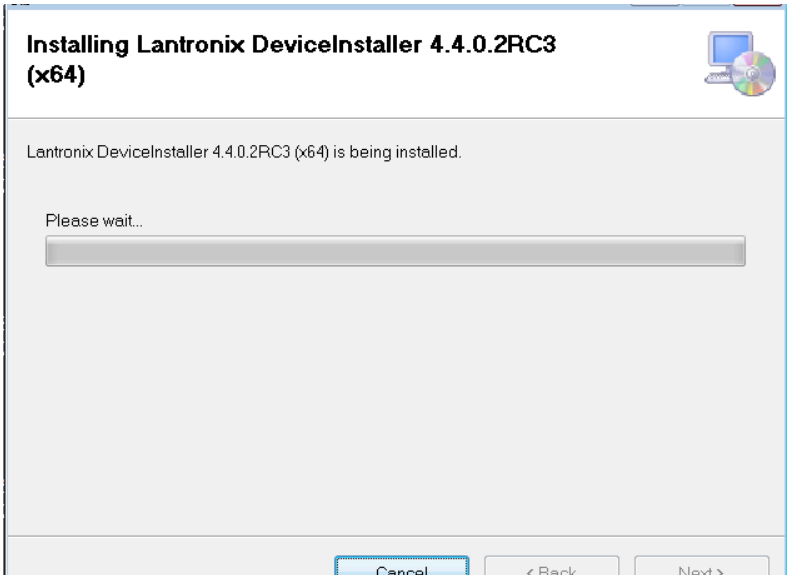
Click on “Next” and the following should appear:



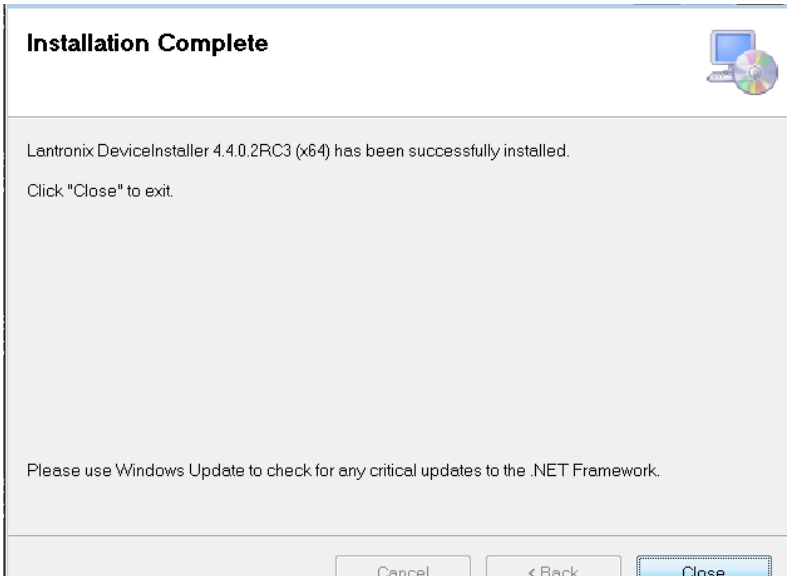
Click on “Next” and the following should appear:



Click on “Next” and the following should appear:

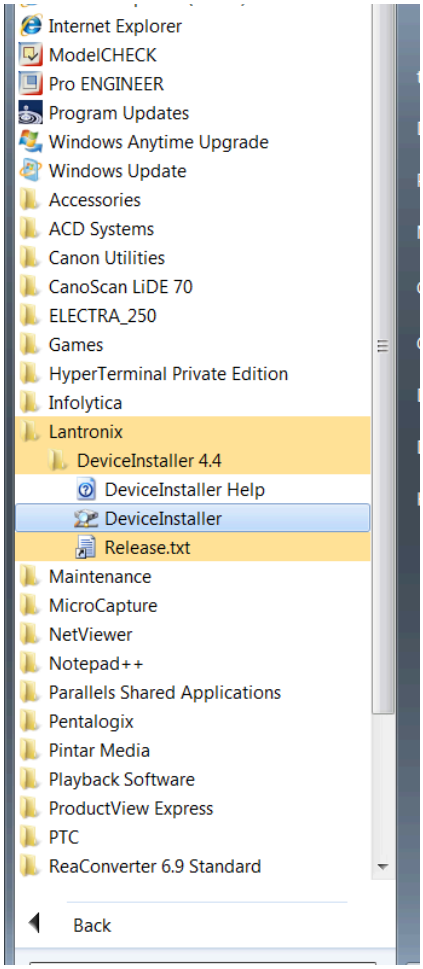


Then when this is complete:

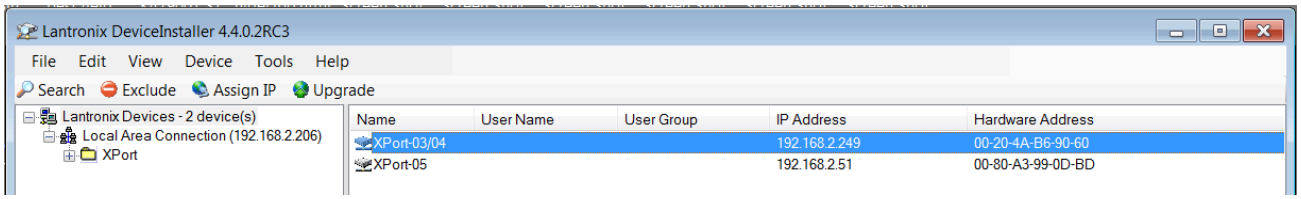


Click “close”

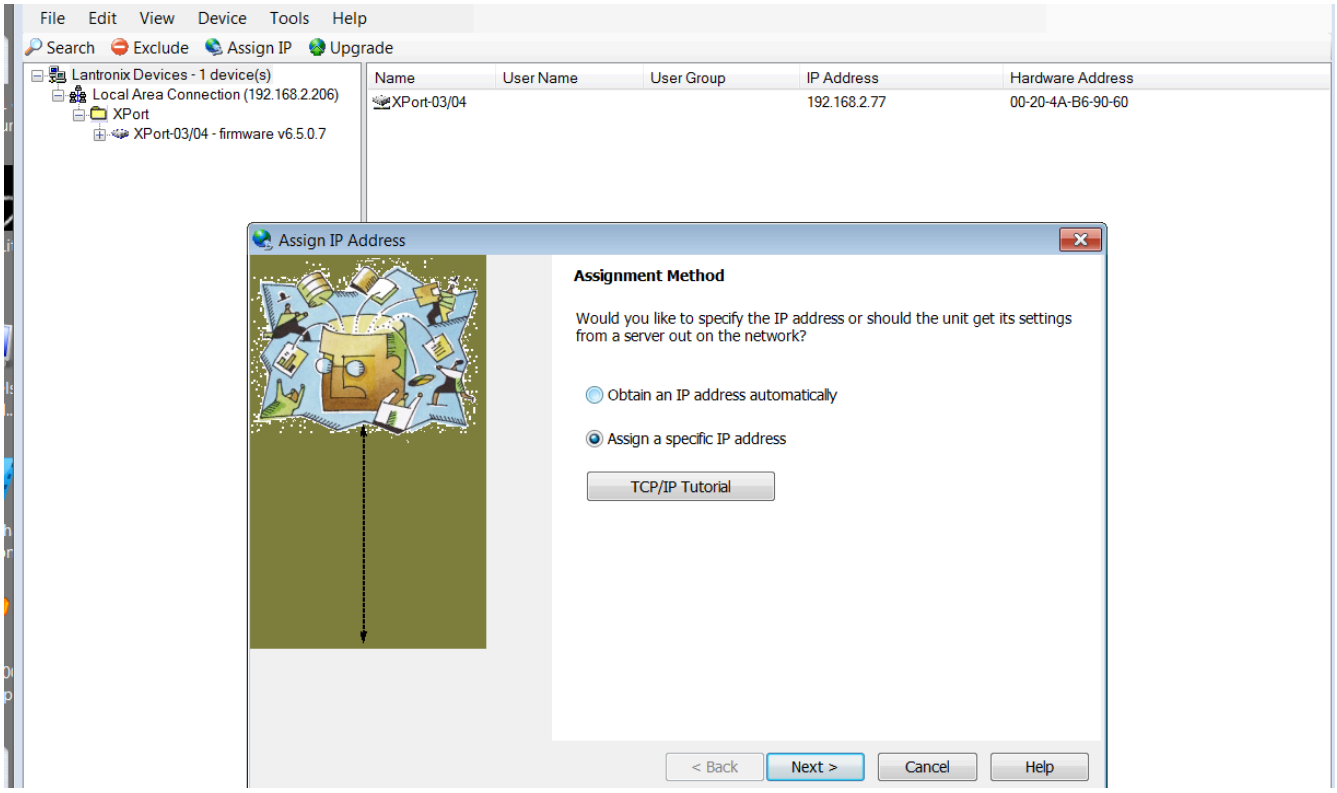
Navigate to the program folder and launch “Device Installer”



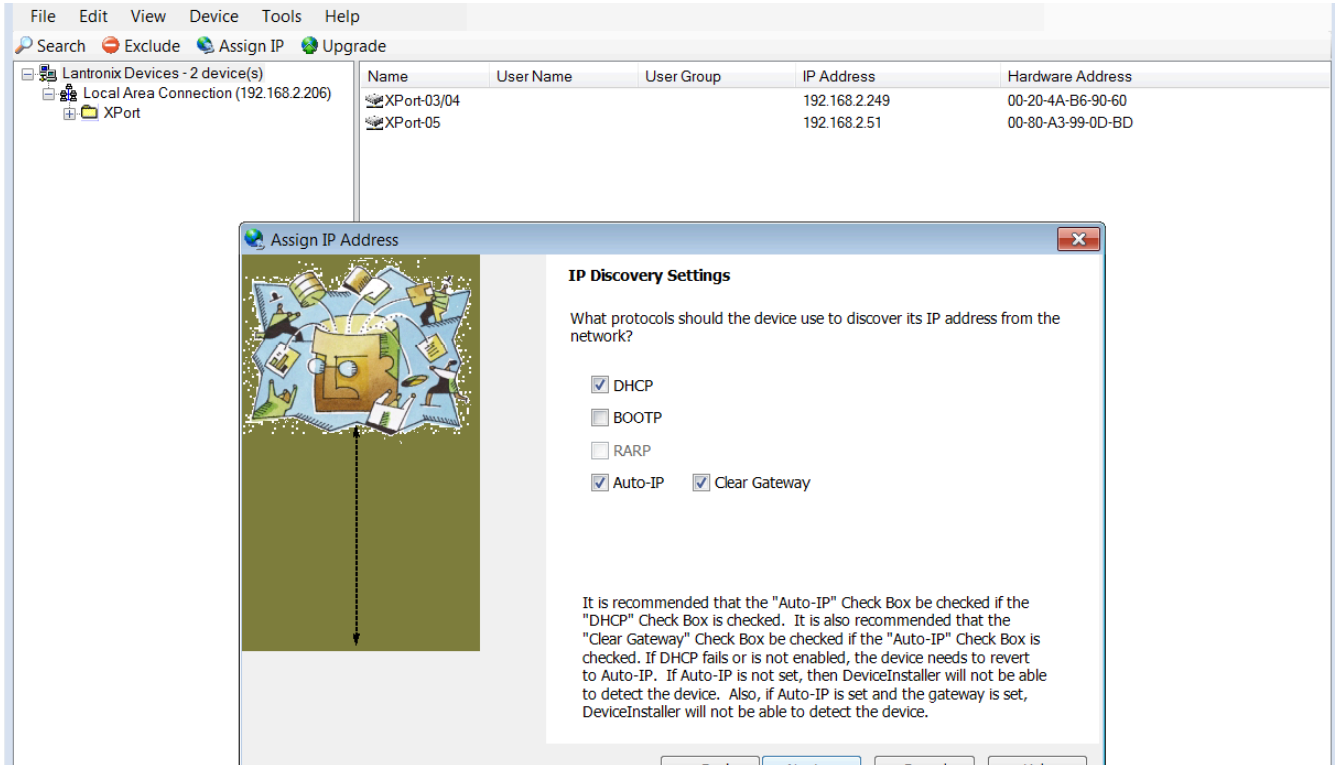
You should see the following:



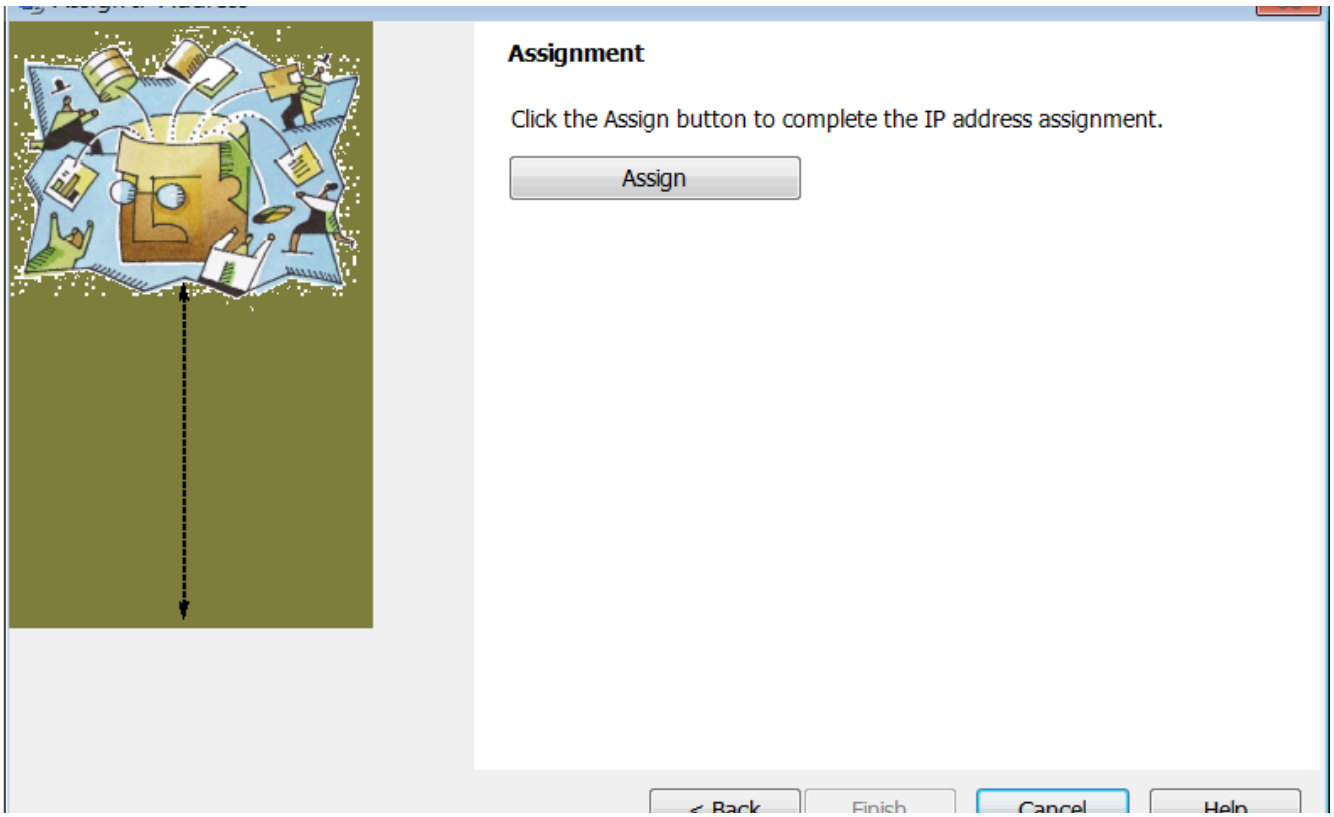
Look at the MAC address on the rear of the PSP1 and match it to one of the Xports in the list. If you only have one Xport you may assume it has the correct device and only one will be listed. Select the device in the list to highlight it. Then click on “assign IP”. The following should appear:



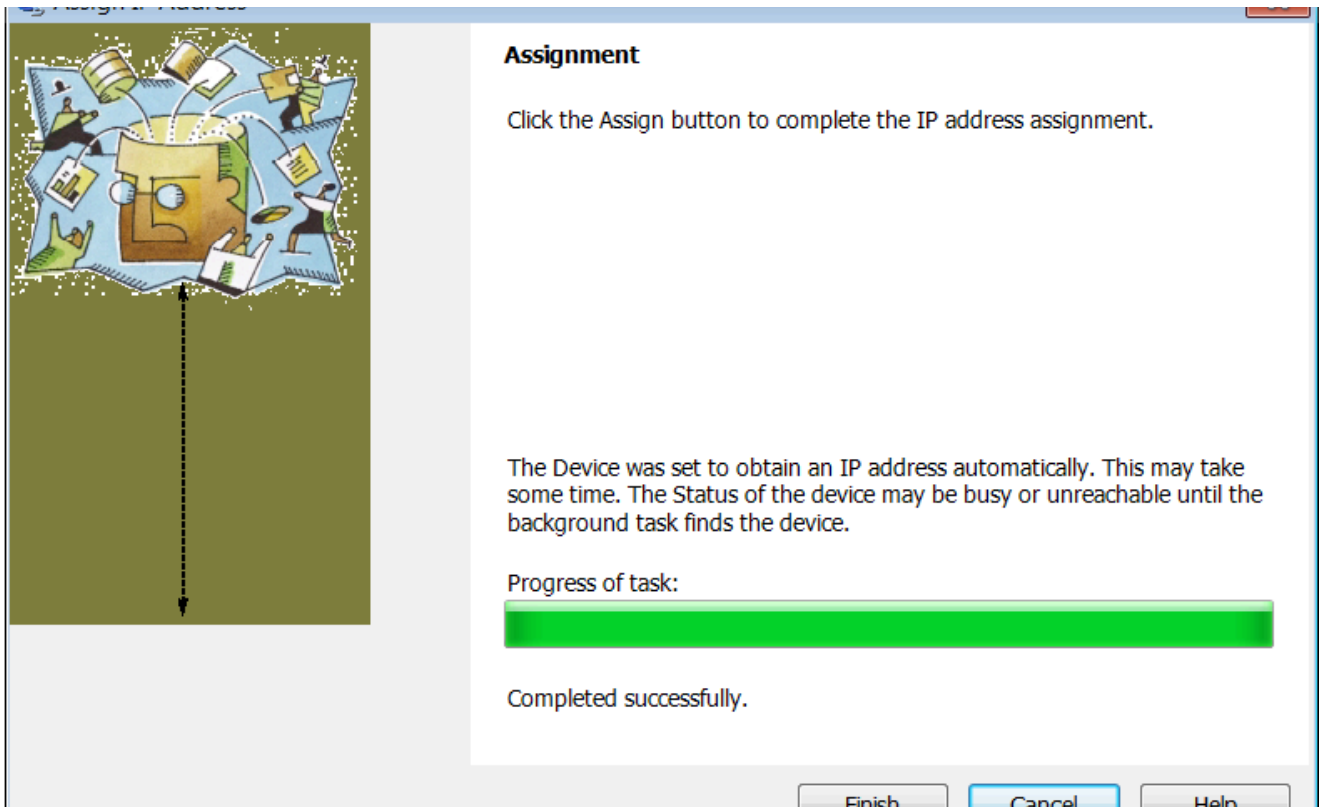
Choose whether to let the LAN router to assign an IP address or whether to set a fixed one. If you are not familiar with IP address click the link to the tutorial. If you select a fixed address you will also need to provide the subnet and gateway IP address. The following assumes that the address is obtained automatically. Select Obtain Ip address automatically and then click Next.



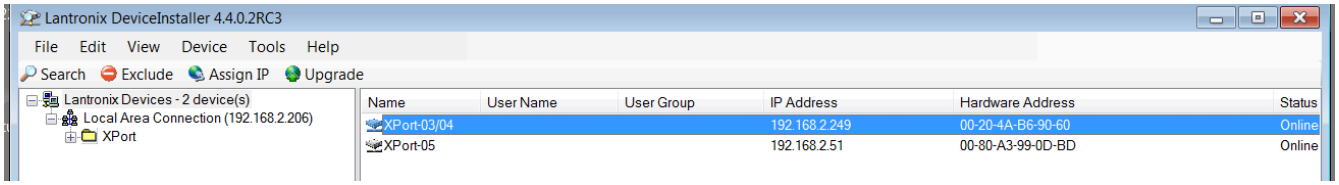
Select DHCP or any other protocol required and click Next.



Click Assign.

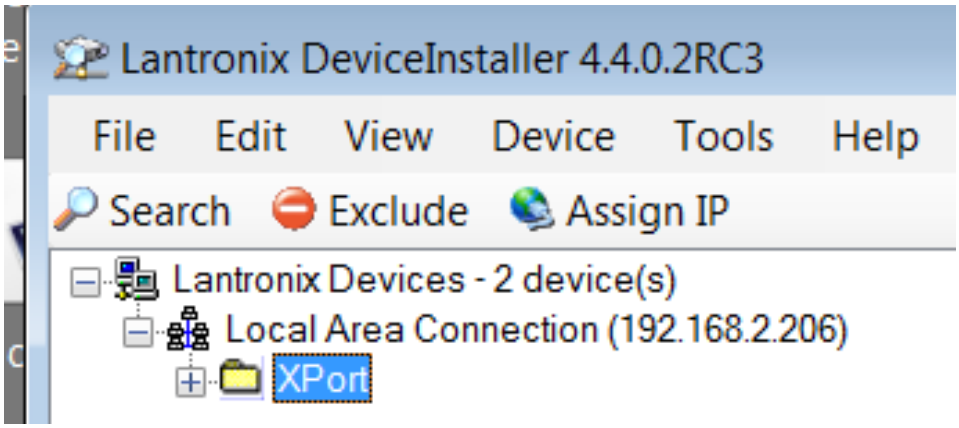


Click Finish.

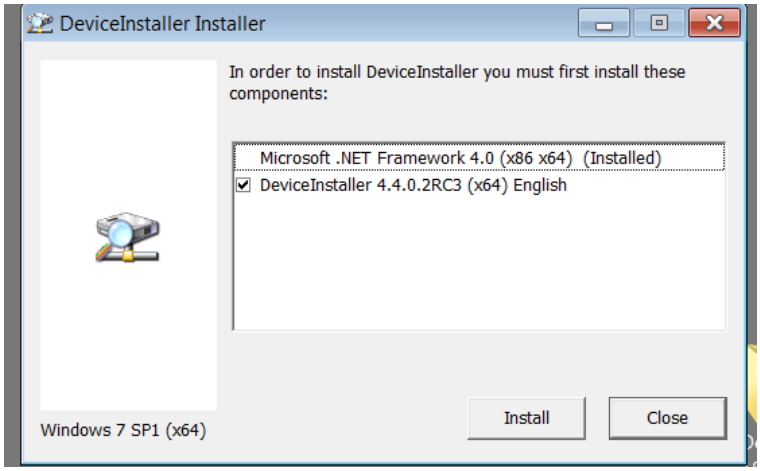


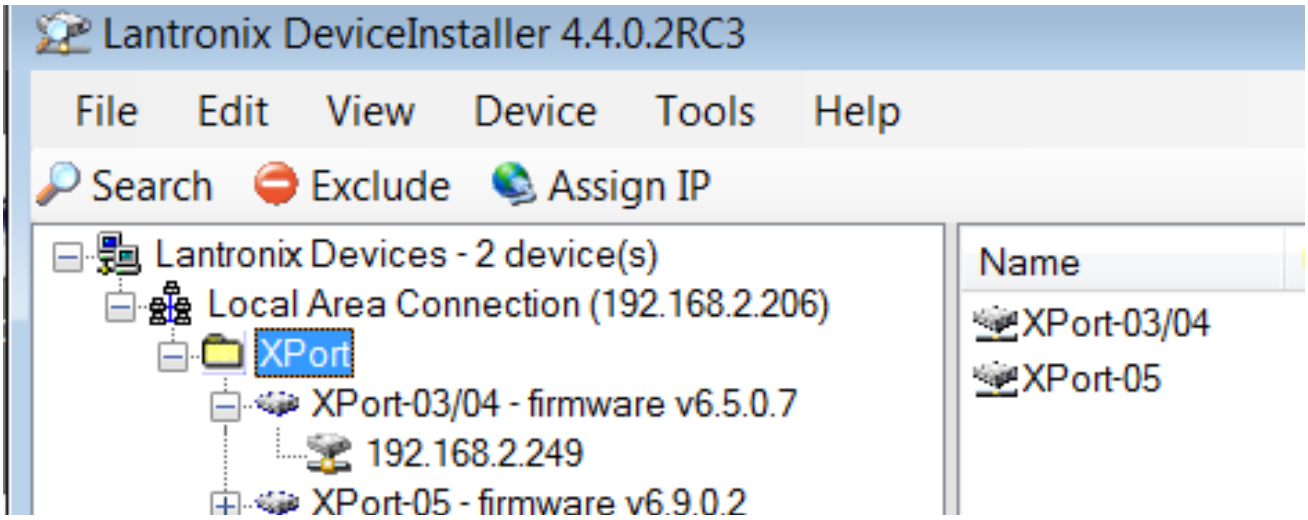
Make a note of the IP address.

The Xport is now set up for use with other communication software. The serial settings should not need to be changed but if they do follow the procedure below:

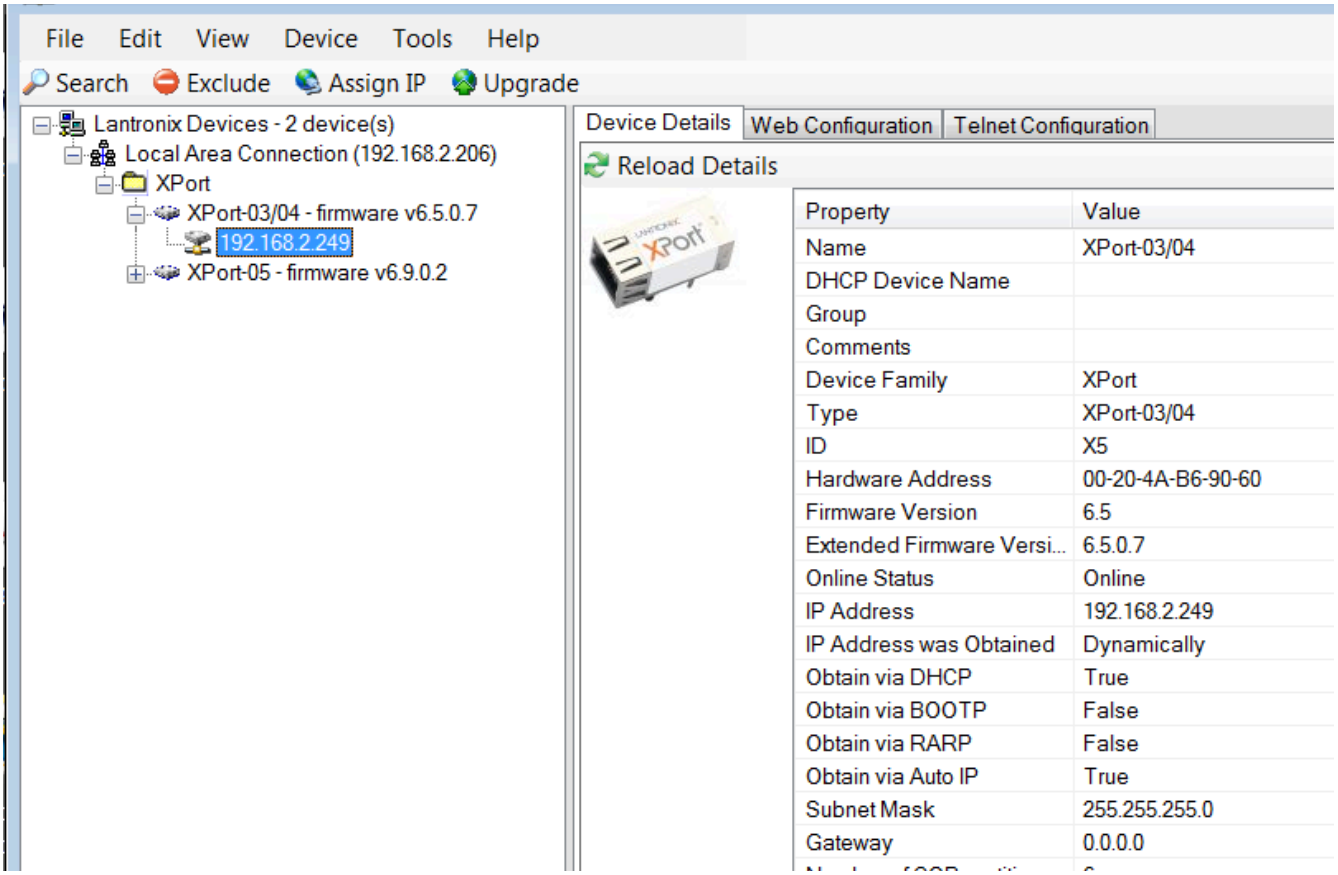


Click on the “+” sign

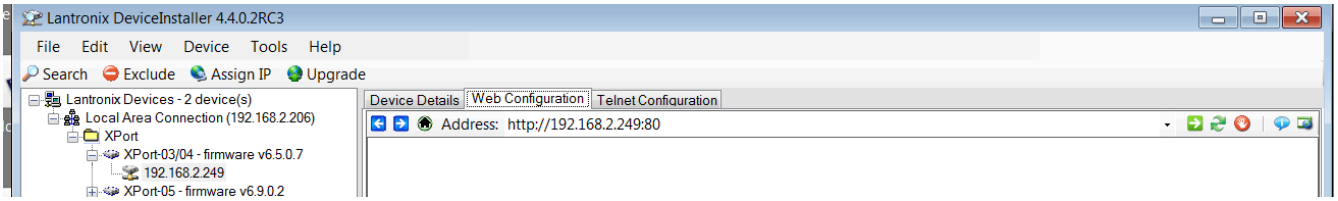




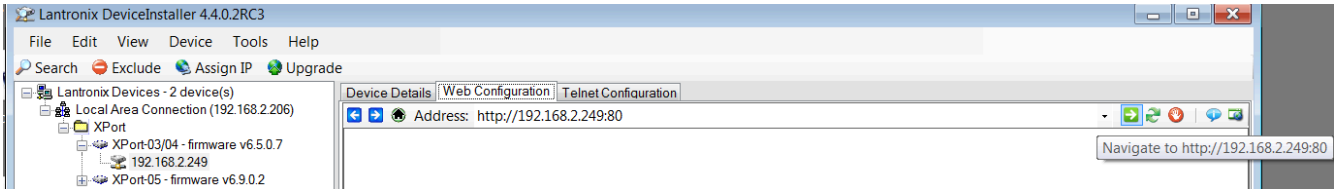
Then click on the IP address, here it is 192.168.2.249.



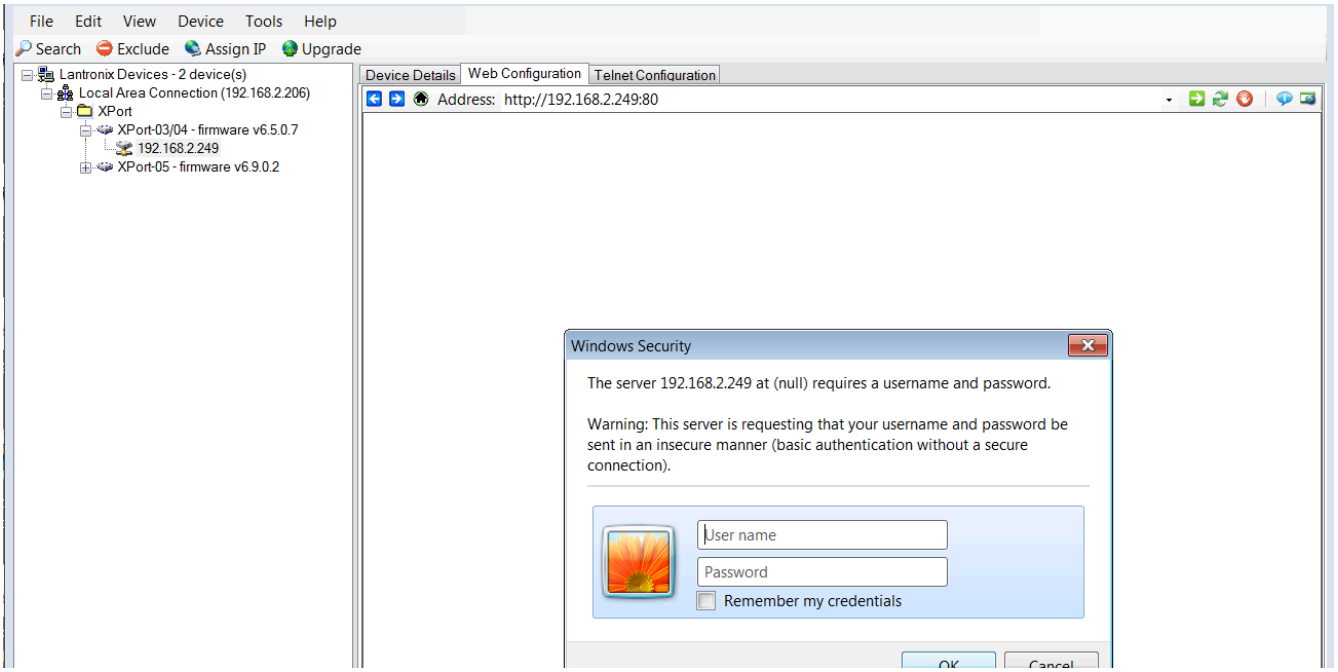
Click on Web Configuration



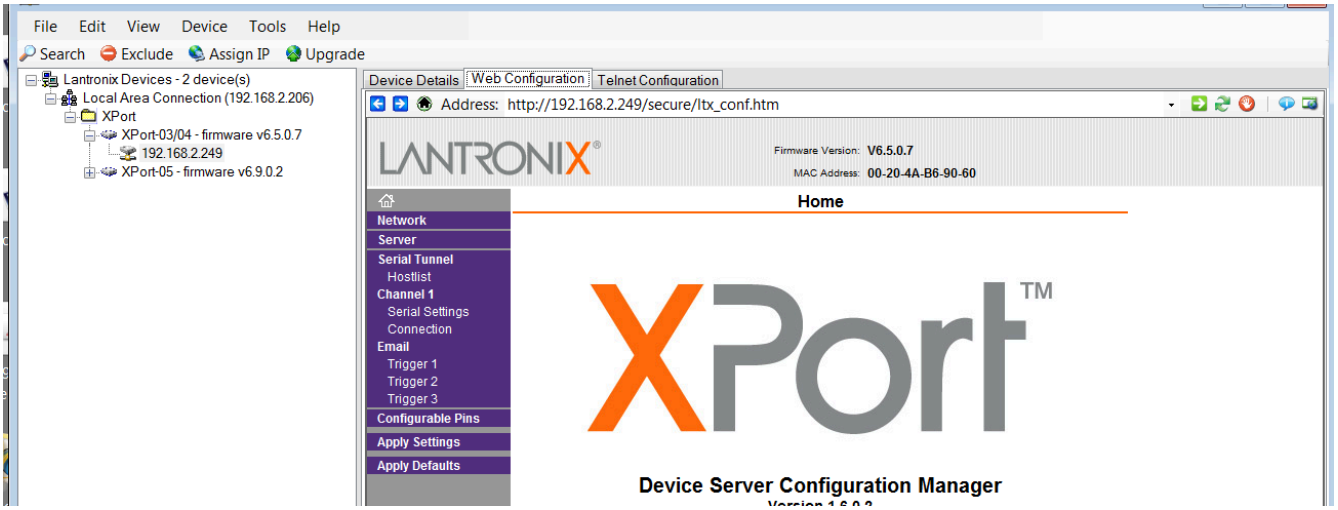
Click on the green arrow pointing to the right and select Navigate to http: etc.



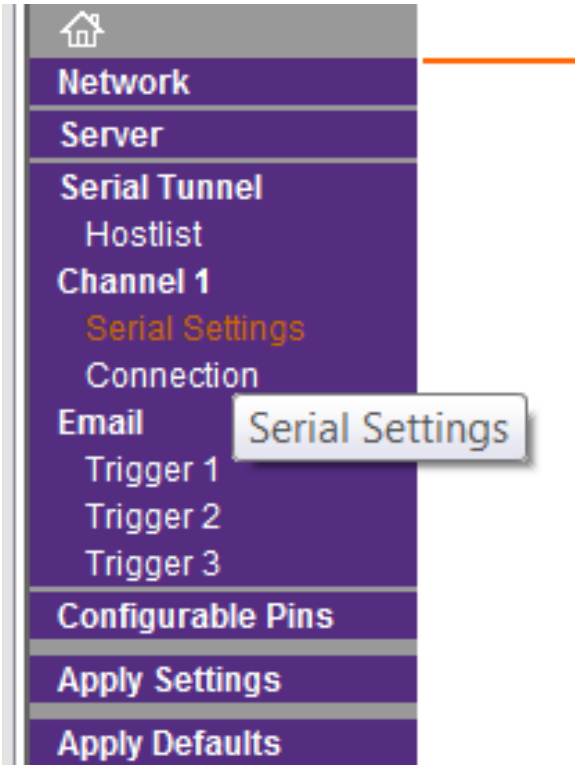
The following should appear:



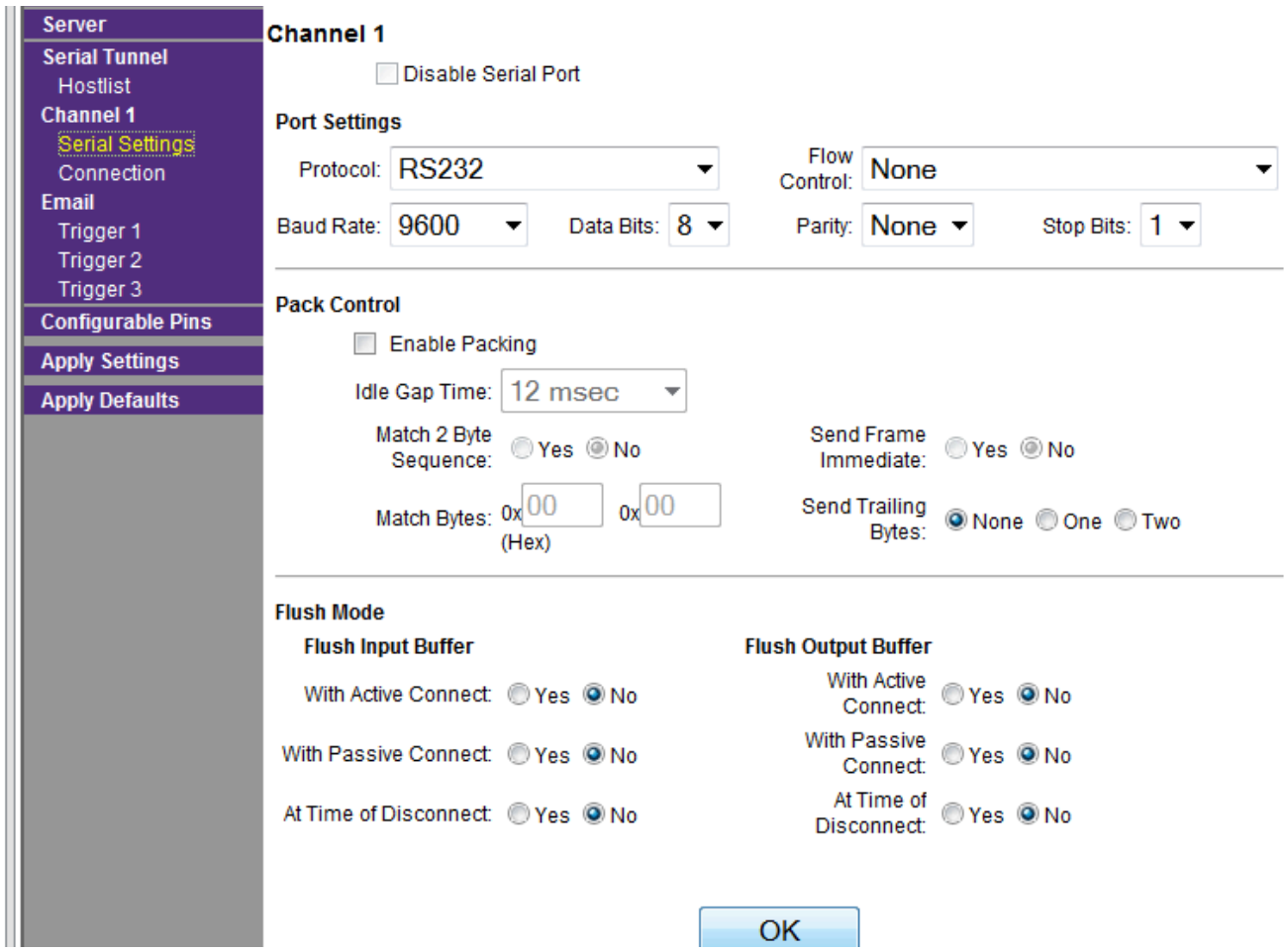
Leaving the entries blank, click on OK.



Click on Serial Settings:

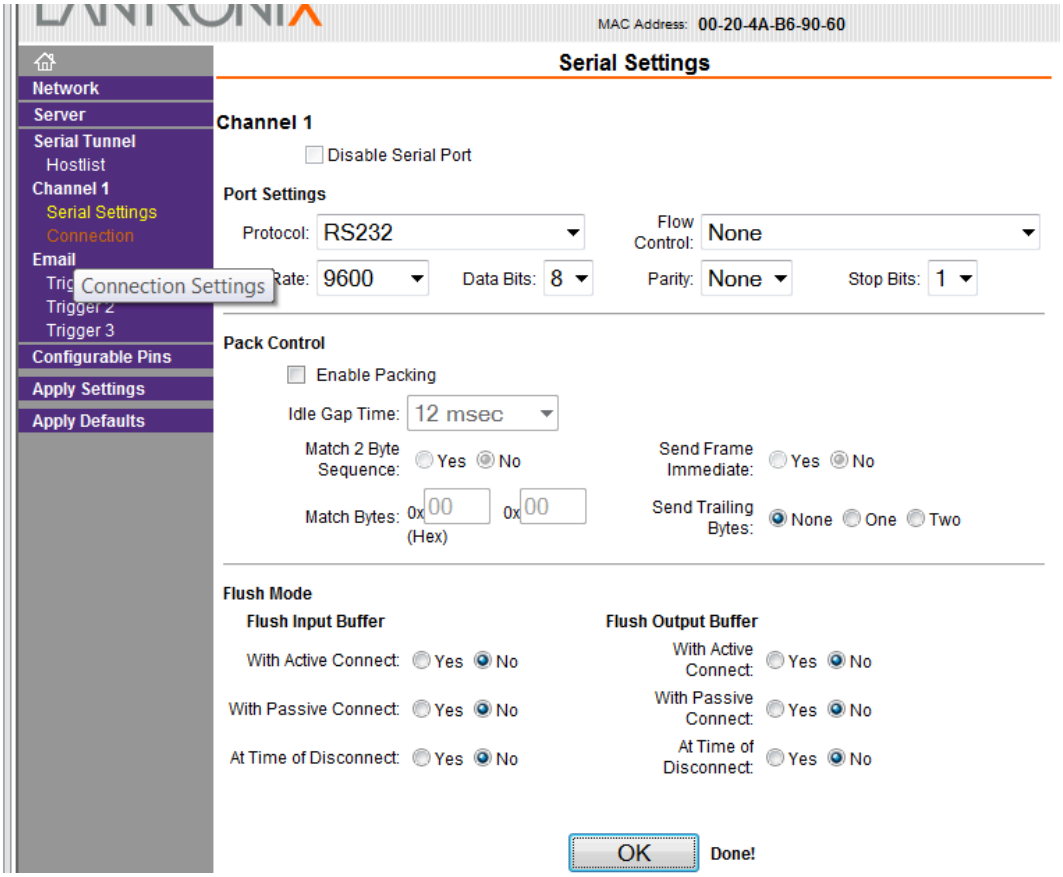


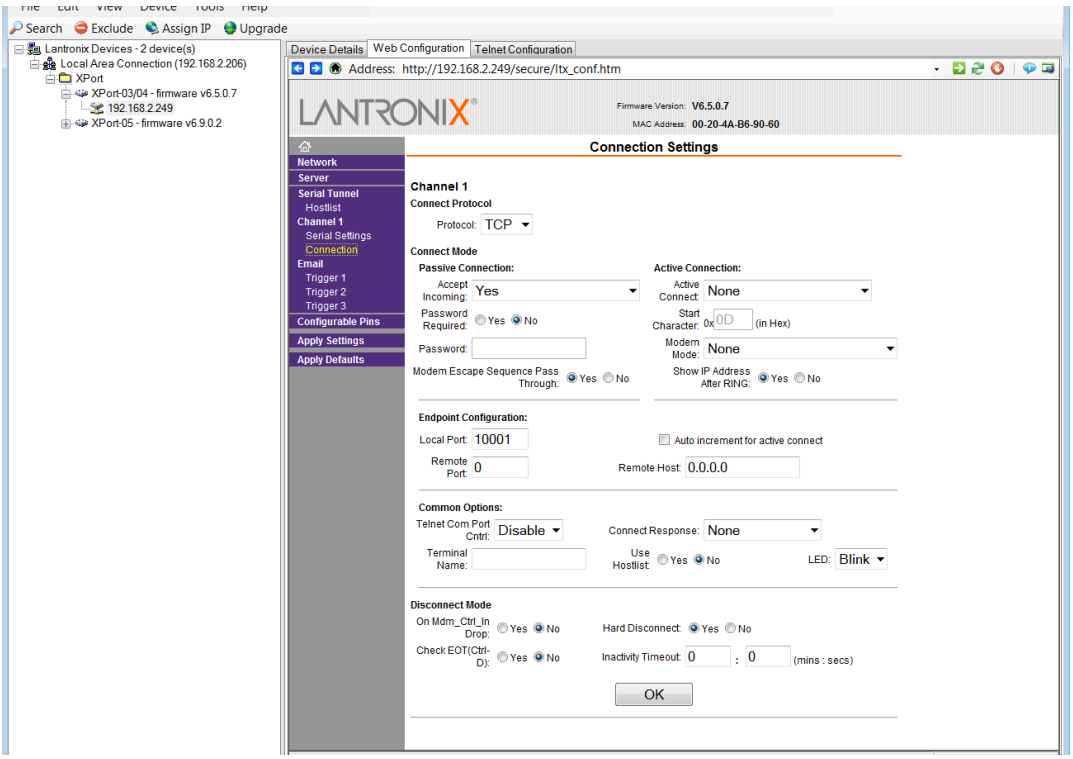
The following will appear:



Check that the options are as indicated, particularly the port settings. Click OK

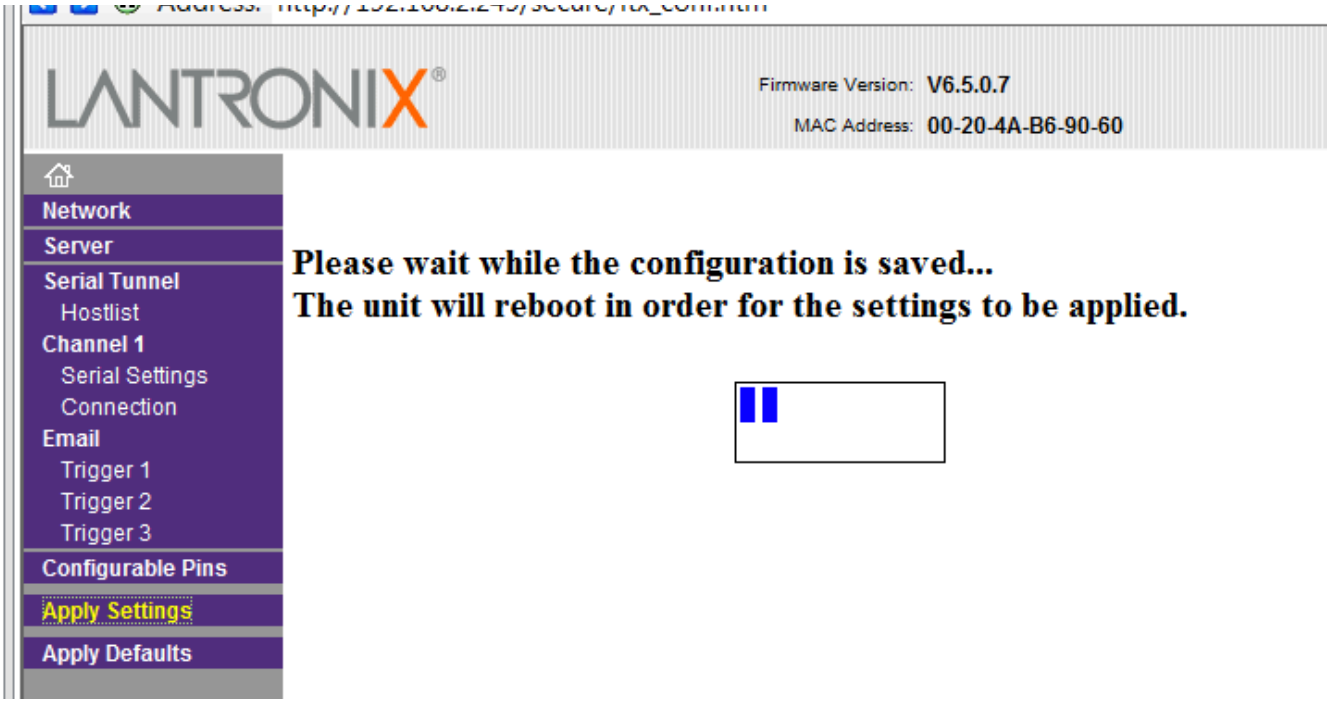
Click on Connection.

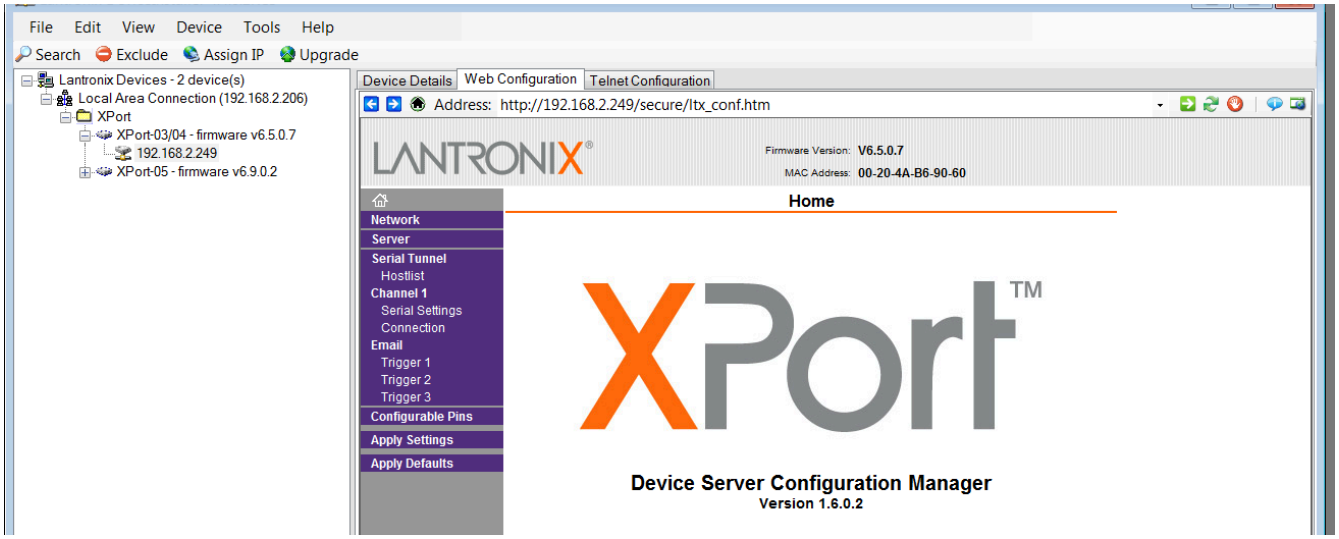




Check that the options are correct, particularly the port number and click OK.

The click Apply Settings.





This completes the Xport Set up.

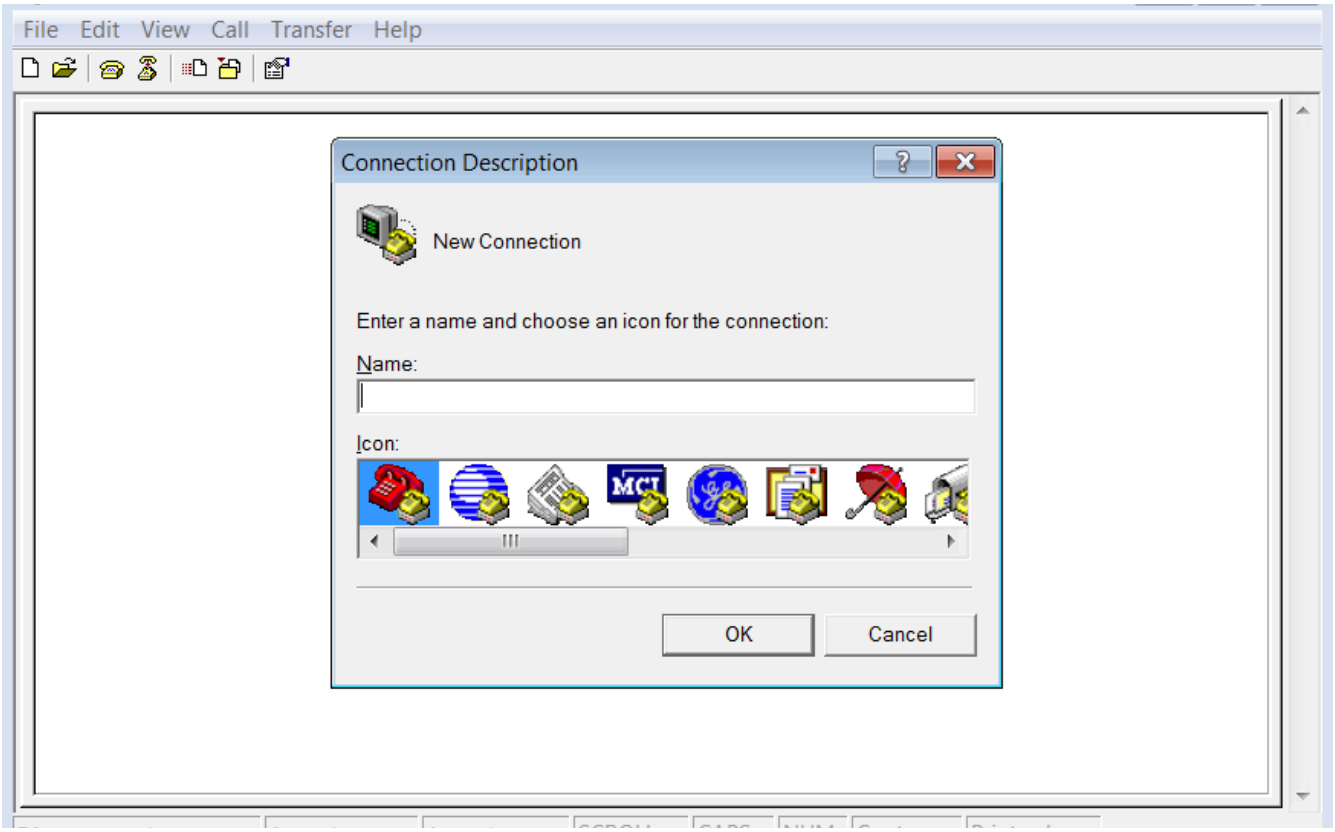
11. EXAMPLE OF A HYPERTERMINAL SESSION

11.1 INTRODUCTION

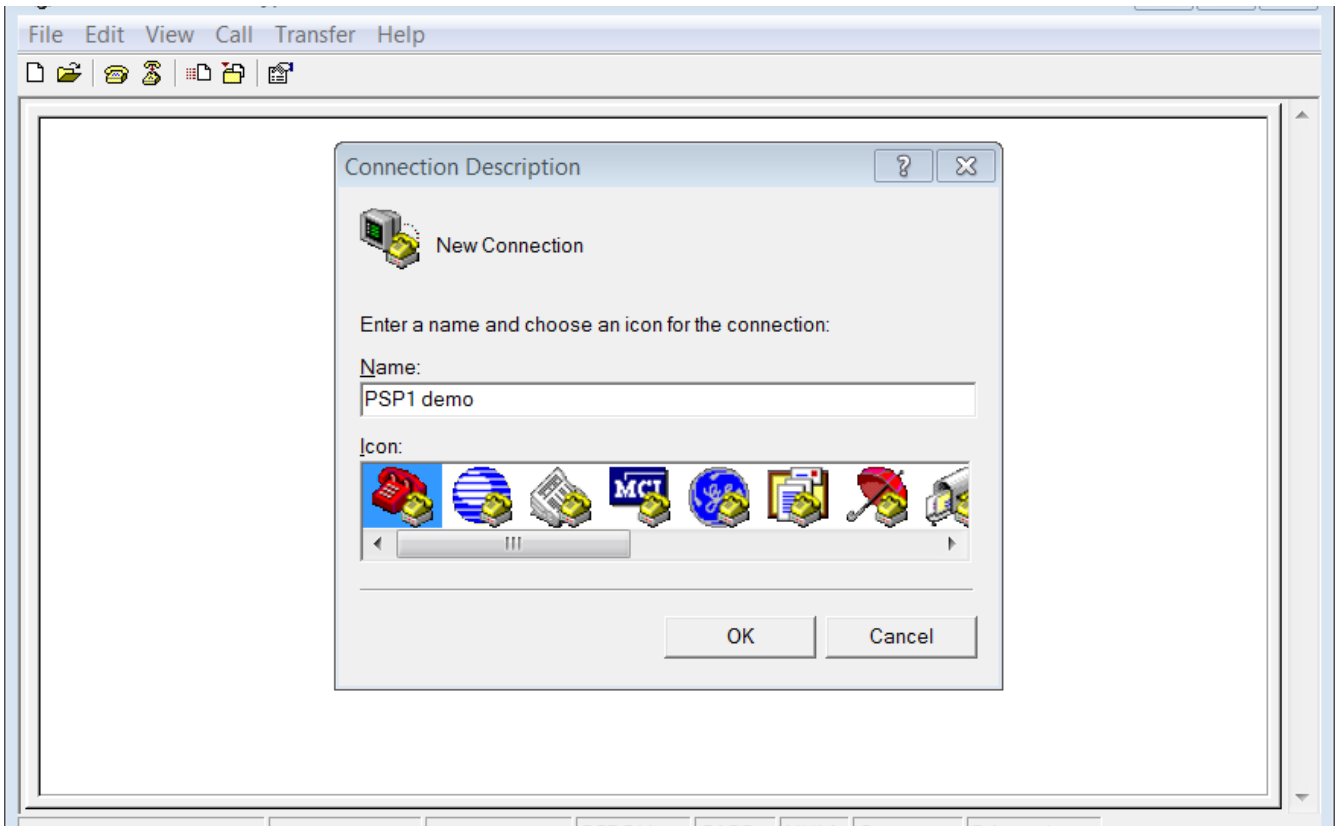
Hyperterminal is one of many terminal emulators that can talk to the PSP1. It is readily available from https://www.hilgraeve.com/hyperterminal-trial/

11.2 CONFIGURING HYPERTERMINAL

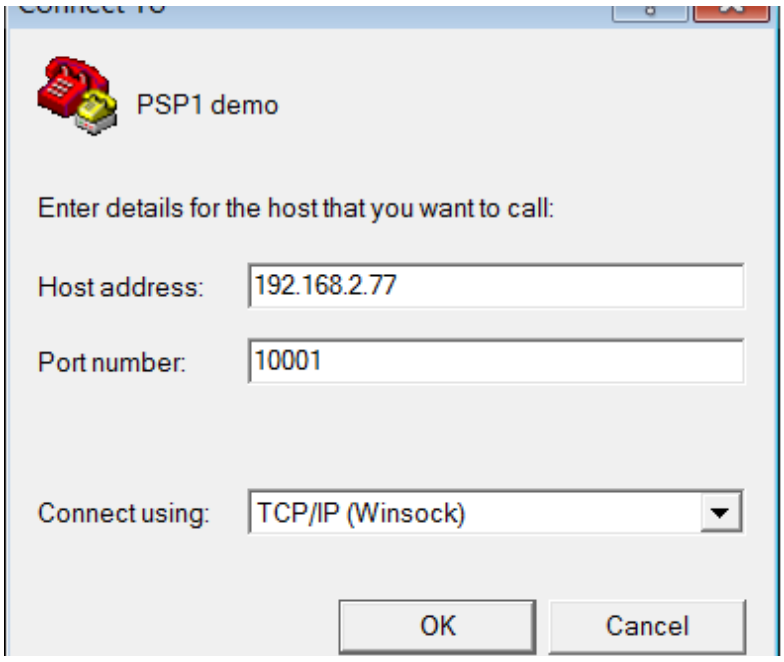
Launch Hyper terminal

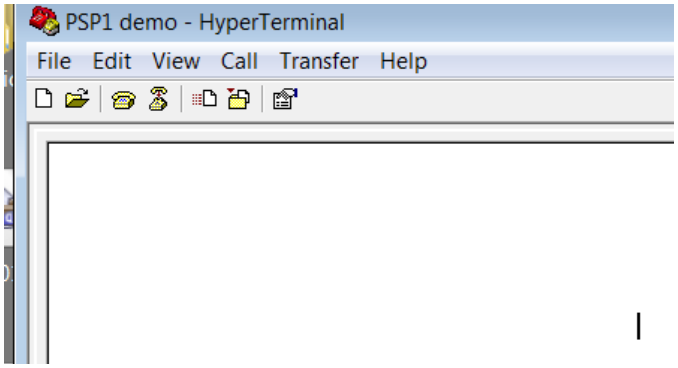


Enter a connection name to identify this connection.



Click OK, then fill in the IP address that was set with Device Installer and set the Port Number to 10001. The connect Using should be set as shown. Click OK

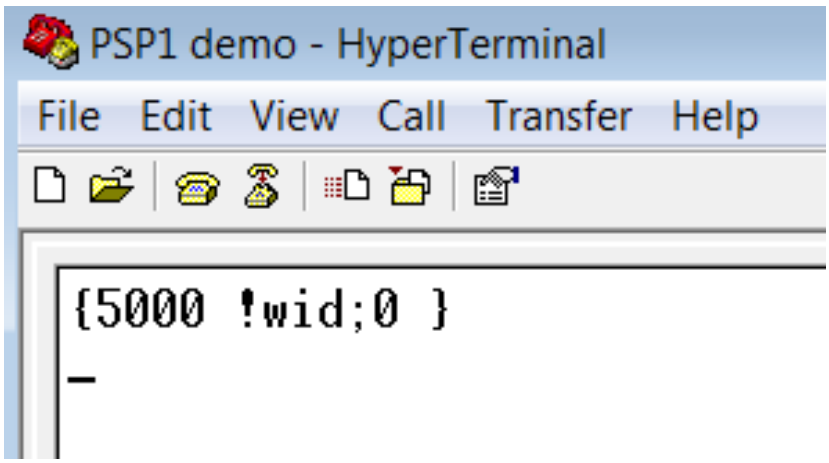




The PSP1 will not respond until a legal command is entered.

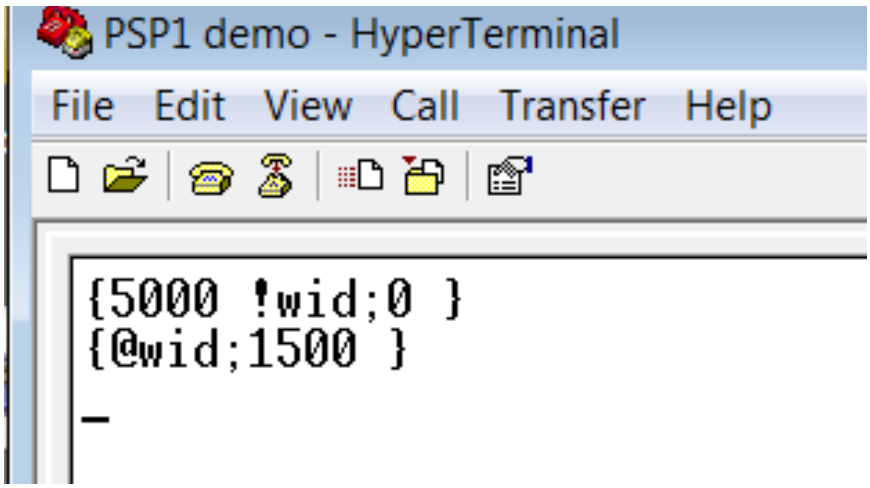
Also it will not echo types characters, but will respond when a legal command is received.

E.g. 5000 !wid to set the pulse width to 5000 ps.

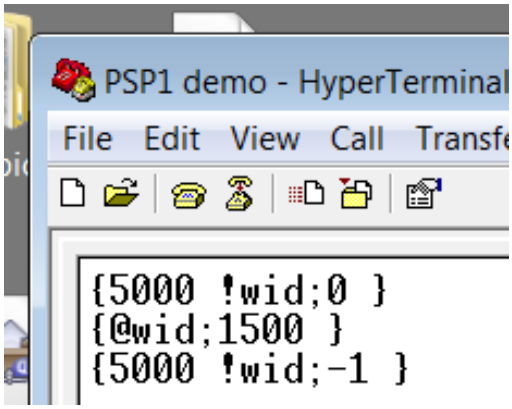


Note that this has responded with a “0” after the command. This implies that the command was not accepted. This is because the PSP1 is set to Local Mode.

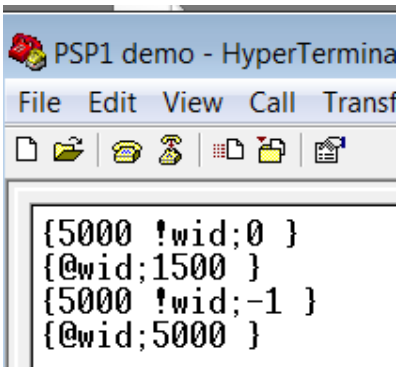
In local mode the PSP1 can be monitored, e.g. try @wid to find what width the pulse width is set to.



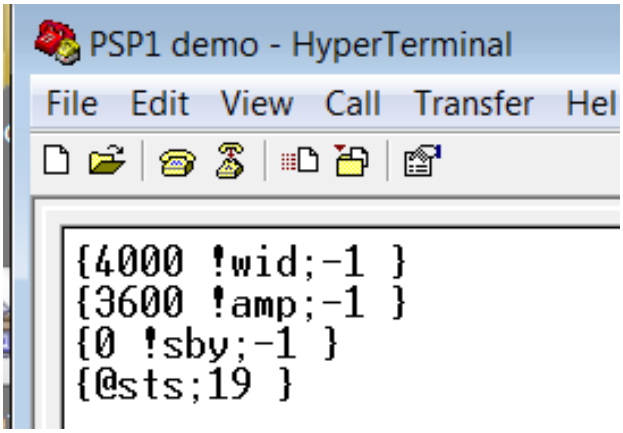
to change the width to 5000 ps first switch the PSP1 to Remote Mode on the front panel, then try again.



Note this time the response includes a -1, this means that the command was accepted. To check, read the width again.



The following might be a suitable initial set up command sequence.



This sets the width to 4000ps, the amplitude to 3600 volts, and takes the unit out of standby. The status is then interrogated.

In local mode the various settings may be saved so that the unit may boot up in run mode.

Other terminal programmes may well work just as well. Remember to set them up as per Hyperterminal.

12. USING THE PULSER WITH A POCKELS CELL

The PSP1 is designed to be used with a through terminated pockels cell. Such devices are available from Fast Pulse Technology (USA) and Leysop (UK). Linos cells may also be available.

In a through termination configuration the crystal of the cell is placed between the live and ground of a transmission line structure. The pulse propagates along the transmission line and charges and discharges the crystal as it passes. The transmission line is then terminated with 50 Ω (its characteristic impedance) to stop pulses being reflected back to the cell. Note that the pulse is not absorbed at the cell and in a perfect world could be re-used for something else. In practice it can typically be re-used once in a second cell. This can be useful for obtaining improved extinction ratios but note that light travels faster through the cells than the electrical pulse does through the cabling, so the light will have to be delayed (with optical folds) to arrive at the second cell at the right time. Another application would be to use a second cell in a second beam line to obtain two highly synchronised pulses.

If a terminator is not fitted the pulse will reflect at the end of the cable from the output of the cell and return to the cell after a round trip. This can be useful to obtain a second pulse at a fixed time after the first. However, note that the pulse will then pass to the pulser where some will be reflected again. This will arrive at the cell and turn it on (partially) once more. With judicious use of cable lengths and incident laser pulse lengths, this can be a simple 2 pulse system

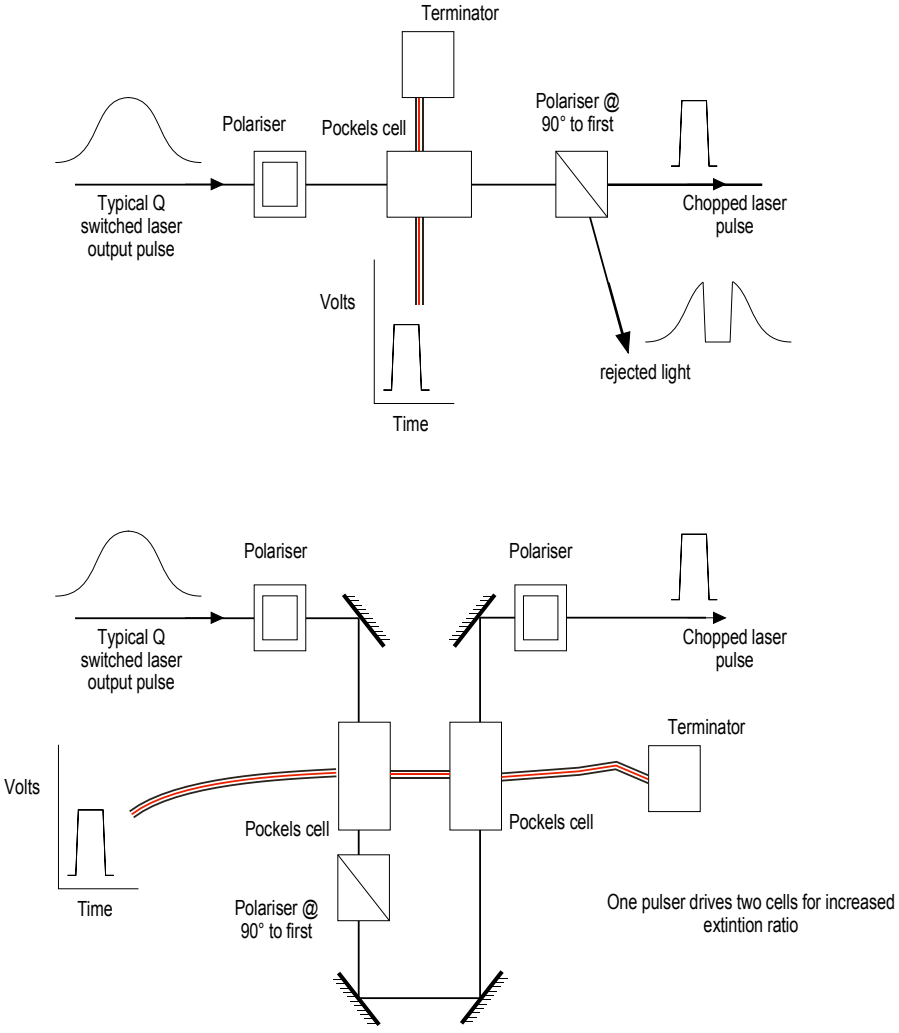


Figure 29 Some typical arrangements of the pockels cell.

13. POCKELS CELL SETUP AND ALIGNMENT

NOTES ON THE SETTING UP AND ALIGNMENT OF POCKELS CELLS. BASED UPON A FAST PULSE TECHNOLOGY USER MANUAL OF 1991.

This procedure is applicable to all modulators and Q-switches both transverse and longitudinal mode, fabricated with KDP, KD*P, ADP, AD*P and similar single axis crystals.

FastPulse Technology type Q-switches are supplied with a marker on one of the stainless steel aperture plates or the outer housing to indicate the polarisation plane of the incoming beam. In some models, the connector or terminals serve as the marker. The input plane of polarisation must be aligned with the marker (or rotated 90° from it) for correct operation. If the marker is missing, then the appropriate directions must be determined by viewing the side of the crystal inside of the device through the clear aperture in a bright light. All crystals have a straight line marked on the barrel of crystal (the crystal is cylindrical) . The input plane of polarisation must be parallel to or perpendicular to the line on the crystal.

CAUTION: Protective laser goggles should be worn during the following alignment procedures.

It is strongly recommended that initial alignment of all pockels cells be done with a low power (0.5 to 2 mW) HeNe laser (or similar) to assist in visualizing beam position. We do not recommend attempting this alignment procedure with an IR laser unless the power can be throttled to 1 or 2 mW and an IR viewer is available. Great care must be taken to insure that the laser beam does not impinge on the external aperture stops or the crystal electrodes. At higher, operating power levels, it is possible to damage the device if the beam strikes the internal electrodes thereby causing thermal damage.

Unless there are strict restraints on space and positioning devices, the device should be mounted in a gimbal that provides accurate and stable pitch and azimuth adjustments. Some means for obtaining horizontal and vertical translation is usually necessary to centre the device on the input laser beam.

If the Pockels cell is being used in a laser cavity, it is recommended that the alignment be done with a HeNe laser having its beam coaxial with the laser rod. This coaxial condition should be confirmed by operating the laser with the HeNe to insure that the beams are indeed coaxial and the HeNe beam centred. If this cannot be done conveniently, then the HeNe beam should be retro-reflected off the nearest laser rod surface back onto itself. The Q- switch can then be placed in the optical train.

It is essential that the laser beam pass through the Pockels cell entrance and exit apertures without vignetting. The beam should be centred in both apertures with at least 0.5 mm clearance all around.

The following procedure has been shown to be most reliable for obtaining optimum alignment. The object is to centre the laser beam in the device apertures and then generate an optical pattern which accurately locates the optical axis of the crystal with respect to the laser beam.

The procedure will probably require several adjustments of pitch, azimuth and translation to optimise the alignment but it will provide positive and visual confirmation of the alignment. The basic alignment configuration is shown in Figure 1.

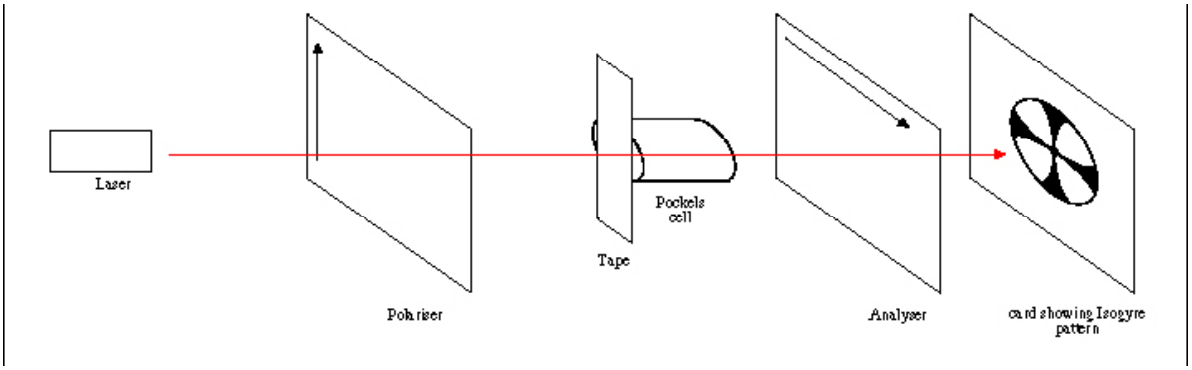


Figure 30 Modulator Between Crossed Polarisers

1. Remove any polarisers used to polarise the beam entering the device. If the laser is already polarised it does not effect this procedure, however, the plane of polarisation must be aligned (eyeball accuracy is usually good enough) with the marks or terminals on the Pockels cell. Position the device in the HeNe laser beam so that the beam is centred and passes through the apertures without touching the aperture edges.

2 Place a light coloured matt finish card in the path of the beam at a distance of between 1 to 2 feet from the exit aperture of the Pockels cell. If the device is located within a laser cavity, the card should be placed against the laser rod holder and a small hole made in the card to locate the centre of the rod aperture. Mark the beam location on the card with a circle or dot and leave the card in place.

3 Place the input polariser in the beam with its polarising axis aligned to the mark on the Pockels cell aperture plate. If the laser rod produces a polarized beam (as with a ruby rod) the polariser must be aligned to the rod polarisation direction. It is assumed that the polariser does not deviate the beam angularly.

Place the output polariser (analyser) at the output side of the device and insure that its polarising axis is rotated 90° from that of the input polariser.

4. Place a strip of frosted adhesive tape (Scotch Magic Mending Tape No. 810 or similar material) over the device entrance aperture. Gently press the tape in place but do not allow it to touch the window surface. A lightly frosted glass plate will provide the same scattering but must be nearly in contact with the entrance aperture.

The actual measurement is usually made in a darkened room after basic alignment and adjustments are completed. In most instances, the pattern to be viewed will be difficult to see in normal room lighting.

When the HeNe beam propagates through the optical train, a pattern, or some part of it, will be projected on the card. This is called an isogyre pattern and is illustrated in Figure 31 and Figure 32.

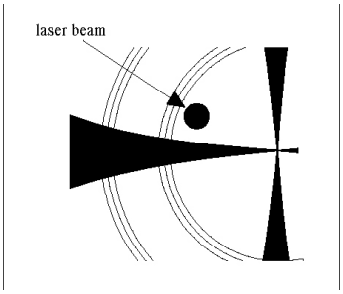


Figure 31 Isogyre Pattern Off Centre

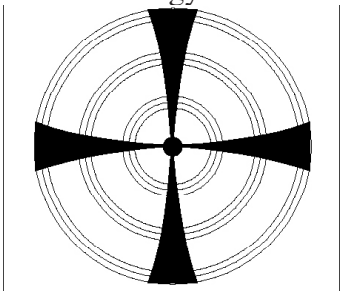


Figure 32 Isogyre Pattern Centred

If the optic axis of the crystal is not parallel to the path of the laser beam, the isogyre pattern will be off-centre and the device must be moved in pitch and azimuth. When the isogyre is centred over the circle or dot or hole in the card this indicates that the device is well aligned.

After making any positional adjustments, the beam position relative to the device aperture stops must be confirmed. The beam must still pass through both apertures without vignetting and with adequate clearance. If it does not, employ horizontal and vertical translation until clearance is confirmed. If the figure is not in the form of a cross, then the polarisers are not rotationally aligned to the faceplate mark or at 90° to each other.

Once the cross of the isogyre is centred, the polarisers can be rotated slightly to maximize the darkness of the centre of the cross. After this is done, the device is not only aligned with the laser beam, it is also nulled with respect to the crossed polarisers for best contrast ratio and it is ready for operation.

The extra polariser, if one was used, may be removed.

13.1 OPERATION *Cautionary Note*

Application of DC voltage to some Pockels cell Q-switches and light modulators for long periods of time may result in permanent damage to the electro-optic crystal(s).

Devices fabricated from KDP, KD*P, ADP and AD*P, in the presence of continuous (DC) high electric fields, are subject to an effect that is not well understood but is apparently electrolytic in nature. With long term application of high voltage, the polished optical surfaces become fogged and etched. All crystal surfaces, including those under the conductive electrodes can be similarly effected. This may result in discontinuities between the crystal and electrode conductors. Application of AC electric fields, even those with a net DC value, appear to minimize the effect and extend lifetimes dramatically.

The effect is independent of the electrode materials used and has been documented for gold, indium, silver and transparent conductive oxide electrode materials. One manufacturer reports that a sustained voltage of 50 volts will eventually have an effect on the crystal. Use of inert index matching fluids does not mitigate the damage. The effect appears with or without the use of fluid.

We recommend that DC voltage not be applied to a Pockels cell when the laser system in which it is employed is not actively in use. When the system is in a stand-by condition, care must be taken to turn off the DC voltage to the Pockels cell. When this procedure is followed, operational lifetimes of more than 5 years is not unusual and where this "voltage off" safeguard has been observed, many Fastpulse/ Lasermetrics Q-switches have been in active use for more than 15 years

13.2 REFERENCES

R. Goldstein, Electro-Optic Devices in Review", Lasers & Applications, April, 1986