Kentech Instruments Ltd.

PBG3-D-V High Voltage Pulse Generator
Serial No. J13*****

Last modified

6-12-2013

PLEASE READ THIS MANUAL CAREFULLY BEFORE USING THE

PULSE GENERATOR.

Blue coloured text contains hyperlinks. Click on them to access the referenced link

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1 DISCLAIMER

This equipment contains high voltage power supplies. Although the current supply capacity is only moderate, 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.

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2 INTRODUCTION

[redacted]ual describes the operation and use of pulse generator model PBG3-D-V, serial number [redacted]

2.1 SAFETY 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 inside this pulse generator when the unit is operating.

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.

2.2 CLEANING

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

2.3 SPECIFICATIONS

Number of channels	1
Maximum output pulse voltage	>12kV into 50Ω.
Pulse shape	Fast rise ~100ps and slow decay ~3ns.
Polarity	Positive
Output voltage adjustment range	down to 21% of maximum. There are 4 ranges and a fine control. There is some overlap between the switched ranges and the fine control.
Trigger delay	~44.2ns in “direct“ trigger mode. ~51.1ns at zero delay in delayed trigger mode.
Jitter	<10ps Standard Deviation in “Direct” mode
Output pulse trigger delay range	~100 ns in 10ns steps + fine delay.
Maximum repetition rate	1kHz gate pulse
Internal rate generator	0.1Hz to 1kHz
External trigger requirements	5 volts into 50Ω rising in < 5ns for optimum jitter.
Pre-trigger output	9V into 50Ω, precedes the main output by the delay set.
Controls	
Mode	Sets one of the following modes:-

	Single shot (delay active). Internal trigger 0.1-1Hz (delay active). Internal trigger 1-10Hz (delay active). Internal trigger 10-100Hz (delay active). Internal trigger 100-1000Hz (delay active). External trigger (delay active) “Delay”. External trigger (delay inactive) “Direct”.
Fine rate	Varies internal rate by a ratio of 10:1.
Coarse delay	Sets internal delay in 10ns steps, up to 100ns.
Fine delay	Single turn potentiometer gives approx. 12ns adjustment.
Single shot button	Depressing this button cause a single trigger when single shot mode selected.
Coarse amplitude	Sets amplitude in steps to 100, 75, 50 or 25%
Fine amplitude	Single turn potentiometer gives ~60 to 100% adjustment of the coarse amplitude voltage setting.
Power	Switches AC power in the pulser.
Input power range	100 to 240 VAC 50 to 60Hz at <5 amps.

Indicators

Power	Shows that AC power is applied and the unit is switched on.
Triggered	Illuminates when the unit is triggered.

Dimensions

width	19 inch rack mount, 482 mm over handles,
depth	405mm into 19 inch rack, 445 mm over handles,
height	128.5 mm (3U)
weight	7.5 kg

Connectors

Power inlet	IEC
Pulse output	HN female
Trigger input	BNC
Pre-trigger output	BNC

2.4 ENVIRONMENTAL ISSUES

2.4.1 STORAGE

The unit should be stored in an environment within the following parameters:

Temperature	between 10°C and 40°C
Humidity	< 60% on condensing
Pressure	40 to 120 kPa
Gas type	Air or nitrogen

2.4.2 USE

The unit should be used in an environment within the following parameters:

Temperature	between 10°C and 30°C
Humidity	< 60% on condensing
Pressure	80 to 120 kPa
Gas type	Air or nitrogen

2.5 SHIPPING

The unit should be sealed in a polythene , or similar, bag at a low humidity. The unit can then be shipped by normal means providing the packaging provides suitable mechanical protection. Shipping by air freight should be in pressurised holds. If this is not possible then the storage temperature and humidity parameters should be observed.

3 OVERALL DESCRIPTION AND USE

3.1 INTRODUCTION

The PBG3 series of pulse generators use avalanche transistor technology to deliver fast high voltage pulses. Many (~500) transistors are used in series parallel arrays to deliver the pulse. Although the output of this unit is >12kV, internally there are no DC voltages above 4kV.

For units fitted with a rate generator and delay option, the trigger pulse is first fed through a circuit that delays the trigger and amplifies it to a level suitable to drive the first avalanche stage. After that the pulse is successively amplified and split several ways to drive parallel arrays of pulse generator. Each array can generate ~6kV into 50 Ω. Four such arrays are then summed to deliver 12kV into 50 Ω.

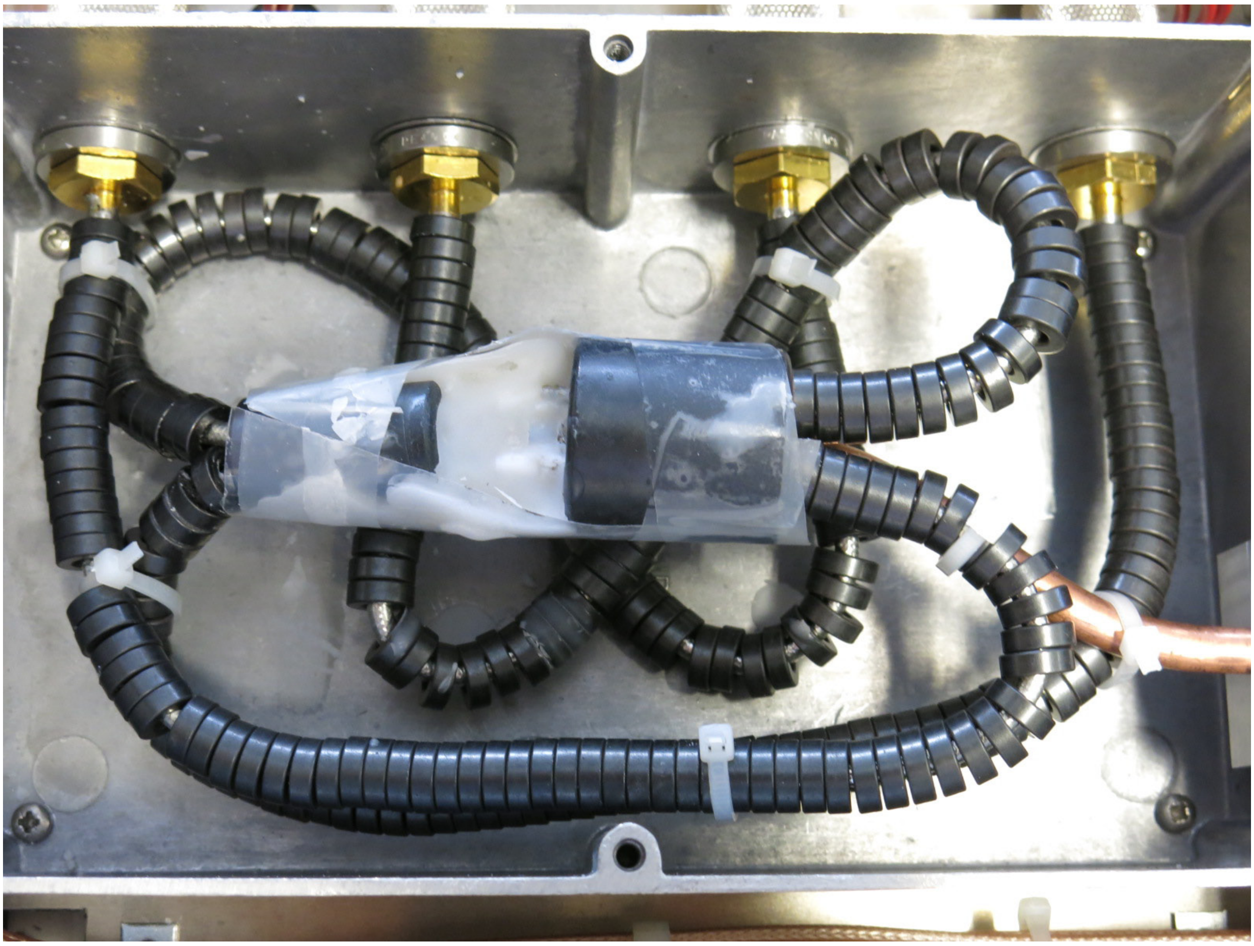


Figure 1 The 4 into 1 output combiner

The rate generator allows the user to trigger externally directly into the pulser or to go via delays. In addition units with the "D" option can generate the trigger pulses internally. These are always routed through the delay section. In addition there is a single shot facility operated with a push button.

A pretrigger output is generated from the initial trigger pulse in all modes. In delayed modes the pretrigger will be generated before the delay section.

3.2 CONNECTIONS

The connections are simple, a single input to trigger the unit (for external triggering modes), a "pre-trigger" output that delivers a low voltage monitor pulse before the start of the delay section (even in non delayed modes) and the main output.

3.2.1 MAIN OUTPUT

The main output is an HN female connector. It is important that the unit is operated with a load connected, as the output connector may arc if not mated and this will erode the insulators.

The mating connector must be fully tightened down to ensure the centre pin makes good connection.

The thread on the HN connector should be lubricated fairly regularly, we recommend vacuum grease or some other non volatile lubricant. Without lubrication small particulates of brass can be eroded off the thread and contaminate the connector leading to a lower breakdown voltage.

Although this connector is being used way beyond its rated voltage, the pulse length is very short and generally these connectors perform very adequately.

3.3 CONTROLS

The controls allow the unit to operate in several modes, with or without delays and over a range of amplitudes. The specification 2.3 on page 4 lists these in detail.

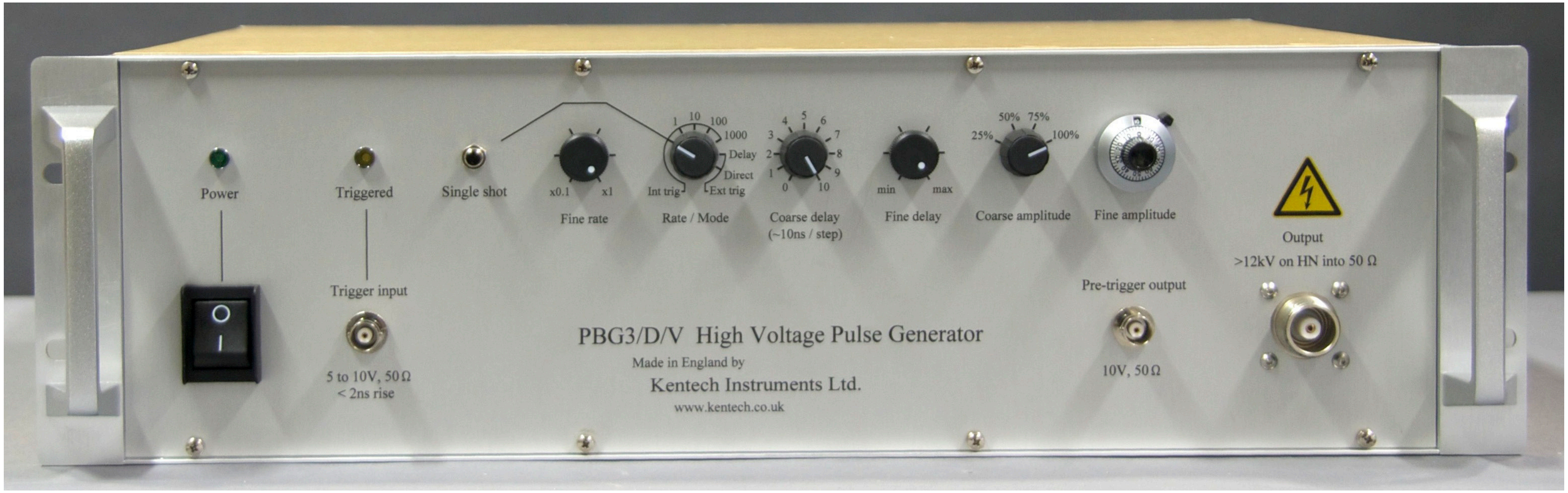


Figure 2 Front panel of the unit

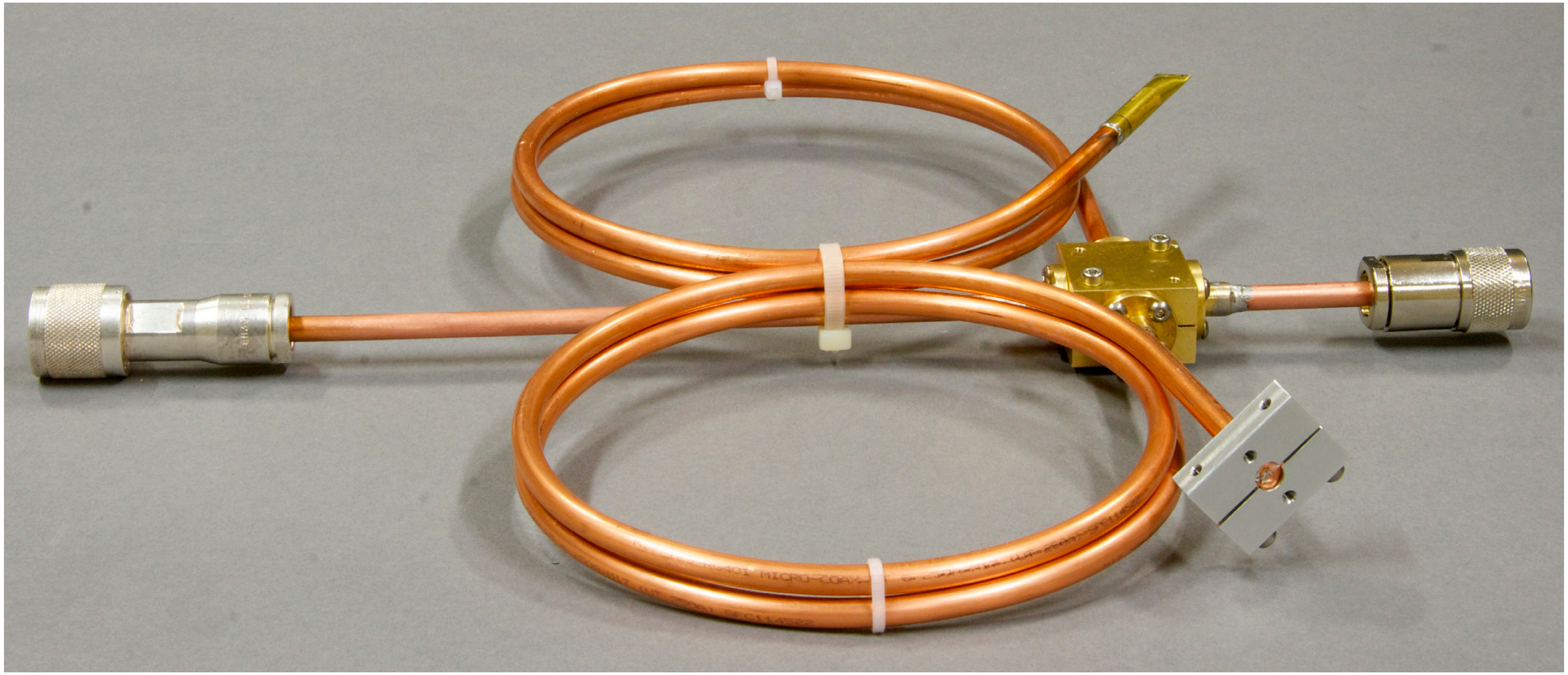


Figure 3 The Suicide “T”

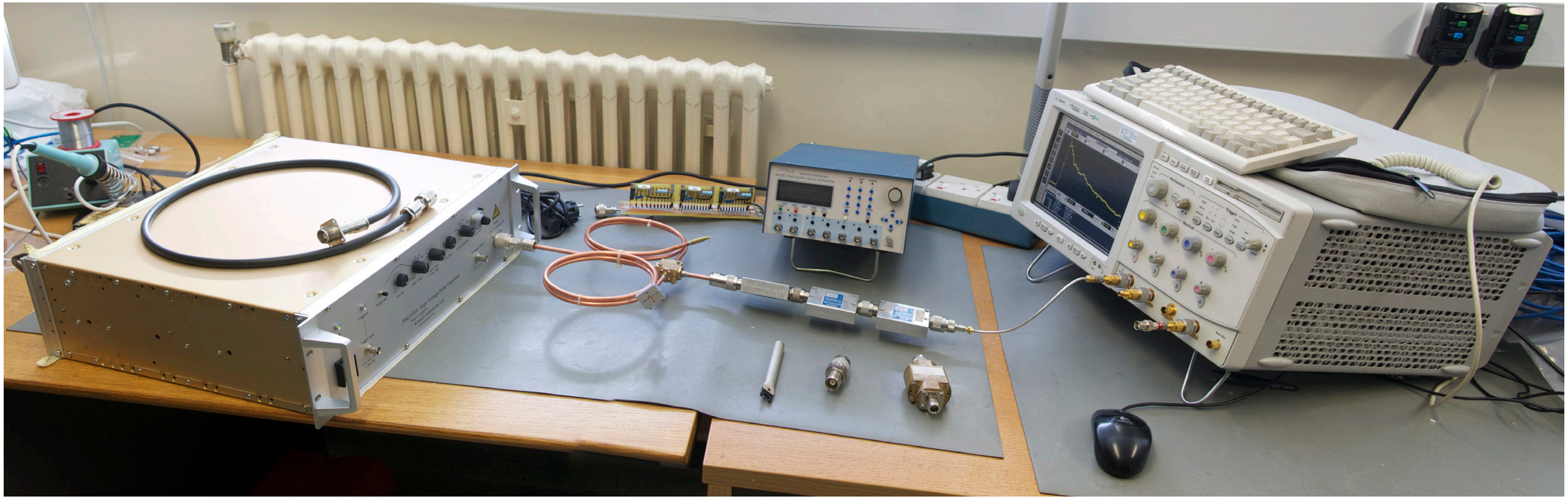


Figure 4 Test set up

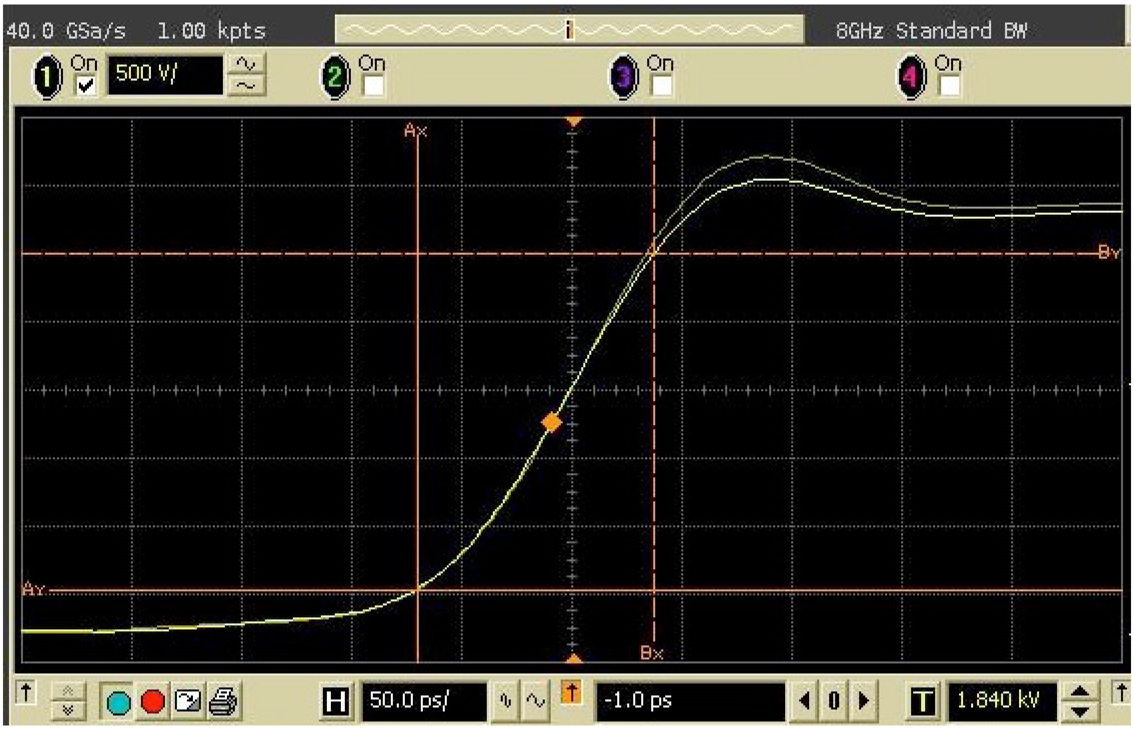


Figure 5 Effect of inserting a cable before the Suicide “T”
Maximum output with and without a 1m length of RG213 between the pulser output and the Suicide “T”

Figure 6 The long time history of the pulse at maximum amplitude.
This is with the extesnsion lead between the pulser and the Suicide “T”. The small negative spike at ~9.5 ns into the pulse is due to the lack of complete cancellation of the pulses in the two side arms of the Suicide “T”.

3.4 EQUIPMENT CAUTION

The >12kV pulse from this unit is capable of destroying most types of power attenuators and loads including most of the high pulse power types.

The pulser was characterised at the factory using the supplied x2 Kentech Suicide "T" attenuator followed by three x10 Barth 142-NMFP-20dB attenuators then one Radiall 20dB attenuator.

The unit will destroy the Barth 142 if no suicide "T" attenuator is used and data obtained before it fails will exhibit non linearities.

The output may be observed with a high bandwidth oscilloscope. This may either be a fast (>3GHz) direct access type or a sampling type.

3.4.1 REPETITION RATE

Barth 142 attenuators are rated at an average power of 2 watts. The average power coming from the pulser is about 14 watts at 1kHz. Although the Suicide "T" reduces the peak power by a factor of 4 it does not change the average power much) some energy is absorbed by the pulser but the rest it transmitted eventually). Consequently:

DO NOT RUN AT MAXIMUM RATE INTO THE TEST RIG FOR MORE THAN A SHORT PERIOD.

We have run the unit at 1kHz into a suitable load for extended periods during testing. The load used was an in house unit that we can easily repair should it become over heated.

3.5 CHARACTERISING THE PULSE OUTPUT

The output is rated at >12kV. Often these unit will achieve 14kV. These voltages are too great for Barth type 142 attenuators, which are generally recognised as the best fast high voltage attenuator.

To overcome this we supply a "Suicide T" section. This consists of a cross of cables. The incident pulse is split four ways when it arrives at the cross. Half the voltage appears in each of the four arms (one arm is the incident arm). So the first transmitted pulse has half the amplitude. This is a completely passive mechanical split and so is insensitive to voltage (provided it does not break down). The Suicide "T" can be checked out at low voltage and it' DC breakdown voltage can be checked..

The pulses in the three arms (other than the output) reflect from the ends of the cables and come back to the cross point. One of the arms is terminated with an open circuit and one with a short circuit (installed after the breakdown voltage is established). These two reflections have equal and opposite amplitudes and so should not contribute to any signal into the output. After another round trip of these two arms the signals are back with the same polarity and do feed into the output.

In addition a signal is reflected back to the pulse generator. Some of this is reflected back from the pulse generator and appears back at the cross point. Some signal will then feed into the output.

Provided the arms of the Suicide "T" are long enough the pulser output can be monitored without contribution from these other signals. In practice, in order to keep the rise time as short as possible the arm back to the pulser is quite short and reflections down this arm will produce a signal on the falling edge of the pulser. So for looking at the long time history of the pulse the Suicide "T" should be separated from the pulsers by a suitable length of cable. See Figure 5 on page 11.

So we recommend that the attenuator system be a Suicide "T" followed by several Barth 142 20dB attenuators and when the voltage is down to <50 volts SMA 18GHz attenuators. The exact amount of attenuation required will depend upon the scope input sensitivity. We have found that when overdriving our 80804A Agilent oscilloscope the gain becomes repetition rate dependent. We therefore never approach the maximum input voltage of the scope. For the measurements presented here we used 80dB of attenuation after the Suicide “T”.

3.6 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.

We believe that with this type of unit it has to be the system builders responsibility to verify that the 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 50mm intervals.
2. That the load is connected to the pulser output with semi-rigid cable. The cable outer must be carefully connected to the HN 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.

3.7 LIFETIME

Solid state high voltage avalanche pulsers have a long but finite lifetime, generally characterised by the integrated number of output pulses. Fast rise time and high voltage lead to high electrical stress and such processes as partial discharges and other minor breakdown effects can gradually degrade insulation and reduce the lifetime.

With this in mind we recommend that pulsers are not operated unnecessarily and that arrangements are made to remove the trigger pulses when the pulse output is not required. This is most important when pulsers are operated near their maximum repetition frequency.

3.8 MAINTENANCE

IT IS VERY IMPORTANT TO MAKE SURE THAT ALL POWER IS DISCONNECTED BEFORE REMOVING THE COVERS.

The operating voltages may be checked by removing the top cover of the unit and connecting a voltmeter to the BNC socket mounted on the monitor PCB. A suitable lead is supplied.

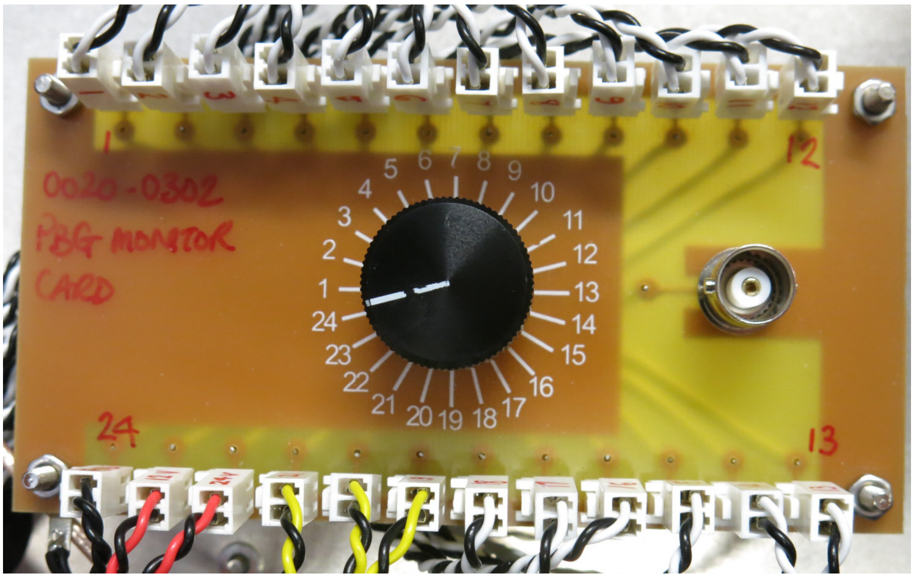


Figure 7 The monitor card under the top cover.
Connect the supplied monitor lead to the BNC connector and the other end to a suitable DMM and measure the voltages at each switch position.

Table 1 Monitor Voltages

Switch position		Voltage reading	Description
1		3.749V	Pulse stack 1
2		3.746V	Pulse stack 2
3		3.765V	Pulse stack 3
4		3.675V	Pulse stack 4
5		3.738V	Pulse stack 5
6		3.752V	Pulse stack 6
7		3.756V	Pulse stack 7
8		3.737V	Pulse stack 8
9		3.762V	Pulse stack 9
10		3.772V	Pulse stack 10
11		3.762V	Pulse stack 11
12		3.778V	Pulse stack 12
13		3.769V	Trigger stack 1 -labelled 13
14		3.742V	Trigger stack 2 -labelled 14
15		3.774V	Trigger stack 3 -labelled 15

16		3.736V	Trigger stack 4 -labelled 16
17		3.735V	Trigger stack 5 -labelled 17
18		3.716V	Trigger stack 6 -labelled 18
19		-1.773V	Pre-trigger 1st. stack
20		-2.517V	Pre-trigger 2nd. stack
21		-2.497V	Pre-trigger 3rd. stack
22		23.97V	24 volt supply
23		11.96V	12 volt supply
24		0.00V	ground

The unit has been made with the ability to replace any of the 6 main pulse cards. This may be required after the unit has been used for a considerable time.

The pulse output cards may be accessed by removing the bottom cover of the unit.

Should this become necessary please contact us and we will advise as to whether we think this can be done by the user or of the unit should be returned for servicing.

The voltages in the table above represent 1000 times divided down voltage of those within the pulser, (apart from the last three).

3.9 DECLARATION OF CONFORMITY

We:- Kentech Instruments Ltd
Isis Building, Howbery Park,
Wallingford,
Oxfordshire,
OX10 8BA, U.K

Certify that this apparatus:-

Kentech P[redacted]V High Voltage Pulse Generator
serial no.[redacted] only.

Conforms with the protection requirements of European Community Directives:-

73/23/EEC	Low Voltage Directive
89/336/EEC	Electromagnetic Compatibility Directive
93/68/EEC	CE Marking Directive

The following harmonized 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

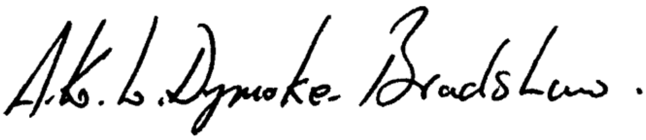
BS EN 61010-1 Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use

The following documents contain additional relevant information:-

Kentech file reference [redacted]

Name: A.K.L. Dymoke-Bradshaw

Signature:



On behalf of Kentech Instruments Ltd

Position: Director Issued: 6-12-2013

3.10 TEST RESULTS

The following test results were obtained using the supplied Suicide "T", or a similar in house one, followed by three Barth type 142 20db attenuators, a Radiall SMA 20dB 18GHz attenuator and an Agilent 80804A oscilloscope.

3.10.1 RISE TIME

All the components in the test gear degraded the output pulse from the unit, in particular the rise time.

Also as the pulse shape is not flat topped, the rise time is not well defined.

The table below indicates the various contributions to the observed rise time and indicates that the pulser is actually quite a bit faster than the data shows.

Table 2 Rise time considerations

Item	Value	Units	Notes
Oscilloscope bandwidth	8.00E+09	Hz	
Oscilloscope rise time	3.96E-11	s	
Barth 142	1.00E-11	s	
18GHz attenuator	1.76E-11	s	
Suicide T on HP sampling oscilloscope	5.00E-11	s	measured
HP oscilloscope rise time	2.50E-11	s	
Suicide "T" alone	4.33E-11	s	
System	6.37E-11	s	
100ps looks like	1.19E-10	s	
104ps measured is actually	8.22E-11	s	

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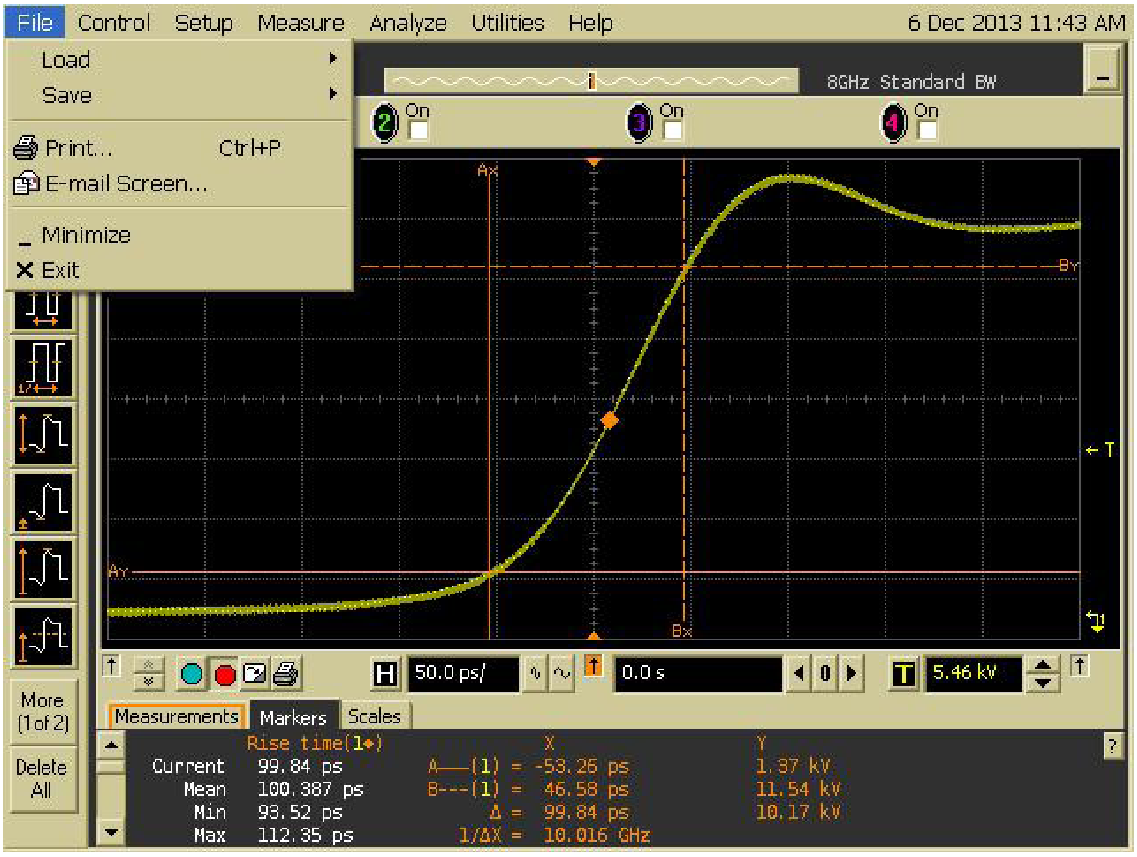

Acquisition	Sampling mode real time Normal Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 2.00 kV/ Offset 7.150 kV Coupling DC Impedance 50 Ohms
Time base	Scale 50.0 ps/ Position 0.0 s Reference center
Trigger	Mode edge Sweep triggered Sensitivity high Holdoff time 100 ns Source channel 1 Trigger level 5.46 kV Slope rising

Measure

	ΔTime(m1-1)	ΔTime(4-1)	V max(1)	Rise time(1•)
Current	Source off	Source off	14.58 kV	99.84 ps
Mean	---------------	---------------	14.517 kV	100.387 ps
Min	---------------	---------------	14.40 kV	93.52 ps
Max	---------------	---------------	14.65 kV	112.35 ps
Range	---------------	---------------	240 V	18.83 ps
Std Dev	---------------	---------------	53 V	2.650 ps
# of Meas	---------------	---------------	104	104
Edge Dir				Rising

Marker

	Rise time(1•)	X	Y
Current	99.84 ps	A—(1) = -53.26 ps	1.37 kV
Mean	100.387 ps	B---(1) = 46.58 ps	11.54 kV
Min	93.52 ps	Δ = 99.84 ps	10.17 kV
Max	112.35 ps	1/ΔX = 10.016 GHz	
Range	18.83 ps		
Std Dev	2.650 ps		

Figure 8 Rise time at maximum amplitude, 100.387ps indicated averaged over 104 shots.

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Acquisition	Sampling mode real time Normal Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 2.00 kV/ Offset 6.150 kV Coupling DC Impedance 50 Ohms
Time base	Scale 50.0 ps/ Position 0.0 s Reference center
Trigger	Mode edge Sweep triggered Sensitivity high Holdoff time 100 ns Source channel 1 Trigger level 5.46 kV Slope rising

Measure

	ΔTime(m1-1)	ΔTime(4-1)	V max(1)	Rise time(1•)
Current	Source off	Source off	11.10 kV	92.38 ps
Mean	---------------	---------------	11.10 kV	92.38 ps
Min	---------------	---------------	11.10 kV	92.38 ps
Max	---------------	---------------	11.10 kV	92.38 ps
Range	---------------	---------------	0 V	0.0 s
Std Dev	---------------	---------------	0 V	0.0 s
# of Meas	---------------	---------------	1	1
Edge Dir				Rising

Marker

	Rise time(1•)	X	Y
Current	92.38 ps	A——(1) = -60.66 ps	1.07 kV
Mean	92.38 ps	B---(1) = 31.72 ps	8.76 kV
Min	92.38 ps	Δ = 92.38 ps	7.69 kV
Max	92.38 ps	1/ΔX = 10.825 GHz	
Range	0.0 s		
Std Dev	0.0 s		

Figure 9 Rise time at 75% amplitude, 92ps indicated

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Acquisition	Sampling mode real time Normal Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 1.00 kV/ Offset 3.750 kV Coupling DC Impedance 50 Ohms
Time base	Scale 50.0 ps/ Position -29.0 ps Reference center
Trigger	Mode edge Sweep triggered Sensitivity high Holdoff time 100 ns Source channel 1 Trigger level 5.46 kV Slope rising

Measure

	ΔTime(m1-1)	ΔTime(4-1)	V max(1)	Rise time(1•)
Current	Source off	Source off	6.891 kV	109.32 ps
Mean	---------------	---------------	6.886 kV	109.36 ps
Min	---------------	---------------	6.882 kV	109.32 ps
Max	---------------	---------------	6.891 kV	109.40 ps
Range	---------------	---------------	9 V	80 fs
Std Dev	---------------	---------------	6 V	60 fs
# of Meas	---------------	---------------	2	2
Edge Dir				Rising

Marker

	Rise time(1•)	X	Y
Current	109.32 ps	A—(1) = -105.06 ps	648 V
Mean	109.36 ps	B---(1) = 4.26 ps	5.652 kV
Min	109.32 ps	Δ = 109.32 ps	5.005 kV
Max	109.40 ps	1/ΔX = 9.1473 GHz	
Range	80 fs		
Std Dev	60 fs		

Figure 10 Rise time at 50% amplitude, 109ps indicated

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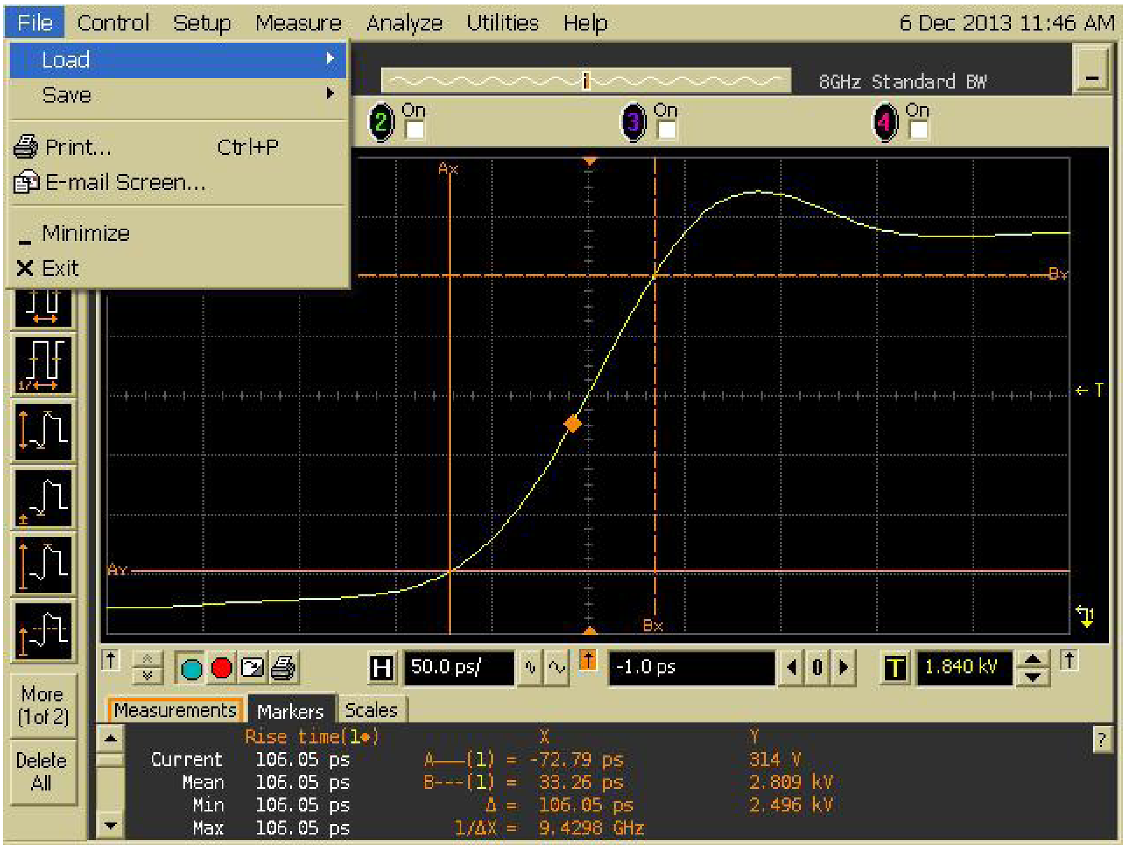

Acquisition
Sampling mode real time Normal
Memory depth automatic 1000 pts
Sampling rate automatic Sampling rate 40.0 GSa/s
Averaging off Interpolation on

Channel 1
Scale 500 V/ Offset 1.790 kV Coupling DC Impedance 50 Ohms

Time base
Scale 50.0 ps/ Position -1.0 ps Reference center

Trigger
Mode edge Sweep triggered
Sensitivity high Holdoff time 100 ns
Source channel 1 Trigger level 1.840 kV Slope rising

Measure

	ΔTime(m1-1)	ΔTime(4-1)	V max(1)	Rise time(1•)
Current	Source off	Source off	3.506 kV	106.05 ps
Mean	---------------	---------------	3.506 kV	106.05 ps
Min	---------------	---------------	3.506 kV	106.05 ps
Max	---------------	---------------	3.506 kV	106.05 ps
Range	---------------	---------------	0 V	0.0 s
Std Dev	---------------	---------------	0 V	0.0 s
# of Meas	---------------	---------------	1	1
Edge Dir				Rising

Marker

	Rise time(1•)	X	Y
Current	106.05 ps	A—(1) = -72.79 ps	314 V
Mean	106.05 ps	B---(1) = 33.26 ps	2.809 kV
Min	106.05 ps	Δ = 106.05 ps	2.496 kV
Max	106.05 ps	1/ΔX = 9.4298 GHz	
Range	0.0 s		
Std Dev	0.0 s		

Figure 11 Rise time at 25% amplitude, 105ps indicated

3.10.2 JITTER - TIMING UNCERTAINTY

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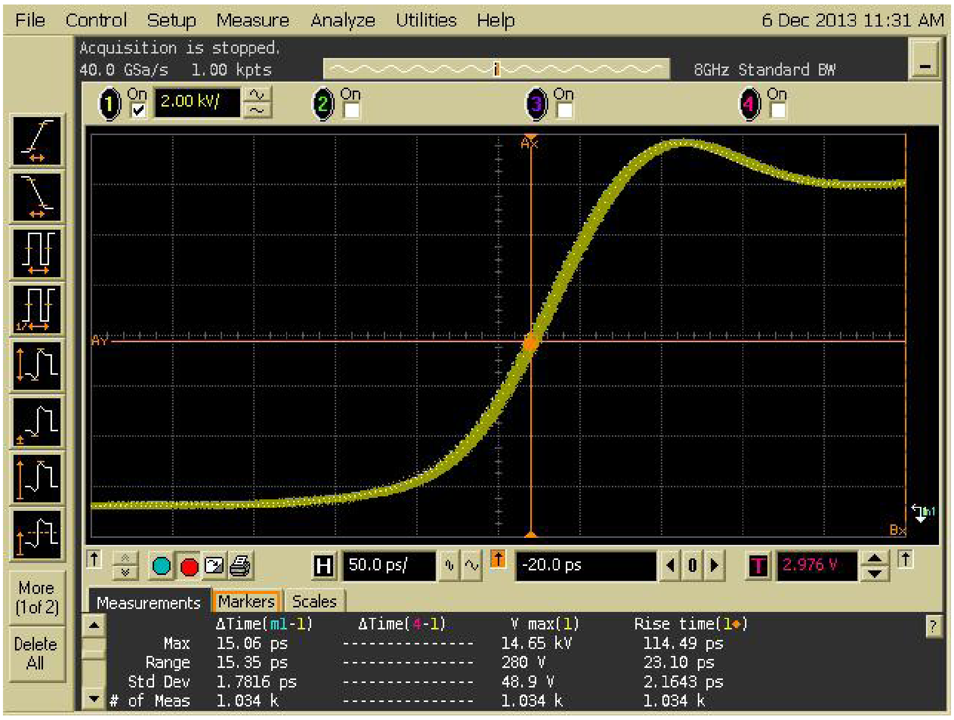

Acquisition	Sampling mode real time Normal Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 2.00 kV/ Offset 6.850 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 100 mV/ Offset 2.900 V Coupling DC Impedance 50 Ohms
Time base	Scale 50.0 ps/ Position -20.0 ps Reference center
Trigger	Mode edge Sweep triggered Sensitivity high Holdoff time 100 ns Source channel 4 Trigger level 2.976 V Slope rising
Memory 1	Vertical scale 2.00 kV/ Offset 6.85000 kV Horizontal scale 50.0 ps/ Position -20.000000000000 ps

Measure

	ΔTime(m1-1)	ΔTime(4-1)	V max(1)	Rise time(1•)
Current	4.34 ps	Source off	14.47 kV	102.13 ps
Mean	5.6925 ps	---------------	14.5074 kV	100.7415 ps
Min	-290 fs	---------------	14.37 kV	91.40 ps
Max	15.06 ps	---------------	14.65 kV	114.49 ps
Range	15.35 ps	---------------	280 V	23.10 ps
Std Dev	1.7816 ps	---------------	48.9 V	2.1643 ps
# of Meas	1.034 k	---------------	1.034 k	1.034 k
Edge Dir				Rising
From Num	1			
From Dir	Rising			
From Lvl	Middle			
To Num	1			
To Dir	Rising			
To Lvl	Middle			

Marker

	Rise time(1•)		X	Y
Current	102.13 ps	A—(1) =	0.0 s	6.62 kV
Mean	100.7415 ps	B---(1) =	51.49381 ns	Off screen
Min	91.40 ps	Δ =	51.49381 ns	--------------
Max	114.49 ps	1/ΔX =	19.419810 MHz	
Range	23.10 ps			
Std Dev	2.1643 ps			

Figure 12 Jitter with external trigger in "Direct" mode.
Standard Deviation 1.78ps over 1034 shots.

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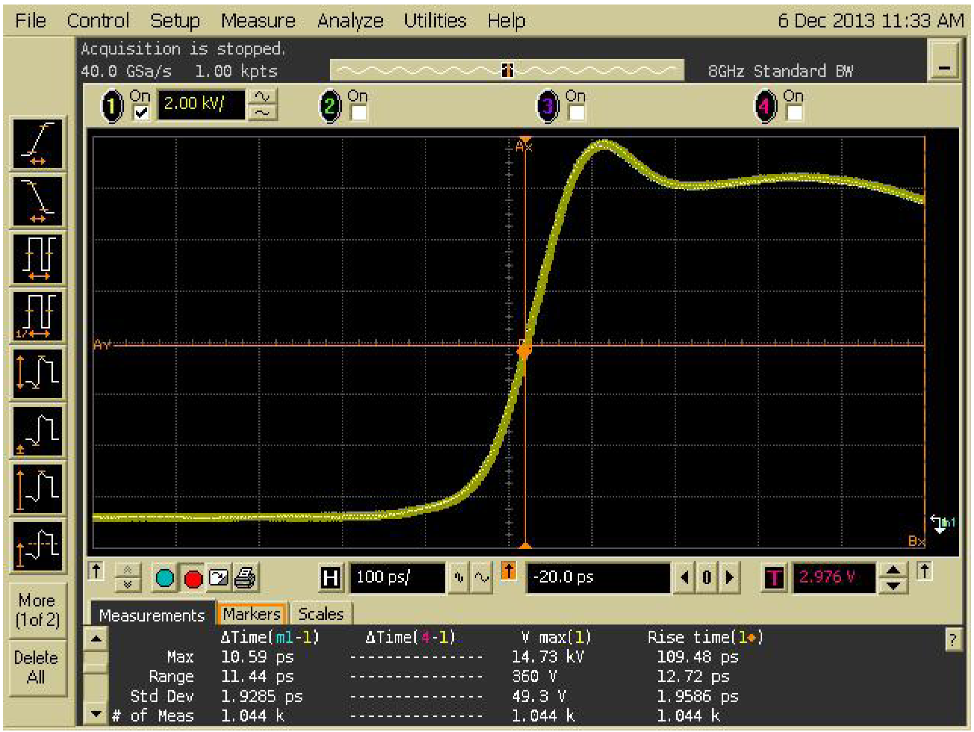

Acquisition	Sampling mode real time Normal Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 2.00 kV/ Offset 6.850 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 100 mV/ Offset 2.900 V Coupling DC Impedance 50 Ohms
Time base	Scale 100 ps/ Position -20.0 ps Reference center
Trigger	Mode edge Sweep triggered Sensitivity high Holdoff time 100 ns Source channel 4 Trigger level 2.976 V Slope rising
Memory 1	Vertical scale 2.00 kV/ Offset 6.85000 kV Horizontal scale 100 ps/ Position -20.000000000000 ps

Measure

	ΔTime(m1-1)	ΔTime(4-1)	V max(1)	Rise time(1•)
Current	2.38 ps	Source off	14.66 kV	103.30 ps
Mean	4.7820 ps	---------------	14.5684 kV	103.1356 ps
Min	-840 fs	---------------	14.37 kV	96.76 ps
Max	10.59 ps	---------------	14.73 kV	109.48 ps
Range	11.44 ps	---------------	360 V	12.72 ps
Std Dev	1.9285 ps	---------------	49.3 V	1.9586 ps
# of Meas	1.044 k	---------------	1.044 k	1.044 k
Edge Dir				Rising
From Num	1			
From Dir	Rising			
From Lvl	Middle			
To Num	1			
To Dir	Rising			
To Lvl	Middle			

Marker

	Rise time(1•)		X	Y
Current	103.30 ps	A——(1) =	0.0 s	6.74 kV
Mean	103.1356 ps	B---(1) =	51.49380 ns	Off screen
Min	96.76 ps	Δ =	51.49380 ns	--------------
Max	109.48 ps	1/ΔX =	19.419814 MHz	
Range	12.72 ps			
Std Dev	1.9586 ps			

Figure 13 Jitter with external trigger in “Delay” mode, set to zero.
Standard Deviation 1.93ps over 1044 shots.

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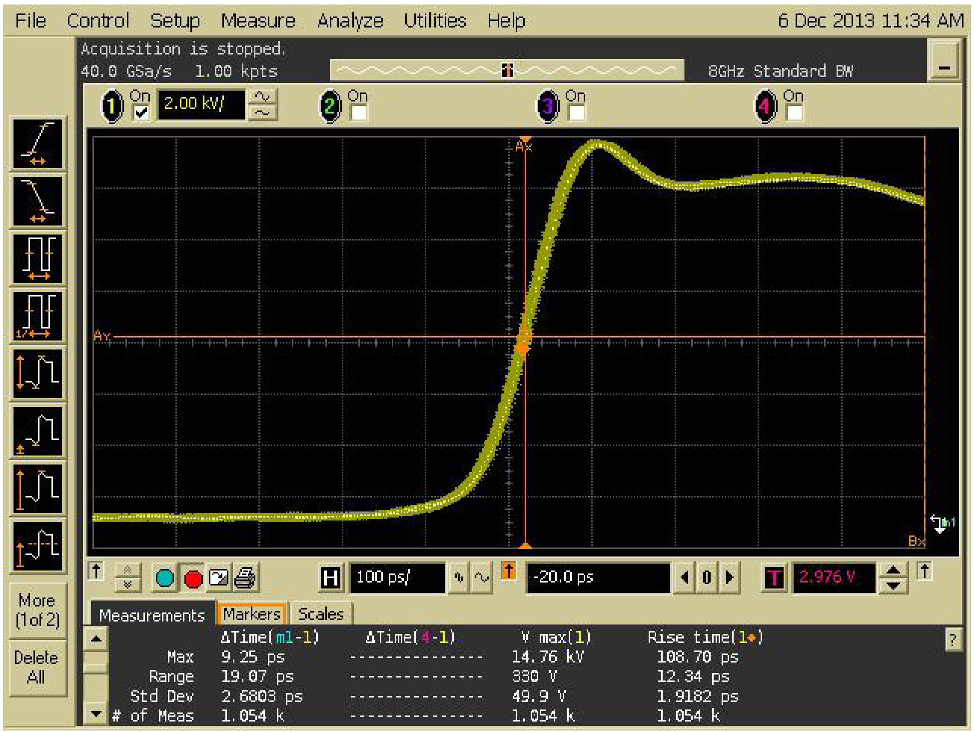

Acquisition	Sampling mode real time Normal Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 2.00 kV/ Offset 6.850 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 100 mV/ Offset 2.900 V Coupling DC Impedance 50 Ohms
Time base	Scale 100 ps/ Position -20.0 ps Reference center
Trigger	Mode edge Sweep triggered Sensitivity high Holdoff time 100 ns Source channel 4 Trigger level 2.976 V Slope rising
Memory 1	Vertical scale 2.00 kV/ Offset 6.85000 kV Horizontal scale 100 ps/ Position -20.000000000000 ps

Measure

	ΔTime(m1-1)	ΔTime(4-1)	V max(1)	Rise time(1•)
Current	980 fs	Source off	14.57 kV	102.46 ps
Mean	-1.5218 ps	---------------	14.5759 kV	103.3019 ps
Min	-9.82 ps	---------------	14.43 kV	96.37 ps
Max	9.25 ps	---------------	14.76 kV	108.70 ps
Range	19.07 ps	---------------	330 V	12.34 ps
Std Dev	2.6803 ps	---------------	49.9 V	1.9182 ps
# of Meas	1.054 k	---------------	1.054 k	1.054 k
Edge Dir				Rising
From Num	1			
From Dir	Rising			
From Lvl	Middle			
To Num	1			
To Dir	Rising			
To Lvl	Middle			

Marker

	Rise time(1•)		X	Y
Current	102.46 ps	A——(1) =	0.0 s	7.06 kV
Mean	103.3019 ps	B---(1) =	51.49380 ns	Off screen
Min	96.37 ps	Δ =	51.49380 ns	--------------
Max	108.70 ps	1/ΔX =	19.419814 MHz	
Range	12.34 ps			
Std Dev	1.9182 ps			

Figure 14 Jitter with external trigger in “Delay” mode, set to maximum. Standard Deviation 2.68ps over 1054 shots.

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Acquisition	Sampling mode real time Normal Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 2.00 kV/ Offset 7.100 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 20 mV/ Offset 4.000 V Coupling DC Impedance 50 Ohms
Time base	Scale 50.0 ps/ Position -207.0 ps Reference center
Trigger	Mode edge Sweep triggered Sensitivity high Holdoff time 100 ns Source channel 4 Trigger level 4.080 V Slope rising
Memory 1	Vertical scale 2.00 kV/ Offset 7.10000 kV Horizontal scale 50.0 ps/ Position -207.00000000000 ps

Measure

	ΔTime(m1-1)	V max(1)	Rise time(1•)
Current	1.60 ps	14.55 kV	97.33 ps
Mean	145.8 fs	14.5230 kV	100.3456 ps
Min	-6.49 ps	14.37 kV	95.15 ps
Max	7.99 ps	14.67 kV	114.40 ps
Range	14.48 ps	300 V	19.26 ps
Std Dev	2.1072 ps	48.6 V	2.0423 ps
# of Meas	1.033 k	1.033 k	1.033 k
Edge Dir			Rising
From Num	1		
From Dir	Rising		
From Lvl	Middle		
To Num	1		
To Dir	Rising		
To Lvl	Middle		

Marker

	ΔTime(m1-1)		X	Y
Current	1.60 ps	A——(m1) =	-179 ps	6.4730 kV
Mean	145.8 fs	B---(1) =	-177.84 ps	6.47 kV
Min	-6.49 ps	Δ =	1.60 ps	0.0 V
Max	7.99 ps	1/ΔX =	624.4844214277 GHz	
Range	14.48 ps			
Std Dev	2.1072 ps			

Figure 15 Jitter with interanl trigger in “Delay” mode, set to zero. Standard Deviation 2.1ps over 1033 shots.

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Acquisition — Sampling mode real time Normal
Memory depth automatic 1000 pts
Sampling rate automatic Sampling rate 40.0 GSa/s
Averaging off Interpolation on

Channel 1 — Scale 200 V/ Offset 1.305 kV Coupling DC Impedance 50 Ohms

Channel 4 — Scale 20 mV/ Offset 4.000 V Coupling DC Impedance 50 Ohms

Time base — Scale 50.0 ps/ Position -143.0 ps Reference center

Trigger — Mode edge Sweep triggered
Sensitivity high Holdoff time 100 ns
Source channel 4 Trigger level 4.080 V Slope rising

Memory 1 — Vertical scale 200 V/ Offset 1.30500 kV
Horizontal scale 50.0 ps/ Position -143.00000000000 ps

Measure

	ΔTime(m1-1)	V max(1)	Rise time(1•)
Current	-3.69 ps	≥ 2.105 kV	70.64 ps
Mean	-970.3 fs	? 2.10500 kV	72.8061 ps
Min	-7.19 ps	? 2.105 kV	68.82 ps
Max	5.10 ps	? 2.105 kV	77.46 ps
Range	12.29 ps	? 0 V	8.64 ps
Std Dev	1.7953 ps	? 0.0 V	1.2555 ps
# of Meas	1.037 k	1.037 k	1.037 k
Edge Dir			Rising
From Num	1		
From Dir	Rising		
From Lvl	Middle		
To Num	1		
To Dir	Rising		
To Lvl	Middle		

Marker

	ΔTime(m1-1)	X	Y
Current	-3.69 ps	A——(m1) = -103 ps	1.30131 kV
Mean	-970.3 fs	B---(1) = -106.94 ps	1.301 kV
Min	-7.19 ps	Δ = -3.69 ps	0.0 V
Max	5.10 ps	1/ΔX = 271.0102383048 GHz	
Range	12.29 ps		
Std Dev	1.7953 ps		

Figure 16 Jitter with internal trigger in "Delay" mode, set to zero, minimum amplitude. Standard Deviation 1.79ps over 1037 shots.

3.10.3 AMPLITUDE CONTROL

There is some overlap of the coarse and fine settings. As the technique for varying the amplitude is different for fine and coarse controls the pulse shape is slightly different. Generally the fine control degrades the shape more, especially at very low settings of the fine control.

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Acquisition	Sampling mode real time Normal Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 2.00 kV/ Offset 7.350 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 20 mV/ Offset 2.900 V Coupling DC Impedance 50 Ohms
Time base	Scale 100 ps/ Position 234.0 ps Reference center
Trigger	Mode edge Sweep triggered Sensitivity high Holdoff time 100 ns Source channel 4 Trigger level 2.820 V Slope rising
Memory 2	Vertical scale 1.00 V/ Offset -3.03000 V Horizontal scale 100 ps/ Position 234.00000000000 ps
Memory 3	Vertical scale 1.00 kV/ Offset -3.06000 kV Horizontal scale 100 ps/ Position 234.00000000000 ps
Memory 4	Vertical scale 1.00 kV/ Offset -3.06000 kV Horizontal scale 100 ps/ Position 234.00000000000 ps

Measure

	V max(1)	Rise time(1•)
Current	9.86 kV	124.75 ps
Mean	12.176 kV	105.630 ps
Min	9.86 kV	100.03 ps
Max	14.47 kV	124.75 ps
Range	4.62 kV	24.71 ps
Std Dev	1.407 kV	6.851 ps
# of Meas	11	11
Edge Dir		Rising

Figure 17 Range of amplitudes adjusted with the fine control at 100% on the coarse control.

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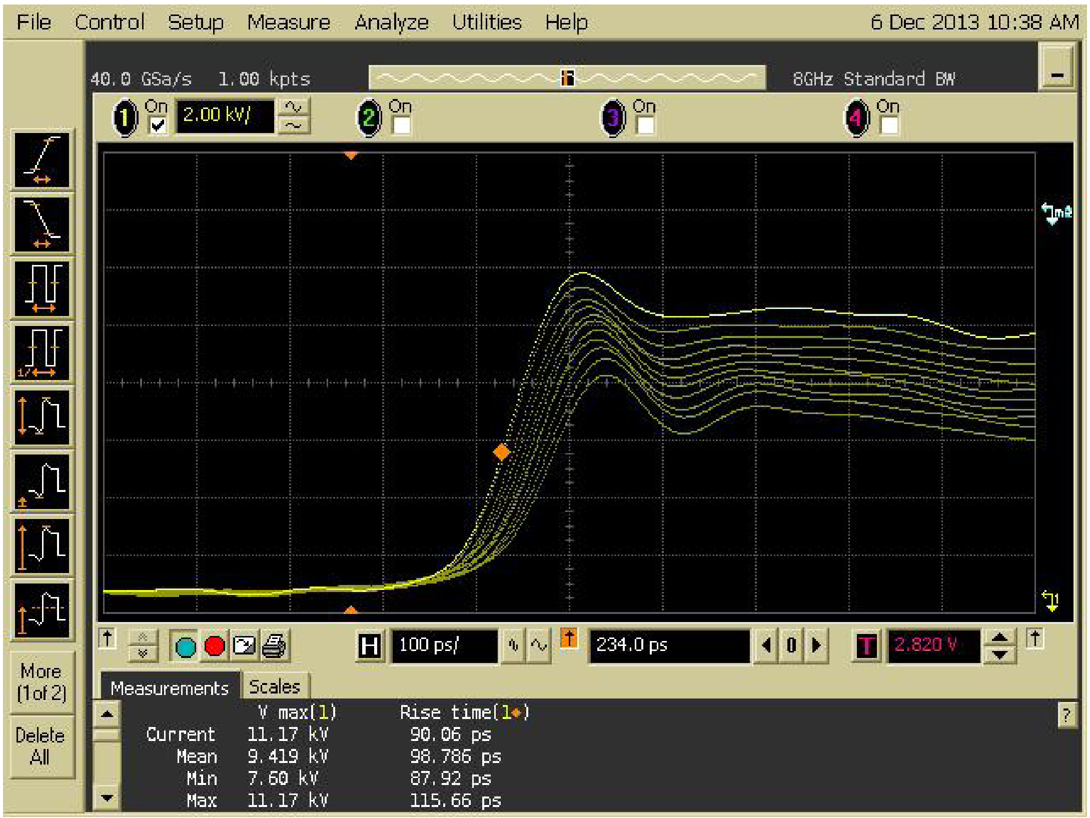

Acquisition	Sampling mode real time Normal Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 2.00 kV/ Offset 7.350 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 20 mV/ Offset 2.900 V Coupling DC Impedance 50 Ohms
Time base	Scale 100 ps/ Position 234.0 ps Reference center
Trigger	Mode edge Sweep triggered Sensitivity high Holdoff time 100 ns Source channel 4 Trigger level 2.820 V Slope rising
Memory 2	Vertical scale 1.00 V/ Offset -3.03000 V Horizontal scale 100 ps/ Position 234.00000000000 ps
Memory 3	Vertical scale 1.00 kV/ Offset -3.06000 kV Horizontal scale 100 ps/ Position 234.00000000000 ps
Memory 4	Vertical scale 1.00 kV/ Offset -3.06000 kV Horizontal scale 100 ps/ Position 234.00000000000 ps

Measure

	V max(1)	Rise time(1•)
Current	11.17 kV	90.06 ps
Mean	9.419 kV	98.786 ps
Min	7.60 kV	87.92 ps
Max	11.17 kV	115.66 ps
Range	3.57 kV	27.74 ps
Std Dev	1.079 kV	8.210 ps
# of Meas	11	11
Edge Dir		Rising

Figure 18 Range of amplitudes adjusted with the fine control at 75% on the coarse control.

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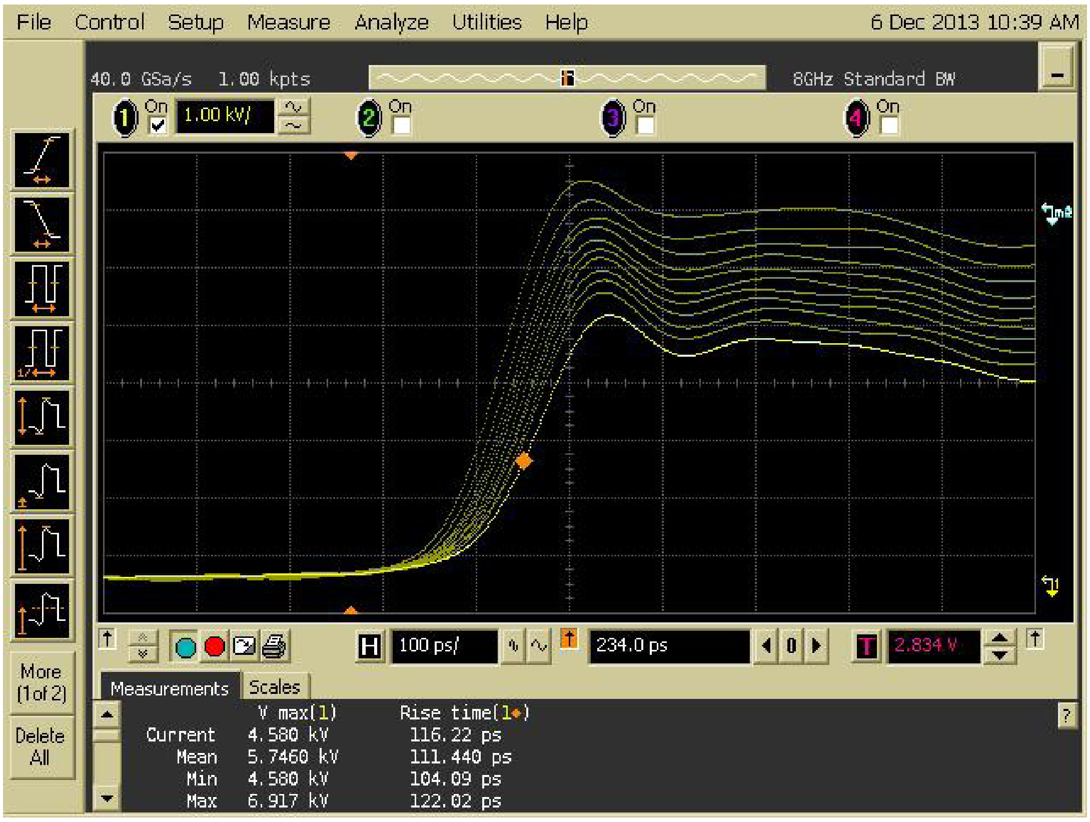

Acquisition	Sampling mode real time Normal Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 1.00 kV/ Offset 3.410 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 20 mV/ Offset 2.900 V Coupling DC Impedance 50 Ohms
Time base	Scale 100 ps/ Position 234.0 ps Reference center
Trigger	Mode edge Sweep triggered Sensitivity high Holdoff time 100 ns Source channel 4 Trigger level 2.834 V Slope rising
Memory 2	Vertical scale 1.00 V/ Offset -3.03000 V Horizontal scale 100 ps/ Position 234.00000000000 ps
Memory 3	Vertical scale 1.00 kV/ Offset -3.06000 kV Horizontal scale 100 ps/ Position 234.00000000000 ps
Memory 4	Vertical scale 1.00 kV/ Offset -3.06000 kV Horizontal scale 100 ps/ Position 234.00000000000 ps

Measure

	V max(1)	Rise time(1•)
Current	4.580 kV	116.22 ps
Mean	5.7460 kV	111.440 ps
Min	4.580 kV	104.09 ps
Max	6.917 kV	122.02 ps
Range	2.337 kV	17.93 ps
Std Dev	703.2 V	5.254 ps
# of Meas	11	11
Edge Dir		Rising

Figure 19 Range of amplitudes adjusted with the fine control at 50% on the coarse control.

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Acquisition — Sampling mode real time Normal
Memory depth automatic 1000 pts
Sampling rate automatic Sampling rate 40.0 GSa/s
Averaging off Interpolation on

Channel 1 — Scale 500 V/ Offset 1.720 kV Coupling DC Impedance 50 Ohms

Channel 4 — Scale 20 mV/ Offset 2.900 V Coupling DC Impedance 50 Ohms

Time base — Scale 100 ps/ Position 234.0 ps Reference center

Trigger — Mode edge Sweep triggered
Sensitivity high Holdoff time 100 ns
Source channel 4 Trigger level 2.834 V Slope rising

Memory 2 — Vertical scale 1.00 V/ Offset -3.03000 V
Horizontal scale 100 ps/ Position 234.00000000000 ps

Memory 3 — Vertical scale 1.00 kV/ Offset -3.06000 kV
Horizontal scale 100 ps/ Position 234.00000000000 ps

Memory 4 — Vertical scale 1.00 kV/ Offset -3.06000 kV
Horizontal scale 100 ps/ Position 234.00000000000 ps

Measure

	V max(1)	Rise time(1•)
Current	2.342 kV	123.04 ps
Mean	2.9158 kV	107.956 ps
Min	2.342 kV	97.36 ps
Max	3.461 kV	123.04 ps
Range	1.119 kV	25.68 ps
Std Dev	341.9 V	6.524 ps
# of Meas	11	11
Edge Dir		Rising

Figure 20 Range of amplitudes adjusted with the fine control at 25% on the coarse control.

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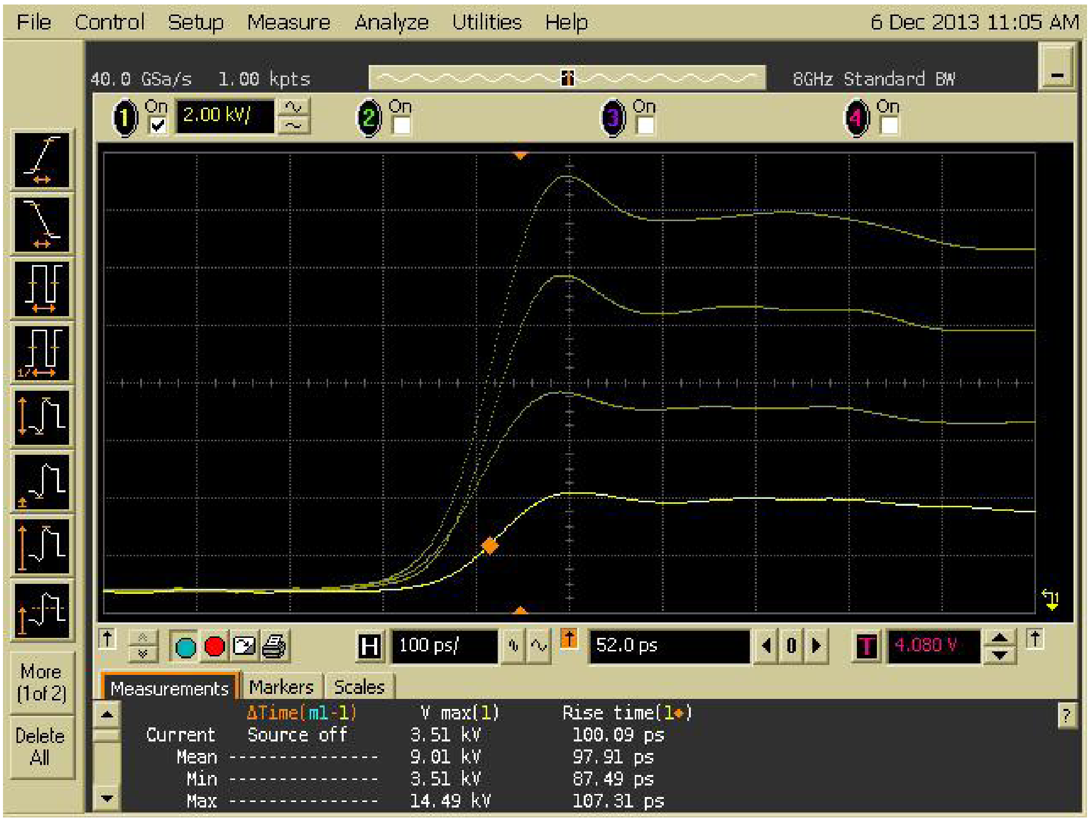

Acquisition	Sampling mode real time Normal Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 2.00 kV/ Offset 7.305 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 20 mV/ Offset 4.000 V Coupling DC Impedance 50 Ohms
Time base	Scale 100 ps/ Position 52.0 ps Reference center
Trigger	Mode edge Sweep triggered Sensitivity high Holdoff time 100 ns Source channel 4 Trigger level 4.080 V Slope rising

Measure

	ΔTime(m1-1)	V max(1)	Rise time(1•)
Current	Source off	3.51 kV	100.09 ps
Mean	---------------	9.01 kV	97.91 ps
Min	---------------	3.51 kV	87.49 ps
Max	---------------	14.49 kV	107.31 ps
Range	---------------	10.98 kV	19.81 ps
Std Dev	---------------	4.78 kV	8.23 ps
# of Meas	---------------	4	4
Edge Dir			Rising

Marker

	ΔTime(m1-1)		X	Y
Current	Source off	A—(m1) =	-------------------	Source off
Mean	---------------	B---(1) =	-------------------	--------------
Min	---------------	Δ =	-------------------	--------------
Max	---------------	1/ΔX =	-------------------	
Range	---------------			
Std Dev	---------------			

Figure 21 Range of amplitudes adjusted with the coarse control at 100% on the fine control.

3.10.4 DELAYS

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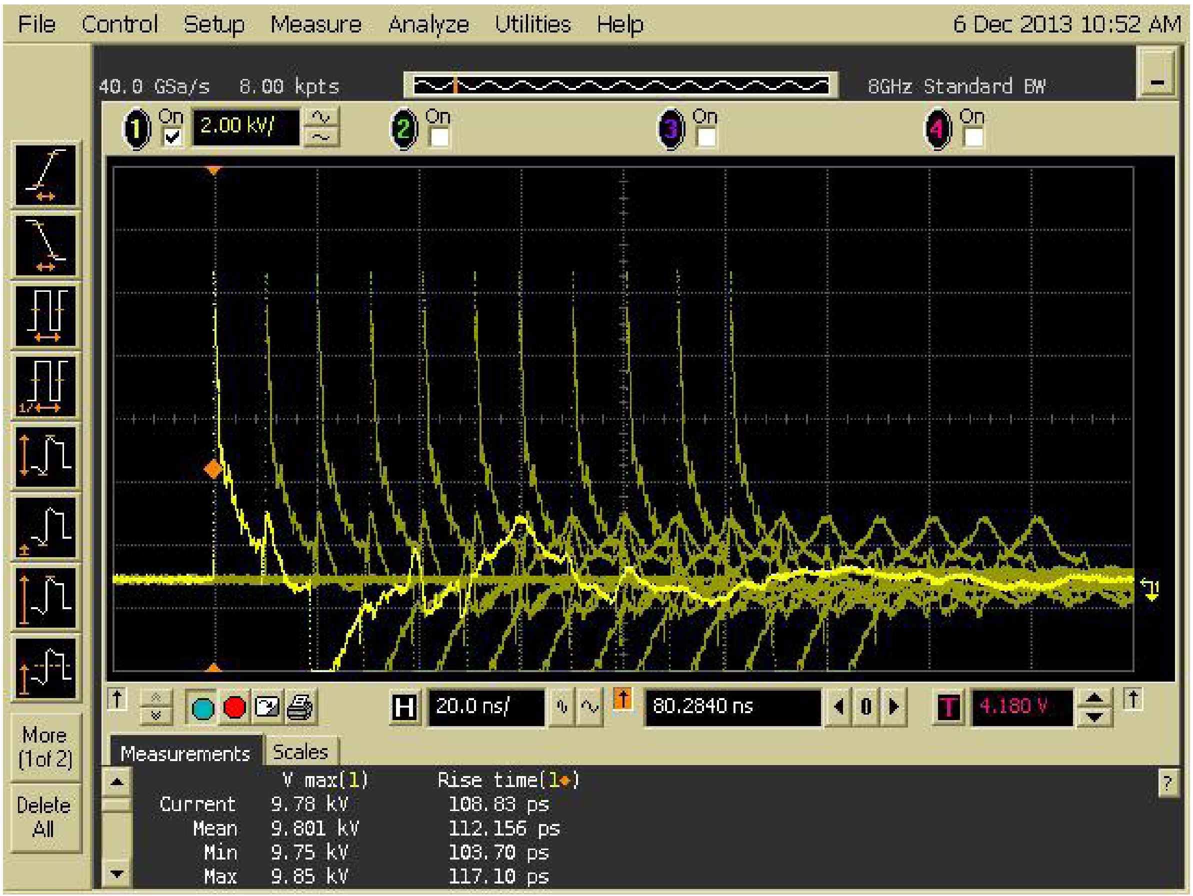

Acquisition — Sampling mode real time Normal
Memory depth automatic 8002 pts
Sampling rate automatic Sampling rate 40.0 GSa/s
Averaging off Interpolation on

Channel 1 — Scale 2.00 kV/ Offset 5.150 kV Coupling DC Impedance 50 Ohms

Channel 4 — Scale 50 mV/ Offset 4.000 V Coupling DC Impedance 50 Ohms

Time base — Scale 20.0 ns/ Position 80.2840 ns Reference center

Trigger — Mode edge Sweep triggered
Sensitivity high Holdoff time 100 ns
Source channel 4 Trigger level 4.180 V Slope rising

Measure

	V max(1)	Rise time(1•)
Current	9.78 kV	108.83 ps
Mean	9.801 kV	112.156 ps
Min	9.75 kV	103.70 ps
Max	9.85 kV	117.10 ps
Range	100 V	13.40 ps
Std Dev	27 V	3.611 ps
# of Meas	11	11
Edge Dir		Rising

Figure 22 Range of coarse delay. Approximately 10ns per step.

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Acquisition	Sampling mode real time Normal Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 2.00 kV/ Offset 5.150 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 50 mV/ Offset 4.000 V Coupling DC Impedance 50 Ohms
Time base	Scale 2.00 ns/ Position 7.9950 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity high Holdoff time 100 ns Source channel 4 Trigger level 4.180 V Slope rising

Measure

	V max(1)	Rise time(1•)
Current	9.77 kV	111.19 ps
Mean	9.799 kV	120.822 ps
Min	9.70 kV	108.38 ps
Max	9.90 kV	166.16 ps
Range	190 V	57.78 ps
Std Dev	43 V	11.693 ps
# of Meas	107	107
Edge Dir		Rising

Figure 23 Range of fine delay at zero coarse delay.

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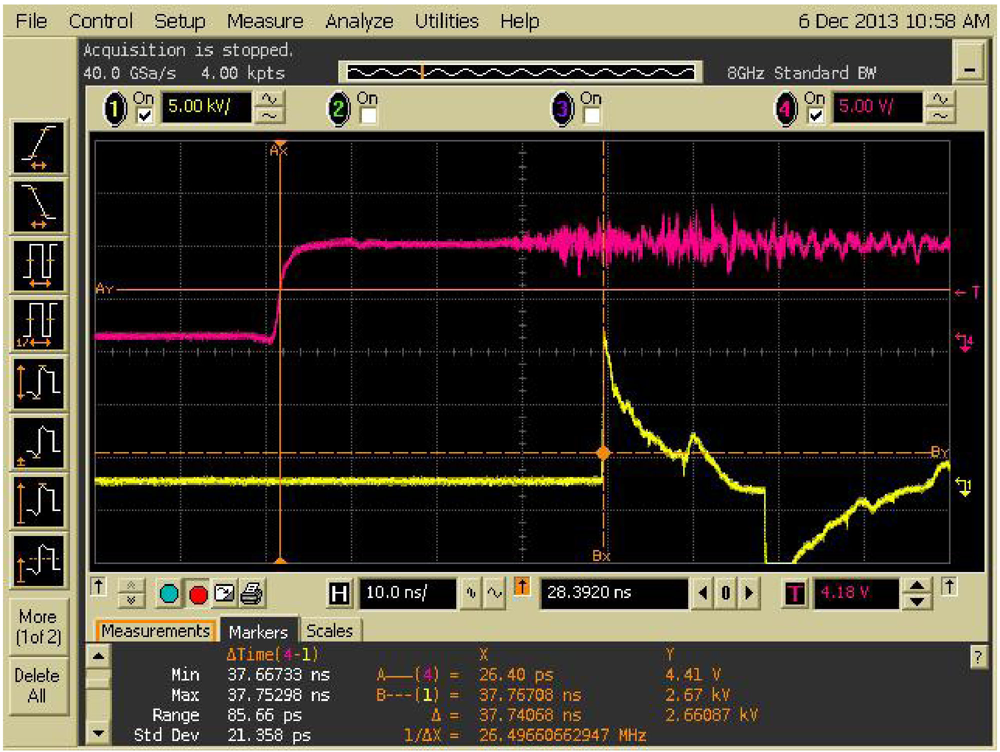

Acquisition	Sampling mode real time Normal Memory depth automatic 4003 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 5.00 kV/ Offset 12.2 kV Coupling DC Impedance 50 Ohms
Channel 4	Scale 5.00 V/ Offset -1.40 V Coupling DC Impedance 50 Ohms
Time base	Scale 10.0 ns/ Position 28.3920 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity high Holdoff time 100 ns Source channel 4 Trigger level 4.18 V Slope rising

Measure		ΔTime(4-1)	V max(1)	Rise time(1•)
	Current	37.74068 ns	14.36 kV	74.27 ps
	Mean	37.720166 ns	14.333 kV	89.525 ps
	Min	37.66733 ns	14.16 kV	73.03 ps
	Max	37.75298 ns	14.47 kV	122.92 ps
	Range	85.66 ps	300 V	49.89 ps
	Std Dev	21.358 ps	93 V	14.400 ps
	# of Meas	23	23	23
	Edge Dir			Rising
	From Num	1		
	From Dir	Rising		
	From Lvl	Middle		
	To Num	1		
	To Dir	Rising		
	To Lvl	Middle		

Marker		ΔTime(4-1)		X	Y
	Current	37.74068 ns	A—(4) =	26.40 ps	4.41 V
	Mean	37.720166 ns	B---(1) =	37.76708 ns	2.67 kV
	Min	37.66733 ns	Δ =	37.74068 ns	2.66087 kV
	Max	37.75298 ns	1/ΔX =	26.49660662947 MHz	
	Range	85.66 ps			
	Std Dev	21.358 ps			

Figure 24 Internal trigger - Pretrigger pulse and main output.
The 37.74 ns needs correcting to 44.77 because of external cables.