Kentech Instruments Ltd.

Notes on the use of

PBG1-N-V-10kHz pulser

PLEASE READ THIS MANUAL CAREFULLY BEFORE USING THE UNIT

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1 DECLARATION OF CONFORMITY

Declaration of Conformity

We:- Kentech Instruments Ltd.
The Isis Building
Howbery Park
Wallingford

Conform 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 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

The following documents contain additional relevant information:-

2 DISCLAIMER

There are high voltage power supplies present in this instrument when the unit is operating. Do not remove any covers from the unit or expose any part of its circuitry. In the event of malfunction, the unit must be returned to Kentech Instruments Ltd. or its appointed agent for repair.

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

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

Read this manual before unpacking and using the instrument. If cleaning is necessary this should be performed with a soft dry cloth or tissue only.

3 EMC CAUTION

This equipment includes circuits intentionally designed to generate short high energy electromagnetic pulses and the EM emissions will be sensitive to the details of the experimental set up.

In practice emissions may exceed E55011 and the unit may cause interference with other equipment in its immediate environment. It is therefore suitable for use only in a laboratory or a sealed electromagnetic environment, unless it is used in a system that has been verified by the system builder to comply with EC directive 89/336/EEC. Use of this apparatus outside the laboratory or sealed electromagnetic environment invalidates conformity with the EMC Directive and could lead to prosecution.

We believe that with this type of unit it has to be the system builders 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. The use of semi rigid cables or conformable semi rigid cables will deliver lower EM radiation from the cabling than any flexible types.

4 ABBREVIATIONS

EHT or eht	Extra High Tension (high voltage)
EMC	Electromagentic Compatibility
f.w.h.m.	full width at half maximum amplitude
PRF	Pulse Repetition Frequency
PSU or psu	power supply unit
SD	Standard Deviation
w.r.t.	With Respect To

5 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 user's 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.

6 UNPACKING AND GENERAL OPERATION

The unit requires a good air flow through from back to front. Ensure all shipping tape is removed and that the airflow is not impeeded during operation.
The pulser requires A.C. power, an interlock connection and a trigger signal to operate. The trigger signal applied to the front panel trigger input (BNC) should be >5V and <15V into 50Ω with a fast rising edge (<5ns) to maintain the low jitter of the system. When triggered the triggered light on the front panel will flash.
The output of the unit is a nominal 6kV negative pulse which appears on the output front panel N type connector. The pulse width is fixed at ~0.5ns. If it is necessary to monitor or characterise the pulse output then suitable attenuators should be used.
Note that the trigger delay will increase at high repetition rates and also will take time to settle down after a change of repetition rates as the unit changes temerature. It runs significantly hotter at high rates.

6.1 CAUTION

The output of this unit will damage or destroy many types of high voltage and high power attenuators. We only recommend the use of a high voltage, high speed attenuator manufactured by Barth™ as the first in a series. Consult the attenuator manufacturer before using any other configuration.
Note that at maximum voltage and repetition rate the average power output is > 4watts and this is higher than Barth's type 142 attenuators can accept for more than a brief period.
The output may be observed with a high bandwidth oscilloscope. This may either be a fast (>3GHz) direct access type or a sampling type.
The trigger delay from trigger input BNC to main output is approximately 26ns. The jitter is <10ps SD with a suitably reproducible and fast rising trigger signal.

7 SPECIFICATIONS

These are general specifications. Data on individual units is available on the CD that accompanies this manual.

Pulse generator:

General:

Output peak amplitude	>6kV (variable) into 50Ω .
Output polarity	Negative.
Pulse shape	fast rise and slow decay
Pulse width	0.5ns FWHM nominal.
Rise time	<150ps 10 to 90%. see test data
Fall time	~0.5ns. see test data
Trigger	>5V and <15V into 50Ω , <5ns rise time.
Jitter	<10ps RMS
Trigger delay	~26ns (BNC trigger input to main output)
Repetition rates	up to > 10kHz
Power supply	100-240V AC 50-60Hz

Maximum power <100W

Front panel

Outputs:

Pulse output	N type >6kV negative pulse
Sync. output	BNC, >5 volts into 50Ω

Inputs:

Trigger input	BNC, >5V, <15V into 50Ω <5ns rise time.
Interlock (short to enable)	Lemo ERA.00 - mating connector FFA.00

Short the centre pin to ground to enable the pulser. cable supplied.

Controls:

Amplitude	10 turn lockable potentiometer with counter.

LED Indicators:

Power	Shows the unit is powered and on.
Enabled	The unit is ready to receive a trigger signal.
Tripped	A fault has been detected. The flash code of the LED will indicate the nature of the problem.
Triggered	Illuminates while the unit is being triggered.

Rear Panel

Connectors

Mains power inlet	IEC
USB	mini. For servicing only.

Controls

Power	Switches AC power in the pulser.

Ambient temperature	5 to 35° C
Humidity	< 95% non-condensing

Altitude	< 3000m
Dimensions	Pulser: H = 142 including feet, W = 450, D = 450 mm3
Weight:	Approximately 9.2kg.

8 TRIPPED FAULT CODES

The unit contains a microprocessor controlled monitor that measures the current consumption of the 6 internal high votlage power supplies. It also monitors the state of the front panel interlock connection and the temperature by way of a themistor on power supply 0.

On start up with the interlock enabled, the power supplies are started up in sequence to reduce the initial start up currents of these supplies from overloading the main 24 volt power supply.

Should the interlock be broken, the temperature be too high or any power supply indicate an over current at any time, the unit will be tripped, the power supplies will be disabled and the tripped light will flash to indicate an error code.

To escape a tripped condition it is necessary to cycle the mains power.

Note that the interlock cannot be used as a trigger inhibit as the trip cannot be reset without cycling the power.

8.1 TRIPPED CONDITION ERROR CODES

While any trip/interlock latch is set the processor flashes the error code on the trip.

LED flash codes are:. This is one long flash followed by a number of short flashes.

0 = l_trip0	PSU 0
1 = l_trip1	PSU 1
2 = l_trip2	PSU 2
3 = l_trip3	PSU 3
4 = l_trip4	PSU 4
5 = l_trip5	PSU 5
6 = l_trip6	Not used
7 = l_trip7	Over temperature trip
8 = l_intlk	Interlock trip.

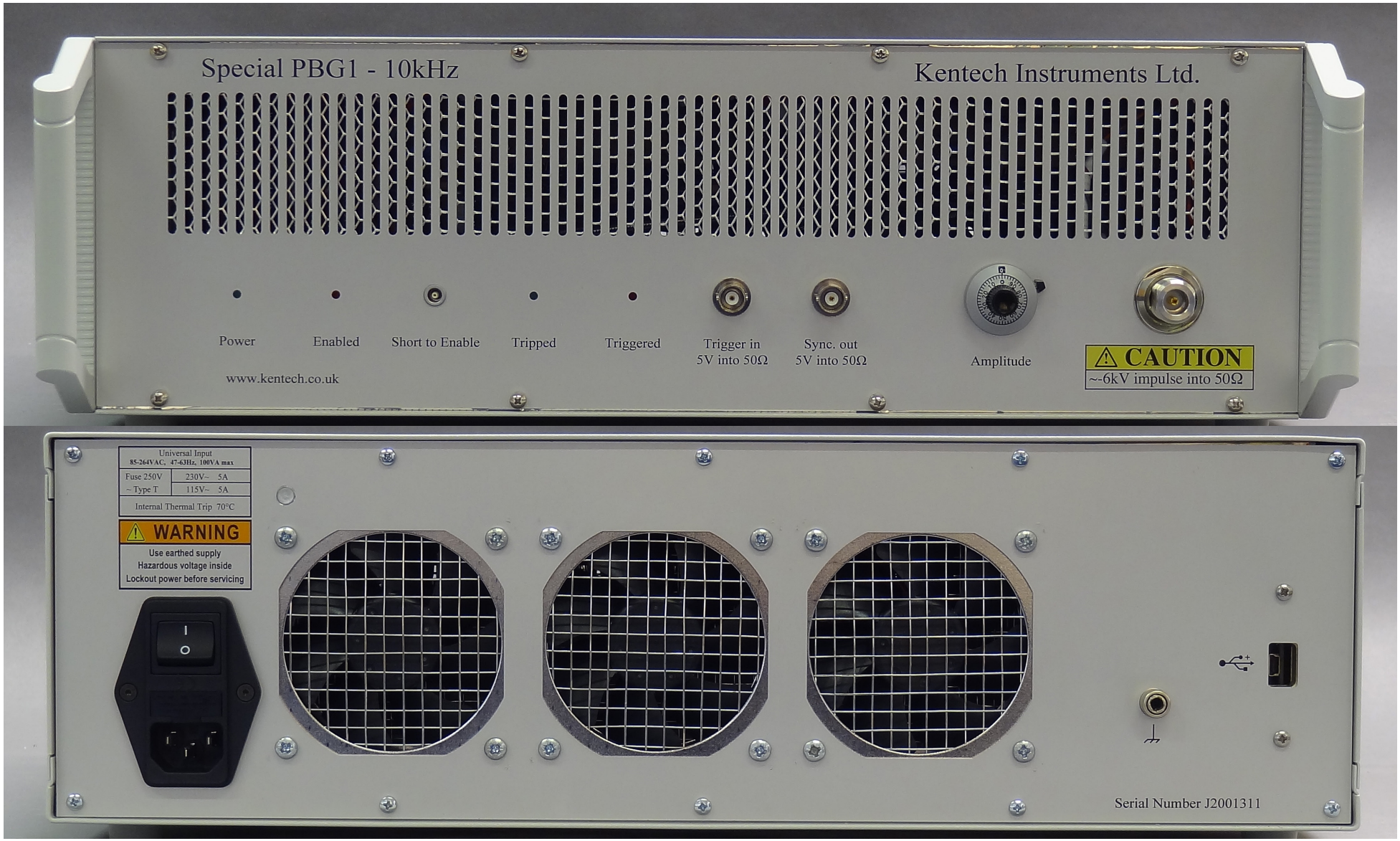

Figure 1 Front and rear panels

9 TEST DATA

Test equipment:

Scope: Agilent DSO81004A

Attenuators: 1st: 3 x Barth 142 20dB

2nd: 1 x Radial SMA 20dB

Note: For sustained operation at 10kHz and maximum amplitude an in house ~x2 attenuator was used in front of the first Barth unit. The in house attenuator has poorer fidelity but is able to operate with 4 watts at the input. It is also easily repairable.

The Barth 142 attenuators were operated at 4 watts for very short periods to establish that the waveform was retained at high repetition rates.

Trigger source: Highland P400 using high voltage outputs.

9.1 TEST DATA WITH THE IN HOUSE X2 ATTENUATOR

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Acquisition Sampling mode real time Normal
Memory depth automatic 83 pts
Sampling rate automatic Sampling rate 40.0 GSa/s
Averaging off Interpolation on

Channel 1 Scale 1.00 kV/ Offset -2.820 kV Coupling DC Impedance 50 Ohms

Channel 4 Scale 10 mV/ Offset 2.400 V Coupling DC Impedance 50 Ohms

Time base Scale 200 ps/ Position 28.8670 ns Reference center

Trigger Mode edge Sweep triggered
Sensitivity high Holdoff time 100 ns
Source channel 4 Trigger level 2.4168 V Slope rising

Memory 1 Vertical scale 1.00 kV/ Offset -2.82000 kV
Horizontal scale 200 ps/ Position 28.867000000000 ns

Measure

	V min(1)	- width(1•)	Fall time(1•)	ΔTime(1-m1)
Current	-6.580 kV	538.32 ps	113.71 ps	102.646 ps
Mean	-6.6016 kV	544.250 ps	113.889 ps	102.4171 ps
Min	-6.706 kV	438.70 ps	102.17 ps	94.485 ps
Max	-6.504 kV	568.14 ps	123.06 ps	110.426 ps
Range	202 V	129.44 ps	20.89 ps	15.940 ps
Std Dev	30.4 V	10.264 ps	3.065 ps	2.9192 ps
# of Meas	882	882	882	882
Edge Dir			Falling	
From Num				1
From Dir				Falling
From Lvl				Middle
To Num				1
To Dir				Falling
To Lvl				Middle

Marker

	V min(1)	X	Y
Current	-6.580 kV	A——(1) = ----------	-6.582 kV
Mean	-6.6016 kV	B---(1) = ----------	-6.582 kV
Min	-6.706 kV	Δ = ----------	0 V
Max	-6.504 kV	1/ΔX = ----------	
Range	202 V		
Std Dev	30.4 V		

Histogram Axis horizontal Scale source channel 1
Ax Position 227.78 ps Bx Position 181.82 ps
Ay Position -3.000 kV By Position -3.000 kV
Scale type linear Size 4.0 div

		Mean	No data	Median	No data
Y Scale	0 hits/	Std Dev	No data	Mode	No data
Y Offset	0 hits	µ±1σ	No data	p-p	No data
		µ±2σ	No data	Min	No data
		µ±3σ	No data	Max	No data

Figure 2 Waveform at 1kHz (yellow) and 10kHz (blue) with the x2 attenuator inserted before the Barths. At 10kHz there is some extra trigger delay and a small loss of amplitude but the pulser is still within specification.

9.2 TEST DATA WITHOUT THE IN HOUSE X2 ATTENUATOR

Acquisition Sampling mode real time Normal
Memory depth automatic 83 pts
Sampling rate automatic Sampling rate 40.0 GSa/s
Averaging off Interpolation on

Channel 1 Scale 1.20 kV/ Offset -2.420 kV Coupling DC Impedance 50 Ohms

Channel 4 Scale 10 mV/ Offset 2.400 V Coupling DC Impedance 50 Ohms

Time base Scale 200 ps/ Position 28.2450 ns Reference center

Trigger Mode edge Sweep triggered
Sensitivity high Holdoff time 100 ns
Source channel 4 Trigger level 2.4168 V Slope rising

Memory 1 Vertical scale 1.20 kV/ Offset -2.42000 kV
Horizontal scale 200 ps/ Position 28.245000000000 ns

Measure

	V min(1)	- width(1•)	Fall time(1•)	ΔTime(1-m1)
Current	-6.60 kV	554.63 ps	113.11 ps	117.582 ps
Mean	-6.582 kV	558.437 ps	112.907 ps	117.9134 ps
Min	-6.70 kV	523.47 ps	104.85 ps	-5.247 ps
Max	-6.33 kV	577.05 ps	125.62 ps	122.642 ps
Range	370 V	53.58 ps	20.77 ps	127.890 ps
Std Dev	42 V	6.699 ps	3.009 ps	6.4577 ps
# of Meas	392	392	392	392
Edge Dir			Falling	
From Num				1
From Dir				Falling
From Lvl				Middle
To Num				1
To Dir				Falling
To Lvl				Middle

Marker

	V min(1)	X	Y
Current	-6.60 kV	A——(1) = ----------	-6.60 kV
Mean	-6.582 kV	B---(1) = ----------	-6.60 kV
Min	-6.70 kV	Δ = ----------	0 V
Max	-6.33 kV	1/ΔX = ----------	
Range	370 V		
Std Dev	42 V		

Histogram Axis horizontal Scale source channel 1
Ax Position 227.78 ps Bx Position 181.82 ps
Ay Position -3.000 kV By Position -3.000 kV
Scale type linear Size 4.0 div

		Mean	No data	Median	No data	Hits	No data
Y Scale	0 hits/	Std Dev	No data	Mode	No data	Peak	No data
Y Offset	0 hits	µ±1σ	No data	p-p	No data		
		µ±2σ	No data	Min	No data		
		µ±3σ	No data	Max	No data		

Figure 3 Waveform at 1kHz (yellow) and 10kHz (blue) without the x2 attenuator inserted before the Barths. At 10kHz there is some extra trigger delay and a small loss of amplitude but the pulser is still within specification.

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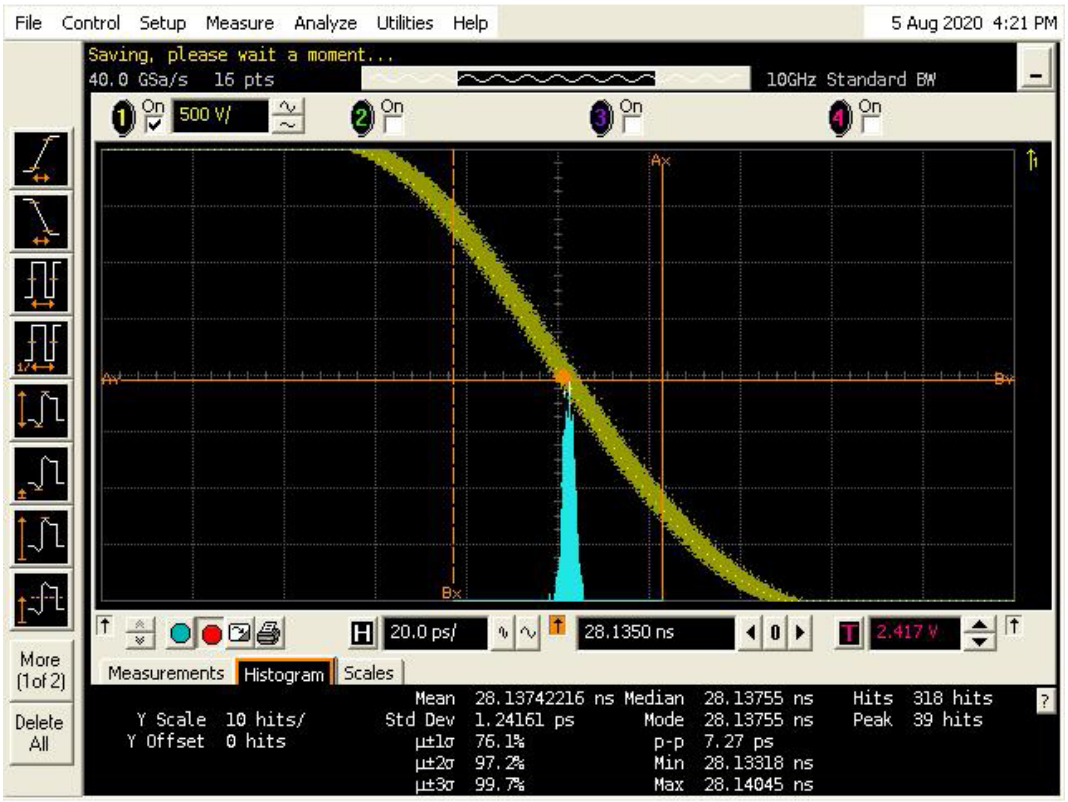

Acquisition Sampling mode real time Normal
Memory depth automatic 16 pts
Sampling rate automatic Sampling rate 40.0 GSa/s
Averaging off Interpolation on

Channel 1 Scale 500 V/ Offset -2.960 kV Coupling DC Impedance 50 Ohms

Channel 4 Scale 10 mV/ Offset 2.400 V Coupling DC Impedance 50 Ohms

Time base Scale 20.0 ps/ Position 28.1350 ns Reference center

Trigger Mode edge Sweep auto
Sensitivity high Holdoff time 100 ns
Source channel 4 Trigger level 2.4168 V Slope rising

Measure

	V min(1)	- width(1♦)	Fall time(1♦)	ΔTime(1-m1)
Current	≤-4.960 kV	Edge?	66.24 ps	Source off
Mean	?-4.96000 kV	----------	65.4349 ps	----------
Min	?-4.960 kV	----------	60.87 ps	----------
Max	?-4.960 kV	----------	68.95 ps	----------
Range	? 0 V	----------	8.08 ps	----------
Std Dev	? 0.0 V	----------	1.4265 ps	----------
# of Meas	2.094 k	----------	2.094 k	----------
Edge Dir			Falling	

Histogram Axis horizontal Scale source channel 1
Ax Position 28.15791 ns Bx Position 28.11209 ns
Ay Position -3.000 kV By Position -3.000 kV
Scale type linear Size 4.0 div

		Mean	28.13742216 ns	Median 28.13755 ns	Hits 318 hits
Y Scale	10 hits/	Std Dev	1.24161 ps	Mode 28.13755 ns	Peak 39 hits
Y Offset	0 hits	µ±1σ	76.1%	p-p 7.27 ps	
		µ±2σ	97.2%	Min 28.13318 ns	
		µ±3σ	99.7%	Max 28.14045 ns	

Figure 4 Jitter at 1kHz 1.24ps SD over 2k measurements.
The unit was allowed to thermally stabalise before the data was taken.

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Acquisition Sampling mode real time Normal
Memory depth automatic 16 pts
Sampling rate automatic Sampling rate 40.0 GSa/s
Averaging off Interpolation on

Channel 1 Scale 500 V/ Offset -2.960 kV Coupling DC Impedance 50 Ohms

Channel 4 Scale 10 mV/ Offset 2.400 V Coupling DC Impedance 50 Ohms

Time base Scale 20.0 ps/ Position 28.2604 ns Reference center

Trigger Mode edge Sweep auto
Sensitivity high Holdoff time 100 ns
Source channel 4 Trigger level 2.4168 V Slope rising

Measure

	V min(1)	- width(1•)	Fall time(1•)	ΔTime(1-m1)
Current	≤-4.960 kV	Edge?	67.44 ps	Source off
Mean	?-4.9600 kV	----------	66.684 ps	----------
Min	?-4.960 kV	----------	62.40 ps	----------
Max	?-4.960 kV	----------	69.83 ps	----------
Range	? 0 V	----------	7.43 ps	----------
Std Dev	? 0.0 V	----------	1.364 ps	----------
# of Meas	732	----------	732	----------
Edge Dir			Falling	

Histogram Axis horizontal Scale source channel 1
Ax Position 28.15791 ns Bx Position 28.34958 ns
Ay Position -3.000 kV By Position -3.000 kV
Scale type linear Size 4.0 div

		Mean	28.26360885 ns	Median	28.26349 ns	Hits 111 hits
Y Scale	3 hits/	Std Dev	1.51643 ps	Mode	28.26385 ns	Peak 11 hits
Y Offset	0 hits	µ±1σ	69.4%	p-p	6.18 ps	
		µ±2σ	98.2%	Min	28.26058 ns	
		µ±3σ	100%	Max	28.26676 ns	

Figure 5 Jitter at 10kHz 1.5ps SD over 732 measurements.
The unit was allowed to thermally stabalise before the data was taken.

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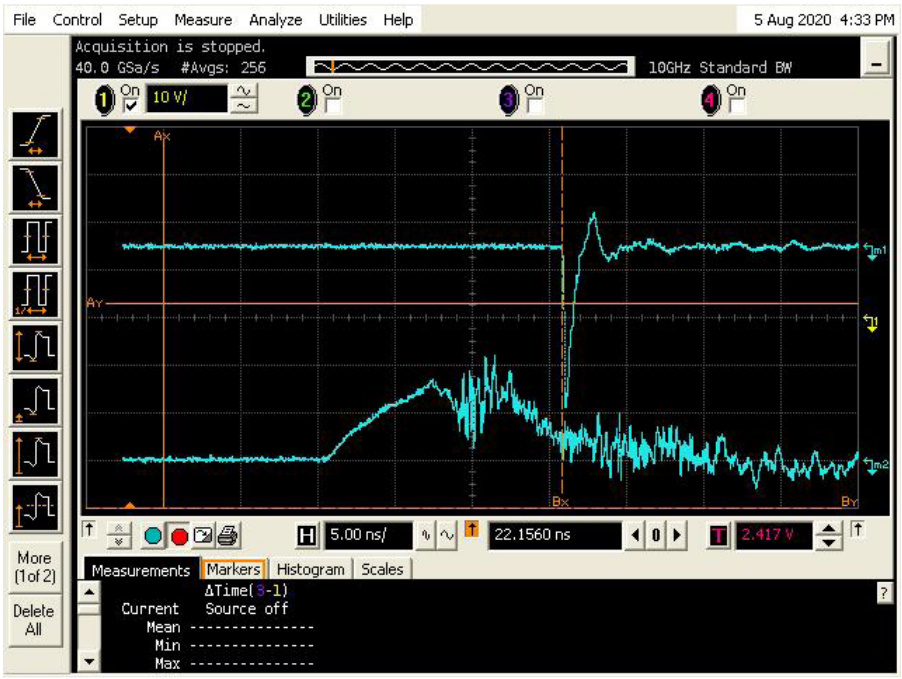


Acquisition	Sampling mode real time Normal Memory depth automatic 2002 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging on # of averages 256 Interpolation on
Channel 1	Scale 10 V/ Offset 0 V Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 2.400 V Coupling DC Impedance 50 Ohms
Time base	Scale 5.00 ns/ Position 22.1560 ns Reference center
Trigger	Mode edge Sweep auto Sensitivity high Holdoff time 100 ns Source channel 4 Trigger level 2.4168 V Slope rising
Memory 1	Vertical scale 2.00 kV/ Offset -3.00000 kV Horizontal scale 5.00 ns/ Position 22.156000000000 ns
Memory 2	Vertical scale 5.00 V/ Offset 14.9300 V Horizontal scale 5.00 ns/ Position 22.156000000000 ns

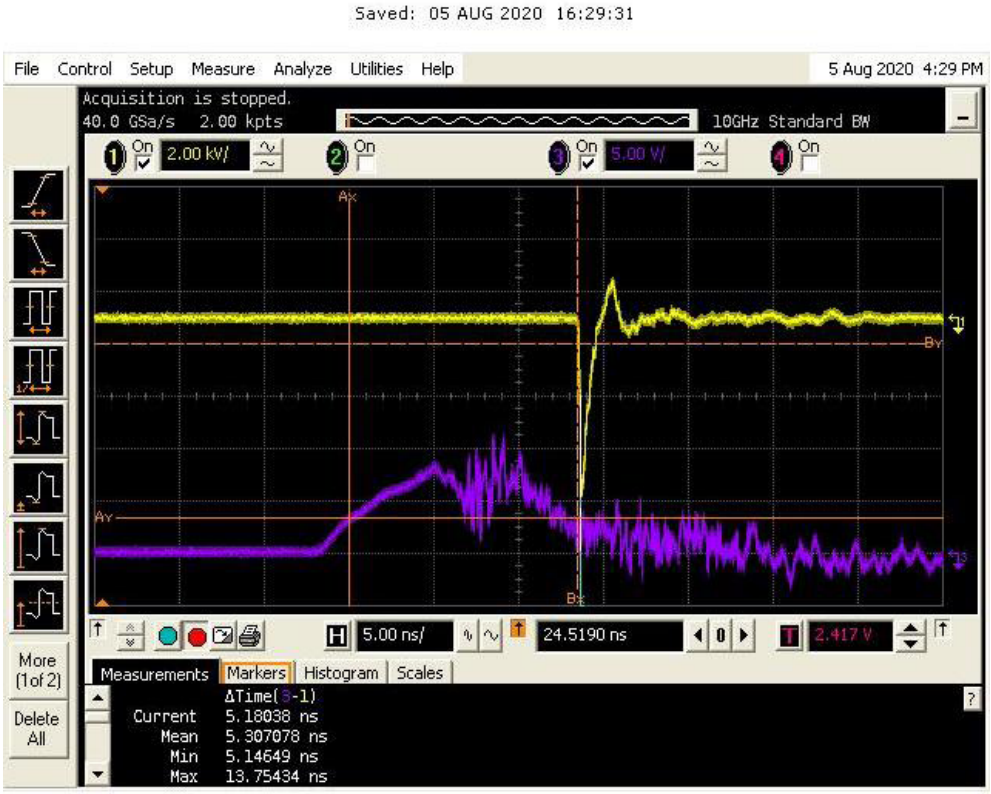
Measure

	ΔTime(3-1)
Current	Source off
Mean	----------
Min	----------
Max	----------
Range	----------
Std Dev	----------
# of Meas	----------

Marker

			X	Y
Current	Source off	A——(1) =	2.1560 ns	3.00 V
Mean	----------	B---(1) =	27.97778 ns	-1.00000 kV
Min	----------	Δ =	25.8218 ns	-1.00300 kV
Max	----------	1/ΔX =	38.7269 MHz	
Range	----------			
Std Dev	----------			

Figure 6 Trigger delay ~25.8ns



Acquisition	Sampling mode real time Normal Memory depth automatic 2002 pts Sampling rate automatic Sampling rate 40.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 2.00 kV/ Offset -3.0 kV Coupling DC Impedance 50 Ohms
Channel 3	Scale 5.00 V/ Offset 14.93 V Coupling DC Impedance 50 Ohms
Channel 4	Scale 10 mV/ Offset 2.400 V Coupling DC Impedance 50 Ohms
Time base	Scale 5.00 ns/ Position 24.5190 ns Reference center
Trigger	Mode edge Sweep auto Sensitivity high Holdoff time 100 ns Source channel 4 Trigger level 2.4168 V Slope rising

Measure

	ΔTime(3-1)
Current	5.18038 ns
Mean	5.307078 ns
Min	5.14649 ns
Max	13.75434 ns
Range	8.60785 ns
Std Dev	835.260 ps
# of Meas	954
From Num	1
From Dir	Rising
From Lvl	Middle
To Num	1
To Dir	Falling
To Lvl	Middle

Marker

		X	Y
Current	A——(3) =	14.52241 ns	3.25 V
Mean	B---(1) =	27.97778 ns	-1.00 kV
Min	Δ =	13.45537 ns	-1.00325 kV
Max	1/ΔX =	74.31976972762 MHz	
Range			
Std Dev			

Figure 7 Sync. output timing. The sync. output arrives ~13.5ns before the main pulse.

Figure 8 Pulse inverted with pulse inverting transformer.

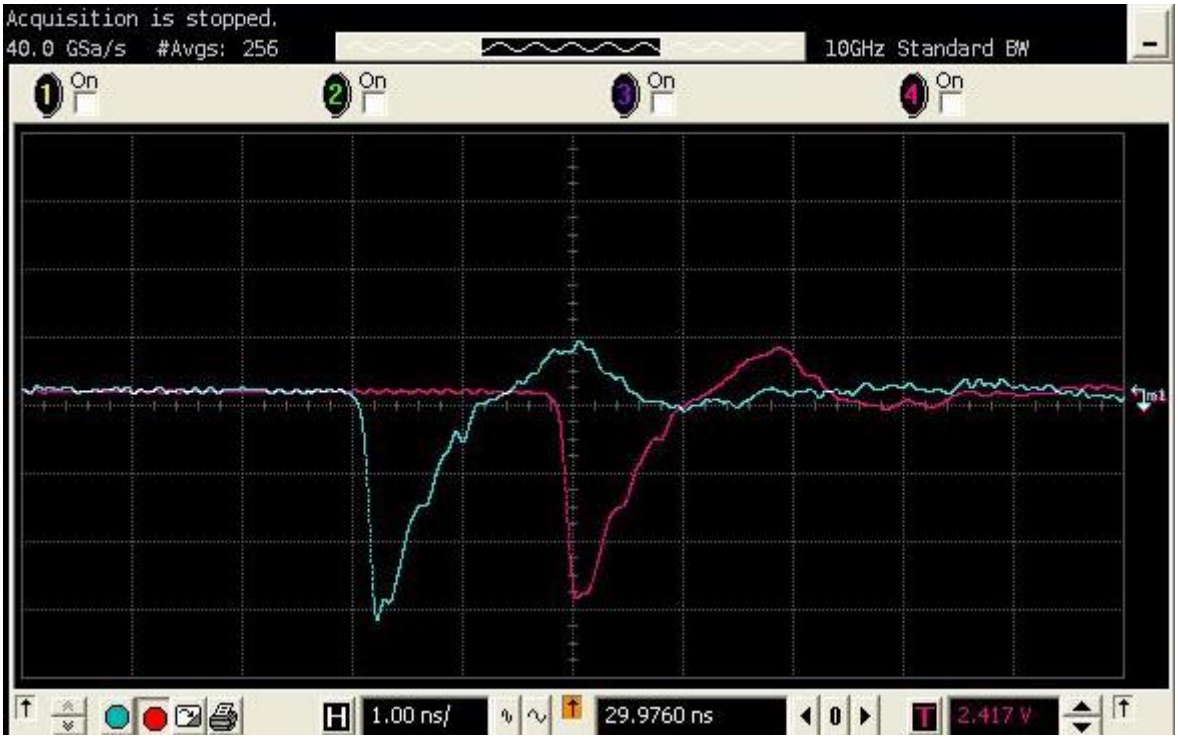


Figure 9 The inverted pulse is re-inverted in the scope (magenta trace) to compare with the original.

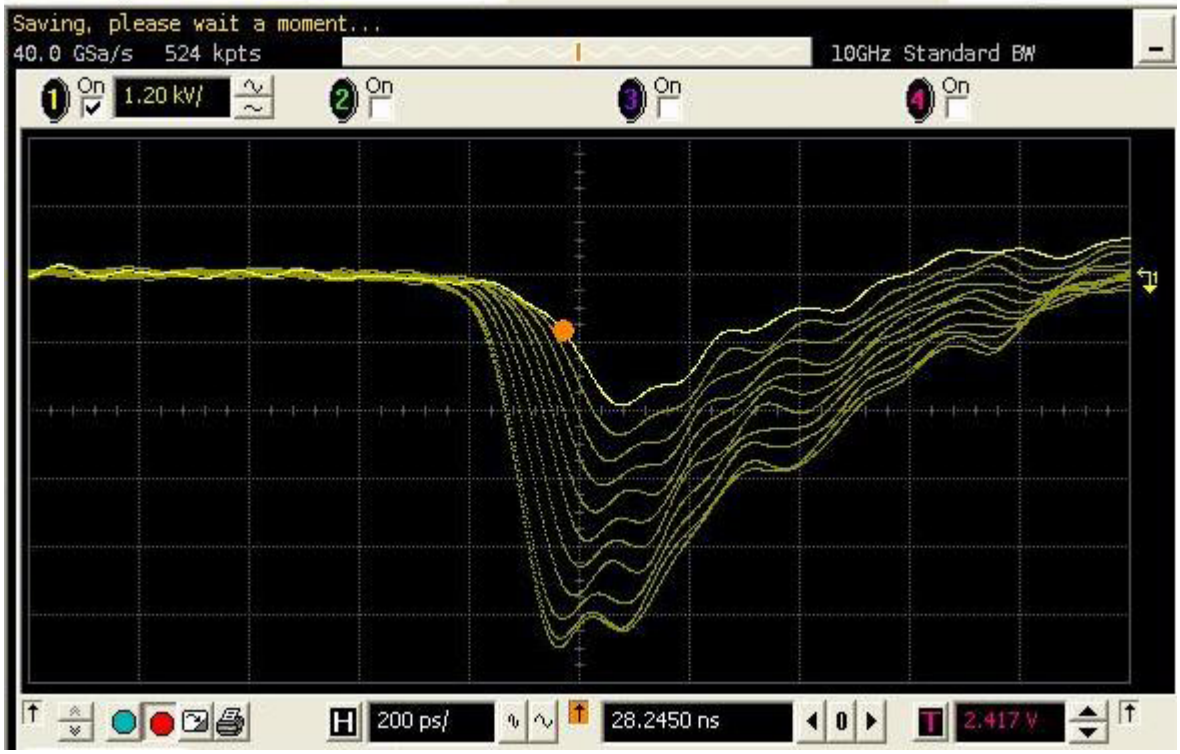


Figure 10 Variation in amplitude at 1kHz. Traces at every full turn of the 10 turn pot.

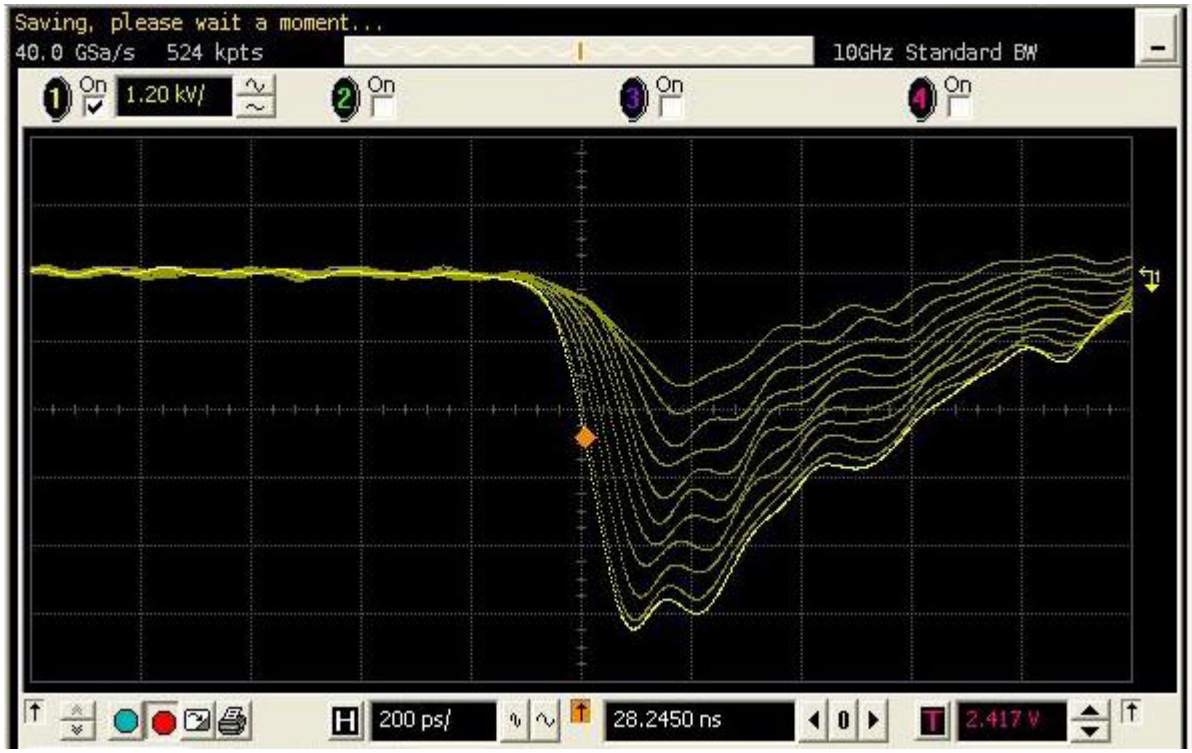


Figure 11 Variation in amplitude at 10kHz. Traces at every full turn of the 10 turn pot.