Kentech Instruments Ltd.

Notes on the use of

PBG7 pulser system
Serial No. *(special)*

It is important to read this manual before operating the system.

2nd April 2004

Caution

PBG7 Pulser System Serial No. xxxxx

This equipment is a scientific research tool that has been intentionally designed to generate short high energy ultrawideband electromagnetic pulses and the EM emissions will be highly sensitive to the load applied by the user. It is suitable for use only in a sealed electromagnetic or laboratory environment, unless it is used in a system that has been verified by the system builder to comply with EC directive 89/336/EEC. It will interfere with and may damage sensitive equipment in the local environment. Use of this equipment outside of a sealed electromagnetic or laboratory environment may result in prosecution. This equipment must not be used or operated in a domestic environment or as part of a safety critical or life support system.

With an appropriate load, and when fitted into a suitable 19" rack system that prevents access to the rear panel connectors, the unit is safe for use by personnel with relevant technical qualifications and UWB training 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 including aeronautical and other safety critical systems. It can cause terminal failure of vital medical electronic systems such as pacemakers and other life support systems and it can inhibit and damage communications systems. The main 45kV 150ps output is likely to be particularly damaging but the 12kV 100ps and 6kV 100ps outputs must also be treated with caution.

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 pulse outputs from this pulse generator will destroy most 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.

The system contains 120W of 4kV power supplies, this can cause death or injury from burns

and electric shock. Do not remove covers. Return to Kentech Instruments Ltd. for servicing. Clean only with soft dry cloth.

Check that all relevant connectors are in place on the rear panels before applying ac power. Do not disconnect the multiway connectors on the rear of the PBG7 45kV output module and PBG7 HV power supply module for 3 minutes after removing ac power.

The equipment must be grounded via the power connector to maintain protection from electric shock.

Introduction

This PBG7 system is a state of the art avalanche pulser utilising a series parallel array of avalanche stacks coupled with various transformers to generate a large single output amplitude of ≥45kV into 50Ω.

The instrument consists of five 19" rack mounting modules which should be mounted into a single 19" enclosure that prevents access to the rear panel connectors. These are:-

1. PBG7 control and trigger module
2. Four channel delay module
3. PBG5 four channel trigger module
4. PBG7 45kV output module
5. PBG7 HV power supply module

The system can be operated in each of three configurations:-

PBG1 configuration. One output signal is taken from the 6kV output on the PBG7 control and trigger module, the other four modules are disconnected and not used.

PBG5 configuration. Four output signals are taken from the four 12kV outputs on the PBG5 four channel trigger module. The PBG7 control and trigger module, Four channel delay module and PBG5 four channel trigger module are used, the other two modules are unused and disconnected.

PBG7 configuration. One output signal is taken from the 45kV output on the PBG7 45kV output module. All modules are used except the four channel delay module which should always remain powered down but must remain in circuit to preserve correct trigger timing.

Note that for each configuration it is necessary to configure both hardware and software - see below.

The PBG7 control and trigger module is 3U high and contains the microprocessor and low voltage trigger electronics and a PBG1 type pulse output board generating approx 6kV amplitude into 50Ω with a risetime <150ps. In PBG5 or PBG7 configurations the output must be connected using the short N to N type 50Ω conformable cable provided to the internal 4 way splitter. This generates 4 approximately simultaneous trigger signals to be used to trigger the PBG5 four channel trigger module. The rear panel has a female 9 way D type connector for RS232 to an optional computer and a male 9 way D connector which is for system control. In PBG5 or PBG7 configurations the sysytem control should be connected to the PBG5 four channel trigger module using the screened D to D type lead provided. There are also one IEC power inlet and two IEC power outlets which should be used to power the PBG5 four channel trigger module and PBG7 HV power supply module.

The four channel delay module is 3U high and sits between the PBG7 control and trigger module and the PBG5 four channel trigger module. Except in PBG1 configuration it should be connected to both these modules using the 8 BNC to BNC cables provided. It's function is to allow independent variation of the delay of the 4 trigger signals in PBG5 configuration to allow beam steering using a 4 element antenna array. In PBG7 configuration the delay module is not used and should remain connected via the 8 BNC to BNC cables but powered down. This module is completely independent of the rest of the system, it has it's own microprocessor with RS232 connection and power input on the rear panel and no connection to the system control link.

PBG5 four channel trigger module is 6U high. It has four BNC trigger inputs and four high voltage HN pulse outputs of approx 12kV amplitude into 50Ω. In PBG7 configuration these outputs are used to trigger the PBG7 45kV output module using the 4 HN to HN cables provided. In PBG5 configuration the outputs can be used to drive an antenna array. The IEC power input must be connected to an outlet on the PBG7 control and trigger module. The 9 way D type control link connectors are daisy chained together, one must be connected to the PBG7 control and trigger module and one to the PBG7 HV power supply module.

PBG7 45kV output module is 9U high. It has four HN 12kV trigger inputs and one pulse output of approx 45kV amplitude using a special Kentech connector. On the rear panel are six multiway connectors and two D type connectors which must be connected to the PBG7 HV power supply module using the cables provided.

PBG7 HV power supply module is 3U high. The six multiway and two D type connectors on

the rear panel must be connected to the PBG7 45kV output module. The IEC power input must be connected to an outlet on the PBG7 control and trigger module.

Use

The equipment should be mounted in a suitable 19" rack. The rear panel and front panel connections should be added depending on the configuration required (PBG1, PBG5 or PBG7) as shown in the diagram below.

Note that ac power for the PBG5 four channel trigger module and PBG7 HV power supply module must be taken from the PBG7 control and trigger module using the IEC male/female leads supplied. The front panel switch will therefore switch power to all three modules. This is important for the software to power up correctly. The four channel delay module is completely independent and should have its independent power supply. The external ac power required is 110 to 240V 50 or 60Hz, approx 250W.

The system is air cooled and at maximum repetition rate the air cooled system will dissipate approximately 250W of thermal power, consequently it requires an adequate and unobstructed flow of clean air.

RF emission from the circuitry inside the PBG5 four channel trigger module and particularly the PBG7 45kV output module is severe, the modules rely upon the integrity of their enclosures to contain the radiation. Further, because of the high power and high frequency requirements the the modules use their chassis as ground return and screen. Therefore it is important for correct operation that all covers remain in place, all screws and fasteners remain secure, and the equipment is earthed via the power lead.

The PBG5 four channel trigger module, PBG7 45kV output module and PBG7 HV power supply module are controlled and tested by the microprocessor in the trigger unit by means of the various control and monitor links on rear panels. It is important that all rear panel connections are configured correctly and all connectors with locking screws are tightened correctly.

If remote control by RS232 is employed we recommend that only screened cables should be use and that the cables should be fitted with clamp on ferrites near to the PBG7 system.

The trigger signal can be generated internally or applied externally to the trigger unit. When external triggering is used, the trigger signal should be ≥5 volts into 50Ω with a fast rising edge (<5ns) to maintain the low jitter of the system. Do not trigger the generator at a rate in excess of 500Hz. The external trigger input is a BNC connector mounted on the front panel. When the trigger unit is triggered the "triggered" LED on the front panel will flash.
There are an additional "triggered" LEDs on the PBG5 four channel trigger module and PBG7 HV power supply module showing the state of the trigger stacks.

In the internal trigger, single shot and delayed modes there is an internal delay which may be adjusted by the user. Another front panel BNC connector "pre-trigger output" provides a signal of ~10V into 50Ω. This is approximately synchronous with the trigger, in advance of the high voltage pulse output and may be used to trigger auxiliary equipment such as a sampling oscilloscope. There are thermal drifts in the delay generator which will stabilise after the pulser has been switched on for ~20 minutes.

The internal trigger generator will only run if the inhibit BNC is shorted, if remote control is not required this may be conveniently achieved using the 50Ω terminator supplied, plugged onto the connector.

In "direct" mode the external trigger signal is applied directly to the avalanche stack and the low level circuitry is bypassed to give the minimum trigger delay. There is no monitor output generated in this mode.

The main output of the PBG7 45kV output module appears at the front panel connector which is a special connector of Kentech design. There are drawings of this connector at the rear of this manual to allow the user to manufacture additional units as required. The pulser will tolerate open circuit, short circuit and arc loads at the end of a 50Ω cable longer than 1m. However prolonged operation like this without a resistive load to dissipate residual energy from the pulse may degrade the lifetime of the insulator in the output connector. This is because the pulse energy is trapped within the output cable for a prolonged time and may cause partial discharges which erode the insulation. We believe the worst case scenario from this perspective is a short circuit at the end of a few nanoseconds of cable.

It is not necessary to have a well matched 50Ω load to preserve pulser lifetime, but we recommend the load should present a dc resistive load to the pulser in the range of approx 25 to 100 ohms.

If it is necessary to monitor or characterise the pulse output then suitable attenuators must be used. **The 12kV and 45kV pulse outputs from this unit are capable of destroying most types of power attenuators and terminators including most of the high pulse power types**. The pulser was characterised at the factory using two methods:-

a) For the 12kV outputs a x2 Kentech suicide T attenuator was followed by two x10 Barth 142-NMFP-20 attenuators then two radial x10 attenuators. These outputs unit will destroy the Barth 142 if used without the T.

b) For the 45kV output a special x10 Kentech resistive attenuator was used followed by two x10 Barth 142-NMFP-20 attenuators then two radial x10 attenuators.

See the photographs enclosed in this manual.

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

If the output of the pulser is to be used directly or via any passive network it is essential that cable lengths are kept as short as possible and that only high quality cable is used. This will enable the fast rising edge generated by the unit to reach the load without serious degradation.

The PBG7 is controlled by the microprocessor unit with LCD display and four button keypad. On power up, the trigger input of the avalanche stack is disabled, note that it is always necessary to issue commands to the microprocessor unit via the keyboard or the RS232 interface to enable the trigger circuit and make the pulser run normally. Please see the software section below.

The μP unit includes a self test routine. This should be run at least once a day at power up, or at any change of configuration and any faults noted, see sections on stack faults and comms faults below. Otherwise there is no regular maintenance required. There is some redundancy in the unit by virtue of its design, and the unit may continue to operate at slightly reduced amplitude

with several faults present. The switching elements in these avalanche pulsers generally have a long life, but their life is finite and therefore it is sensible to switch off the unit or at least not trigger it when it is not required. It is not possible to write a test routine to find 100% of all possible faults, so if the unit appears to malfunction, and the procedures below fail to isolate the problem please contact Kentech Instruments for advice.

There is a facility provided under the Stack Status menu to disable individual stacks. This may be used in certain circumstances to disable faulty stacks that are causing problems. It is also permissible to use this facility to disable output stacks to reduce the output amplitude. Note this information is stored in non volatile memory, ie it will be remembered even when ac power is removed. If the output amplitude appears low please check under the system status menu that all 86 stacks are enabled.

IMPORTANT

When fitting the output connector ensure that:
i) all six fixing screws are tightened to maintain a low impedance ground connection
ii) the plastic insulating collar and sprung centre contact are fitted
Failure to fit the fixing screws will result in severe RF emission.

PBG7 V1.0 Software

The microprocessor used is a Hitachi H8/532 running a FORTH operating system and it is programmed in the FORTH programming language. It is not necessary to have any knowledge of the H8 or FORTH to operate the pulser.

a) Main menu

On power up or on entering LOCAL mode from remote, the unit will briefly display the "Kentech Instruments" banner and then the main menu:-

```
Run...            >
Test menu...      >
System status...  >
Stack status...   >
```

The cursor will be under Run as shown, press the **up** and **down** keys to select one of Run, Test , System status or Stack status then press the right key to execute. While the main menu is displayed, the serial port is monitored. If the μP receives a character it will enter REMOTE mode.

b) Run

The display will indicate that the pulser is running and the configuration selected (see system status to edit configuration).

```
<Running

 PBG7 Configuration
```

The HT is switched on to each enabled stack. The trigger is enabled, and the unit will now run normally while waiting for the user to press a key. All keys are ignored except for **left** which causes the trigger to be disabled, the HT to be switched off and a return to the main menu

c) Test menu

```
<Voltage test...    >
 Test mode 7...     >
 Test mode 5...     >
```

Press up or down for appropriate selection, then right to select.

d) Voltage test

The display will indicate that the pulser is being tested and the configuration selected (see system status to edit configuration).

```
Testing...

PBG7 Configuration
```

First, depending on the configuration the processor checks that it can communicate with the PBG5 four channel trigger module and the PBG7 HV power supply module.

Then each of a total of up to 86 stacks is powered up in turn. Its voltage is measured and checked to be within acceptable limits. This takes a few seconds, during this period all keys are ignored.

Finally a summary of the test is displayed

```
<PBG7 system tested
 PBG5 comms pass
 PBG7 comms fail
  3 stacks faulty
```

The first line displays the configuration selected. The second and third lines display the status of the necessary system control links for this confguration to each of the PBG5 four channel trigger module (PBG5) and PBG7 HV power supply module (PBG7). If a comms fail is indicated it is necessary to investigate and rectify. Note that modules that are not powered up should be disconnected from the control link.

The fourth line displays the number of stacks whose voltage is outside the test limits. Only faults in stacks that are enabled are counted. Press left to return to main menu.

d) Test mode 7

```
<PBG7Row# {S22} =  0
 Run -row...       >
 PBG7Card#      =  0
 Run -card...      >
```

Test mode 7 is provided to help to isolate faulty stacks within the PBG7 module using a matrix method.
The first and third line allow the selection of a row number and card number respectively within the PBG7 module. The second and third line allow one to run the pulser with a complete row of stacks disabled or a complete card disabled respectively. For any given row number and card number there is just one stack in common, this number is displayed in brackets after “S” on line one.

See **Dealing with stack faults** for details of useage.

e) Test mode 5

```
<PBG5Row# {S 2} =  0
 Run -row...       >
 PBG5Card#      =  0
 Run -card...      >
```

Test mode 5 is provided to help to isolate faulty stacks within the PBG5 module using a matrix method.
The first and third line allow the selection of a row number and card number respectively within the PBG5 module. The second and third line allow one to run the pulser with a complete row of stacks disabled or a complete card disabled respectively. For any given row number and card number there is just one stack in common, this number is displayed in brackets after “S” on line one.

See **Dealing with stack faults** for details of useage.

f) System status

The display will indicate the system status page.

```
<Config = PBG7
 82 stacks enabled

 Test results...    >
```

The cursor will be under Config as shown.
From this cursor postion:-
Left returns to main menu
Right moves cursor to under PBG7, press **up/down** to edit configuration then **left** to exit.
Down moves cursor to under Test, **right** displays the test result summary as above.

The configuration is kept in nonvolatile memory, it is stored as you exit the system status page. Therefore if you have edited the configuration you will see this message momentarily as you exit.

```
 Saving user data..."
```

g) Stack status

The selected stack number is displayed.

```
<Stack#= 20
 ( PBG5  stack# 18 )
 Enable= 1
 Test% = 100  99  99
```

The cursor will be under Stack as shown.
From this cursor postion:-
Left returns to main menu
Right moves cursor to under 20, press **up/down** to change selected stack then **left** to exit.
Down moves cursor to under Enable

With cursor under Enable
Right moves cursor under 1

The configuration is kept in nonvolatile memory, it is stored as you exit the system status page. Therefore if you have edited the configuration you will see this message momentarily as you exit.

The state of the ENABLE flag is displayed. Press Down/No to return to the FAULT flag display, Left or Right to toggle the flag, Up/Yes has no effect. The ENABLE flags are stored in battery backed RAM.

h) REMOTE

The μP will enter REMOTE mode if it receives an ESC character while displaying the main menu. In REMOTE, the unit accepts commands in simple ASCII characters and transmits its responses. There is no handshake, this mode is designed to work with a simple terminal or terminal emulator.

On entering REMOTE, the μP prints a "Kentech Instruments" banner, then waits for the user commands. The commands are:-

RUN {cr} to enable all stacks with enable flag set and trigger, thereafter any character will terminate run mode and disable all stacks

TEST {cr} to run self test routine and print out a summary of results

.TESTRESULTS {cr} to print out summary of test results from the self test routine

PBG1CONFIG {cr} to select PBG1 configuration, you need also to change hardware
PBG5CONFIG {cr} to select PBG5 configuration, you need also to change hardware

PBG7CONFIG {cr} to select PBG7 configuration, you need also to change hardware

.STATUS {cr} to give a listing of status information, ie the current configuration setting and the number of stacks enabled

n .STACKSTATUS {cr} to give a listing of status information for stack n, ie the location within the sytem, the state of the enable flag and any test voltages as a % of initial value

.ALLSTATUS {cr} to give a listing of status information and stack information for all stacks

n +ENABLE {cr} to set high the enable flag for stack no. n
n -ENABLE {cr} to reset low the enable flag for stack no. n
LOCAL {cr} to return to local mode ok

On returning to local mode, the "Kentech Instruments" banner is displayed once again on the LCD, quickly followed by the main menu.

i) Example dialogue in REMOTE mode

Transmitted commands are shown in red

```
TDS2020 Fig-FORTH    Triangle Digital Services Ltd   Ver 2.13
 ok
RUN
Running PBG7 configuration
Press any key to stop
Stopped ok
TEST
Testing PBG7 configuration
PBG7 system tested
PBG5 comms pass
PBG7 comms pass
 0 stacks faulty ok
.TESTRESULTS
```

PBG7 system tested
PBG5 comms pass
PBG7 comms pass
0 stacks faulty ok
PBG1CONFIG ok
.STATUS
PBG1 configuration
2 stacks enabled ok
PBG7CONFIG ok
.STATUS
PBG7 configuration
86 stacks enabled ok
ok
42 .STACKSTATUS
Stack#= 42 (PBG7 stack# 20) Enable= 1 Test% = 100 100 100 ok
42 DISABLE DISABLE ? - UNDEFINED
ok
42 +ENABLE ok
42 .STACKSTATUS
Stack#= 42 (PBG7 stack# 20) Enable= 1 Test% = 100 100 100 ok
42 -ENBLE -ENBLE ? - UNDEFINED
42 -ENABLE ok
42 .STACKSTATUS
Stack#= 42 (PBG7 stack# 20) Enable= 0 Test% = 100 100 100 ok
.STATUS
PBG7 configuration
85 stacks enabled ok
42 +ENABLE ok
.STATUS
PBG7 configuration
86 stacks enabled ok
.ALLSTATUS
PBG7 configuration
86 stacks enabled
Stack#= 0 (PBG1 stack# 0) Enable= 1 Test% = 100 100 100
Stack#= 1 (PBG1 stack# 1) Enable= 1 Test% = 100 100 100

Stack#= 2 (PBG5 stack# 0) Enable= 1 Test% = 100 100 100
Stack#= 3 (PBG5 stack# 1) Enable= 1 Test% = 100 100 100
Stack#= 4 (PBG5 stack# 2) Enable= 1 Test% = 99 99 100
Stack#= 5 (PBG5 stack# 3) Enable= 1 Test% = 100 99 100
Stack#= 6 (PBG5 stack# 4) Enable= 1 Test% = 100 100 100
Stack#= 7 (PBG5 stack# 5) Enable= 1 Test% = 100 100 100
Stack#= 8 (PBG5 stack# 6) Enable= 1 Test% = 100 100 100
Stack#= 9 (PBG5 stack# 7) Enable= 1 Test% = 99 99 100
Stack#= 10 (PBG5 stack# 8) Enable= 1 Test% = 100 100 100
Stack#= 11 (PBG5 stack# 9) Enable= 1 Test% = 100 100 100
Stack#= 12 (PBG5 stack# 10) Enable= 1 Test% = 100 100 100
Stack#= 13 (PBG5 stack# 11) Enable= 1 Test% = 100 100 100
Stack#= 14 (PBG5 stack# 12) Enable= 1 Test% = 100 99 100
Stack#= 15 (PBG5 stack# 13) Enable= 1 Test% = 100 100 100
Stack#= 16 (PBG5 stack# 14) Enable= 1 Test% = 100 100 100
Stack#= 17 (PBG5 stack# 15) Enable= 1 Test% = 100 100 100
Stack#= 18 (PBG5 stack# 16) Enable= 1 Test% = 100 100 100
Stack#= 19 (PBG5 stack# 17) Enable= 1 Test% = 100 100 100
Stack#= 20 (PBG5 stack# 18) Enable= 1 Test% = 100 99 100
Stack#= 21 (PBG5 stack# 19) Enable= 1 Test% = 100 99 100
Stack#= 22 (PBG7 stack# 0) Enable= 1 Test% = 100 100 100
Stack#= 23 (PBG7 stack# 1) Enable= 1 Test% = 100 100 100
Stack#= 24 (PBG7 stack# 2) Enable= 1 Test% = 100 100 100
Stack#= 25 (PBG7 stack# 3) Enable= 1 Test% = 100 100 100
Stack#= 26 (PBG7 stack# 4) Enable= 1 Test% = 100 100 100
Stack#= 27 (PBG7 stack# 5) Enable= 1 Test% = 100 100 100
Stack#= 28 (PBG7 stack# 6) Enable= 1 Test% = 100 100 100
Stack#= 29 (PBG7 stack# 7) Enable= 1 Test% = 100 100 100
Stack#= 30 (PBG7 stack# 8) Enable= 1 Test% = 100 100 100
Stack#= 31 (PBG7 stack# 9) Enable= 1 Test% = 100 100 100
Stack#= 32 (PBG7 stack# 10) Enable= 1 Test% = 100 100 100
Stack#= 33 (PBG7 stack# 11) Enable= 1 Test% = 100 100 100
Stack#= 34 (PBG7 stack# 12) Enable= 1 Test% = 100 100 100
Stack#= 35 (PBG7 stack# 13) Enable= 1 Test% = 100 100 100
Stack#= 36 (PBG7 stack# 14) Enable= 1 Test% = 100 100 100
Stack#= 37 (PBG7 stack# 15) Enable= 1 Test% = 100 100 100

Stack#= 38 (PBG7 stack# 16) Enable= 1 Test% = 100 100 100
Stack#= 39 (PBG7 stack# 17) Enable= 1 Test% = 100 100 100
Stack#= 40 (PBG7 stack# 18) Enable= 1 Test% = 100 100 100
Stack#= 41 (PBG7 stack# 19) Enable= 1 Test% = 100 99 100
Stack#= 42 (PBG7 stack# 20) Enable= 1 Test% = 100 100 100
Stack#= 43 (PBG7 stack# 21) Enable= 1 Test% = 100 100 100
Stack#= 44 (PBG7 stack# 22) Enable= 1 Test% = 100 100 100
Stack#= 45 (PBG7 stack# 23) Enable= 1 Test% = 100 100 100
Stack#= 46 (PBG7 stack# 24) Enable= 1 Test% = 100 100 100
Stack#= 47 (PBG7 stack# 25) Enable= 1 Test% = 100 100 100
Stack#= 48 (PBG7 stack# 26) Enable= 1 Test% = 100 100 100
Stack#= 49 (PBG7 stack# 27) Enable= 1 Test% = 100 100 100
Stack#= 50 (PBG7 stack# 28) Enable= 1 Test% = 100 100 100
Stack#= 51 (PBG7 stack# 29) Enable= 1 Test% = 100 100 100
Stack#= 52 (PBG7 stack# 30) Enable= 1 Test% = 100 100 100
Stack#= 53 (PBG7 stack# 31) Enable= 1 Test% = 100 100 99
Stack#= 54 (PBG7 stack# 32) Enable= 1 Test% = 100 100 100
Stack#= 55 (PBG7 stack# 33) Enable= 1 Test% = 100 100 100
Stack#= 56 (PBG7 stack# 34) Enable= 1 Test% = 100 100 100
Stack#= 57 (PBG7 stack# 35) Enable= 1 Test% = 100 100 99
Stack#= 58 (PBG7 stack# 36) Enable= 1 Test% = 100 100 100
Stack#= 59 (PBG7 stack# 37) Enable= 1 Test% = 100 100 100
Stack#= 60 (PBG7 stack# 38) Enable= 1 Test% = 100 100 100
Stack#= 61 (PBG7 stack# 39) Enable= 1 Test% = 100 99 100
Stack#= 62 (PBG7 stack# 40) Enable= 1 Test% = 100 100 100
Stack#= 63 (PBG7 stack# 41) Enable= 1 Test% = 100 100 100
Stack#= 64 (PBG7 stack# 42) Enable= 1 Test% = 100 100 100
Stack#= 65 (PBG7 stack# 43) Enable= 1 Test% = 100 100 100
Stack#= 66 (PBG7 stack# 44) Enable= 1 Test% = 100 100 100
Stack#= 67 (PBG7 stack# 45) Enable= 1 Test% = 100 100 100
Stack#= 68 (PBG7 stack# 46) Enable= 1 Test% = 100 100 100
Stack#= 69 (PBG7 stack# 47) Enable= 1 Test% = 100 100 100
Stack#= 70 (PBG7 stack# 48) Enable= 1 Test% = 100 100 100
Stack#= 71 (PBG7 stack# 49) Enable= 1 Test% = 100 100 100
Stack#= 72 (PBG7 stack# 50) Enable= 1 Test% = 100 100 100

Stack#= 73 (PBG7 stack# 51) Enable= 1 Test% = 100 100 100
Stack#= 74 (PBG7 stack# 52) Enable= 1 Test% = 100 100 100
Stack#= 75 (PBG7 stack# 53) Enable= 1 Test% = 100 100 100
Stack#= 76 (PBG7 stack# 54) Enable= 1 Test% = 100 100 100
Stack#= 77 (PBG7 stack# 55) Enable= 1 Test% = 100 100 100
Stack#= 78 (PBG7 stack# 56) Enable= 1 Test% = 100 100 100
Stack#= 79 (PBG7 stack# 57) Enable= 1 Test% = 100 100 100
Stack#= 80 (PBG7 stack# 58) Enable= 1 Test% = 100 100 100
Stack#= 81 (PBG7 stack# 59) Enable= 1 Test% = 100 100 100
Stack#= 82 (PBG7 stack# 60) Enable= 1 Test% = 100 100 100
Stack#= 83 (PBG7 stack# 61) Enable= 1 Test% = 99 99 100
Stack#= 84 (PBG7 stack# 62) Enable= 1 Test% = 100 100 100
Stack#= 85 (PBG7 stack# 63) Enable= 1 Test% = 100 100 100 ok
ok
LOCAL

Note on module names

In the various status displays from the microprocessor, the following abbreviated names are used:-

Full name	**Abbreviation**
PBG7 control and trigger module	PBG1
PBG5 four channel trigger module	PBG5
PBG7 45kV output module and power supply	PBG7

Note on stack numbers

The parameter n here refers to the "global" stack number 0 to 85. This is a number used by the microprocessor to identify uniquely every stack.

Every stack also has a "local" stack number within its module to assist in fault finding, the two are related as follows:-

Global stack number	**Module**	**Local stack number**
0 to 1	PBG1	0 to 1
2 to 21	PBG5	0 to 21
22 to 85	PBG7	0 to 63

f) Software Maintenance

Every effort has been made to minimise the number of errors in the software. Please email reports of any problems to help@kentech.co.uk .

Stack faults

From time to time as the PBG7 unit ages the self test routine will inevitably find faults with the system. If the measured stack voltages are low, say a readout of 80 or 90% this indicates the failure of one or more semiconductor devices. There are thousands of devices in the pulser so provided triggering is stable this will generally have an imperceptible effect on the output and is therefore not too important.

Occasionally a failed device or other fault may cause the pulser to self trigger, ie the triggered leds will flash and output will be present with no trigger input. Do not leave the pulser running for prolonged periods if this codition occurs. In this case one can try to isolate the fault by disabling stacks in turn and operating the pulser to see which stack is causing the problem. Once this is determined, depending on the positon of the stack it may be possible to operate the system with it disabled.

Refering to the diagrams of stack architecture towards the end of the manual. You can see that in effect, in the PBG7 module there are 60 stacks in parallel driving the output. Disabling one stack will reduced the output by 1/60th of maximum amplitude. Therefore it is possible to operate the PBG7 module with one or more stacks disabled. This is in fact an acceptable way of reducing the output amplitude if necessary though there will be progressive deterioration of pulse shape as more stacks are disabled. If you disable several stacks it is best to distribute them over the architecture if possible, eg if you want to disable 16 stacks do not disable local stack numbers 0 to 16, rather choose 0, 4, 8, 12, 16, ... etc.

In the PBG5 module there are four stacks driving each output. Disabling one will cause a reduction of approx 25% in amplitude on one output. This will cause some deterioration of the PBG7 main output in terms of risetime but the the unit should still be operable. Again this can be used as a means of reducing amplitude if necessary.

In the PBG1 module, there are two stacks in series. Therefore the unit is inoperable if either stack is disabled.

To isolate faults that cause self triggering the following procedure is recommended:-

1) First determine which module is causing problems. With the hardware configured for PBG7 operation you can change the software configuration to PBG5 in the system status page, then run the pulser. No power will be applied to stacks in the PBG7 module. Stable triggering now indicates the PBG7 module is at fault.

If maloperation continues, next change the software configuration to PBG1. No power will be applied to stacks in the PBG5 module (or PBG7 module). Stable triggering now indicates the PBG5 module is at fault.

If maloperation continues the PBG1 trigger module is at fault. This being so the system cannot be operated, contact Kentech for advice.

2) If the problem lies within the PBG7 module, you can isolate the fault using a matrix procedure using test mode 7 under the test menu.

In this mode you can disable each one of eight pulse cards in turn and run the pulser, you should find with one particular card disabled the problem goes away. Leave this card selected.

Next you can disable each one of eight rows of stacks in turn and run pulser, again you should find that with one particular row selected the problem disappears. Leave this row selected.

Now with the correct card and correct row selected, the number displayed in brackets on the first line is the global number of the only stack that is common between the card number and the row number, ie the faulty stack. You should disable this stack in the stack status pages and recheck that the pulser runs normally.

Disabling any one stack in the PBG7 module reduces the output by approximately 1/60 part, the unit may be operated with several stacks disabled before repair is required to meet specification.

3) Similarly if the problem lies within the PBG5 module, you can try to isolate the fault using test mode 5. Test mode 5 does not work on card number 0 in the PBG5 module which contains the four trigger stacks numbers 2 to 5 inclusive (local stack numbers 0 to 3), see architecture diagram. If test mode 5 does isolate the fault, then the fault lies in one of the output stacks 6 to 21 inclusive (local stack numbers 4 to 19) and it is permissible to operate in PBG5 and PBG7 configuration with the stack disabled though there may be some increase in risetime.

If the PBG5 module is at fault and test mode 5 does not isolate the fault it is necessary to isolate stack numbers 2 to 5 manually in turn using the stack status pages. If the fault lies within one of these four stacks the PBG5 can still be used on 3 channels but do not operate like this in PBG7 configuration - contact Kentech for advice.

Comms faults

If a PBG5 or PBG7 comms fault is indicated check that the system control linked is correctly configured with all connectors fully engaged and retaining screws tightened and that power is applied to PBG5 and PBG7 modules. Note that if a module is connected to the system control link it must be powered up for the link to operate correctly.
In PBG1 configuration the control link connection to the PBG5 and 7 modules should be removed, in PBG5 configuration the PBG7 connection should be removed.

SPECIFICATIONS

1. PBG7 control and trigger module
2. Four channel delay module
3. PBG5 four channel trigger module
4. PBG7 45kV output module
5. PBG7 HV power supply module

PBG7 control and trigger module

Number of outputs	One
Polarity	Negative
Output amplitude	5.8kV into 50 ohms.
Rise time	<=100ps (10 to 90%)
Pulse width	~2ns FWHM
Maximum rep rate	>=500Hz
Trigger to output jitter	<10ps rms

Output protected against open circuit, short circuit and arcing loads.

MTBF	approx 10^10 shots
Output connector	N

Outputs:

Pulse output	N type
Pretrigger output	BNC ~10V into 50Ω, ~2ns risetime leads main output by selectable delay when delay active
Auxiliary output	BNC ~10V into 50Ω, ~2ns risetime approx synchronous with pulse output.
AC power	2 x IEC outlets
Splitter outputs	4 x BNC, approx 500V into 50Ω 0.5ns risetime
System control	9 way D type male

Inputs:

Trigger input	BNC 5V, 50Ω, <5ns risetime
RS232	9 way D type female 9600 baud, 1 stop bit, no parity, 8 bit pin1 = receive pin3 = transmit pin2 = ground
AC power	IEC, 110 to 240V ac, 50/60Hz

Splitter input	N type, approx 6kV into 50Ω

Timing:

Trigger input to pulse out delay	~31ns (direct mode) ~50ns (delay mode)
Trigger input to pretrig out	~18ns (delay mode - delay set to minimum)
Jitter	<10ps RMS

Controls:

Mode	Sets one of the following modes: Single shot (delay active) 0.05 to 0.5Hz (delay active) 0.5 to 5Hz (delay active) 5Hz to 50Hz (delay active) 50Hz to 500Hz (delay active) External trigger (delay active) External trigger (delay inactive)
Fine rate	Varies internal rate by a ratio of 10:1
Coarse delay	Varies internal delay in ~10ns steps
Fine delay	Varies internal delay continuously over ~15ns
Single shot button	Gives a single trigger in single shot mode
Power	Switches AC power in the pulser
Keypad	Up, Down, Left and Right keys

Indicators:

Power	Shows that AC power is applied and the unit is switched on
Triggered	Illuminates when the unit is triggered
LCD	Four line 20 character display

<u>PBG5 four channel trigger module</u>

Number of outputs	Four
Polarity	negative
Output amplitude	>12kV into 50 ohms.

Rise time	<=100ps (10 to 90%)
Pulse width	~2ns FWHM
Maximum rep rate	>=500Hz
Trigger to output jitter	<15ps rms
Channel to channel jitter	<15ps rms

Output protected against open circuit, short circuit and arcing loads.

MTBF	approx 10^10 shots
Output connectors	HN x 4

Outputs:

Pulse outputs	HN

Inputs:

Trigger inputs	4 x BNC approx 500V iinto 50Ω, <0.5ns risetime
AC power	IEC, 110 to 240V ac, 50/60Hz
System control	2 x 9 way D type

Timing:

(refered to trigger input on the trigger module)

Trigger input to pulse out delay	~52ns (direct mode) ~71ns (delay mode)

Indicators:

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

<u>PBG7 output module and power supply</u>

Number of outputs	One
Polarity	negative
Output amplitude	>45kV into 50 ohms.
Rise time	<=150ps (10 to 90%)
Pulse width	~2ns FWHM
Maximum rep rate	>=500Hz
Trigger to output jitter	<20ps rms
Channel to channel jitter	<15ps rms

Output protected against open circuit, short circuit and arcing loads

MTBF	approx 10^10 shots

Outputs:

Pulse output	special Kentech Instruments connector

Inputs:

Trigger inputs	4 x HN approx 12kV into 50Ω, <100ps risetime
AC power	IEC, 110 to 240V ac, 50/60Hz
System control	9 way D type

Timing:

(refered to trigger input on the trigger module)

Trigger input to pulse out delay	~62ns (direct mode) ~80ns (delay mode)

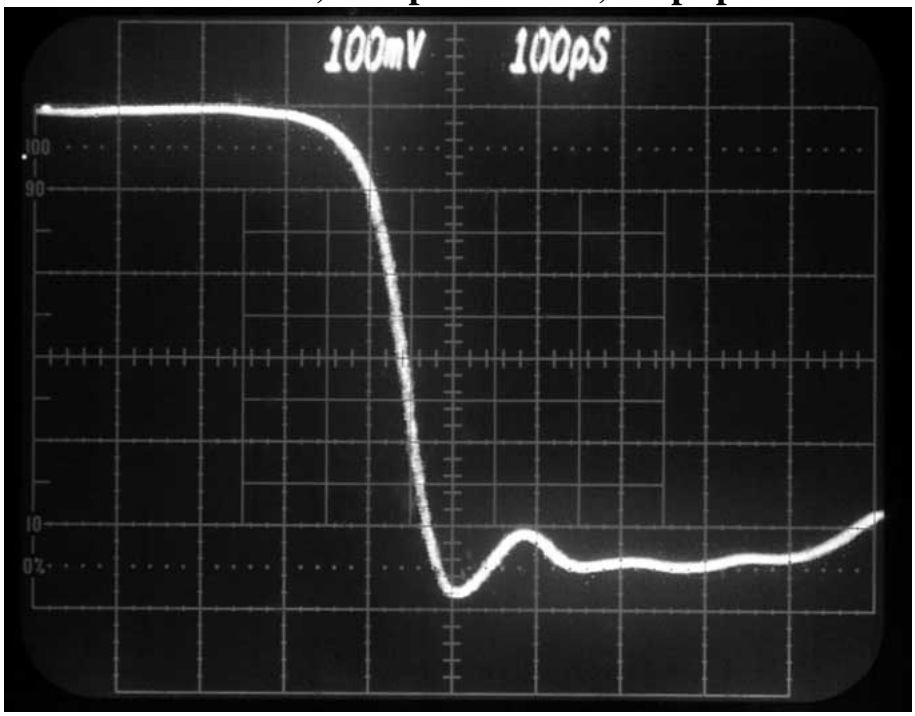
Indicators:

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

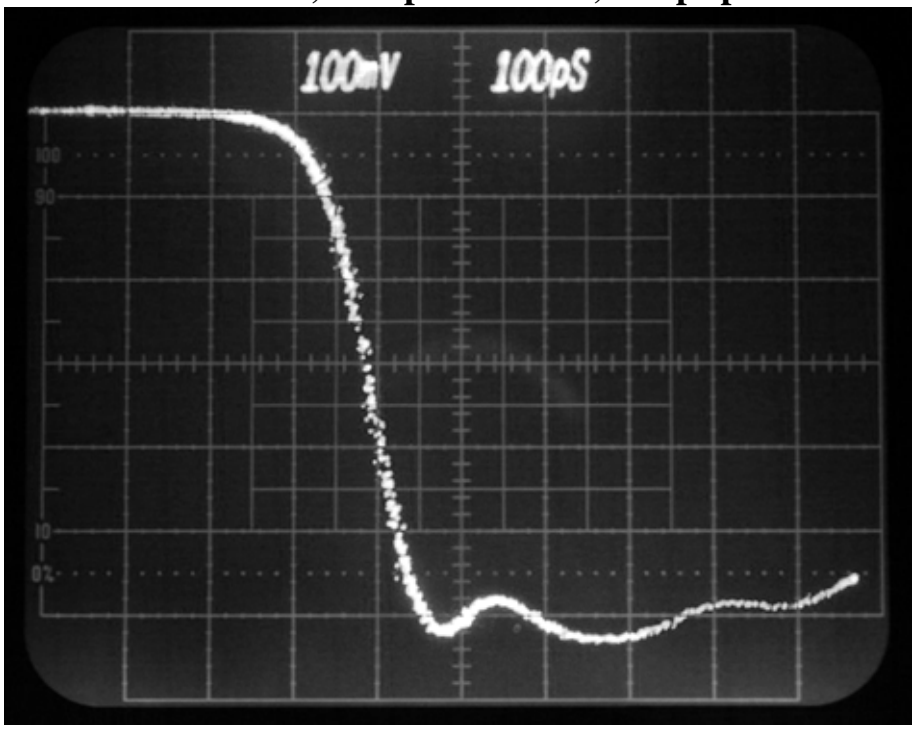
Test data - SN xxxxx

Test equipment:
Tek S4, 7S11, 7T11
Barth 142 20dB x 2, Radial 20dB SMA x 2, suicide T x 2 or special Kentech attenuator.

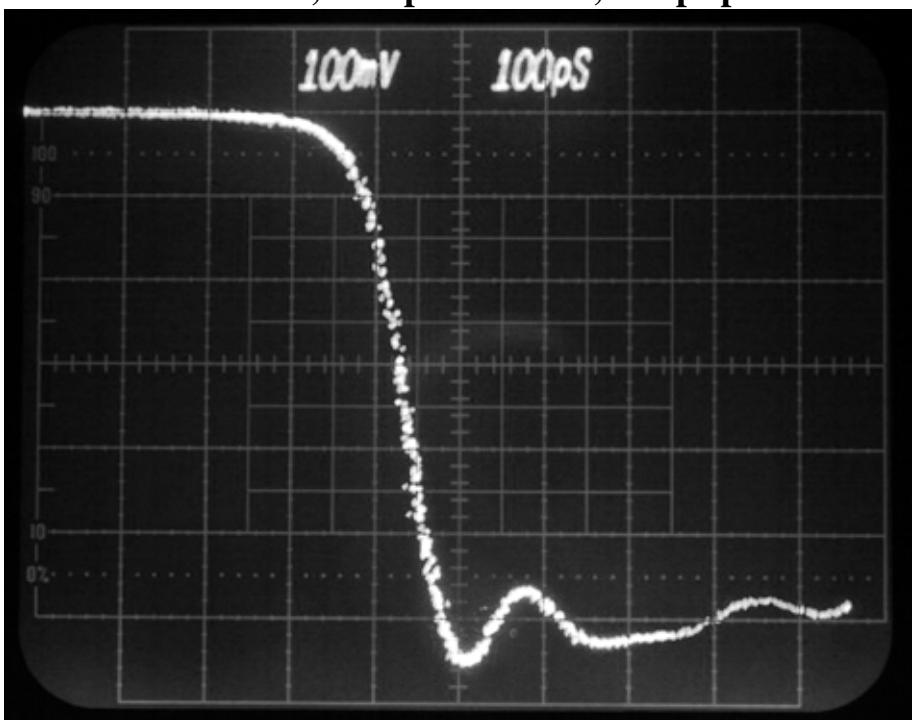
PBG1 output from PBG7 control and trigger module
10000x attenuation, 1kV per division, 100ps per division



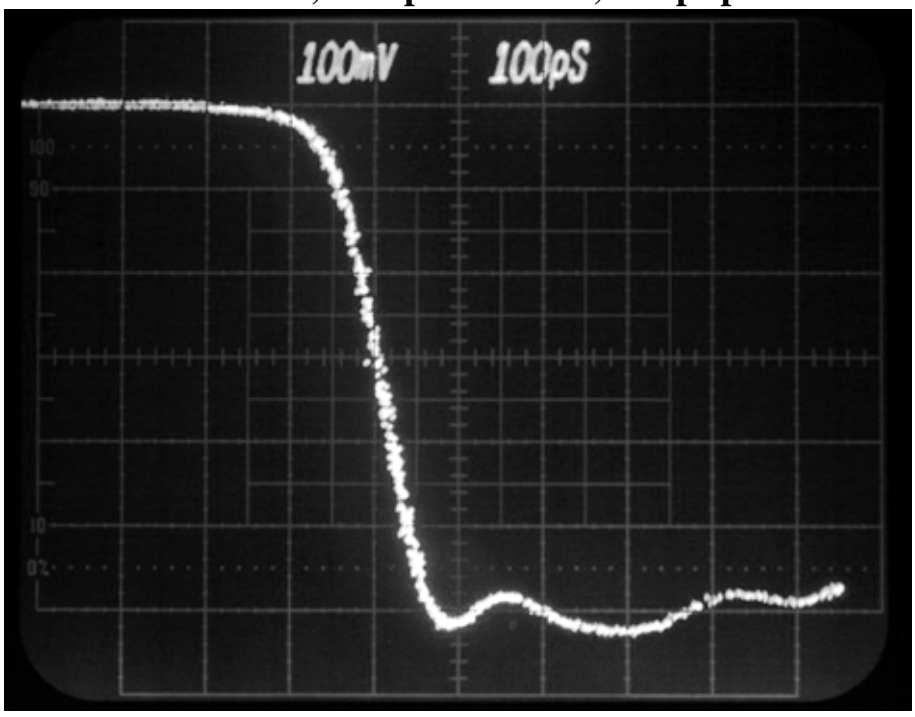
PBG5 channel 1 output using suicide T attenuator.
20000x attenuation, 2kV per division, 100ps per division



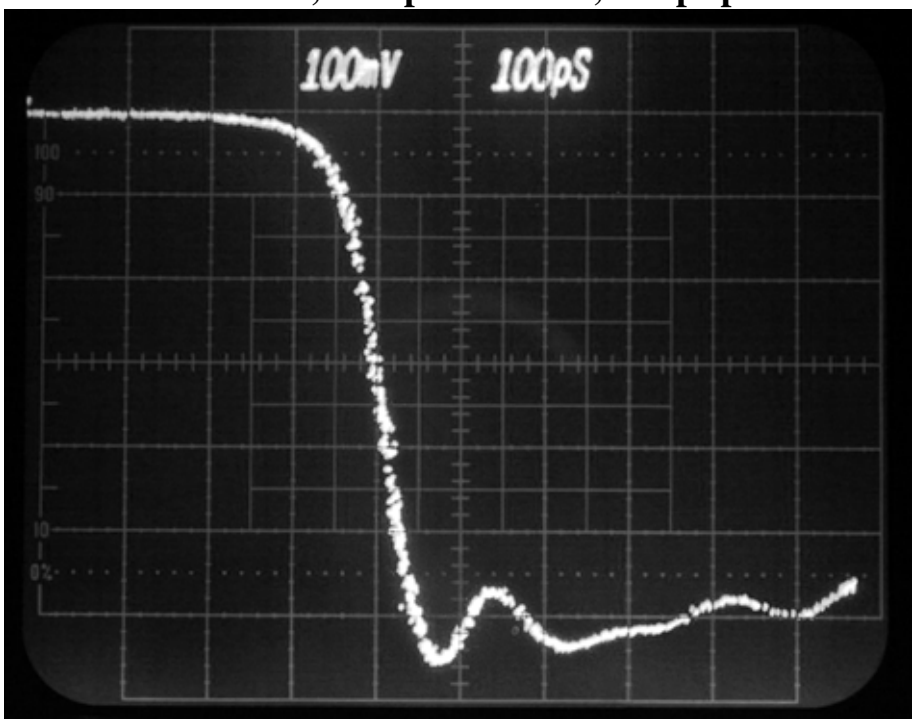
PBG5 channel 2 output using suicide T attenuator.
20000x attenuation, 2kV per division, 100ps per division



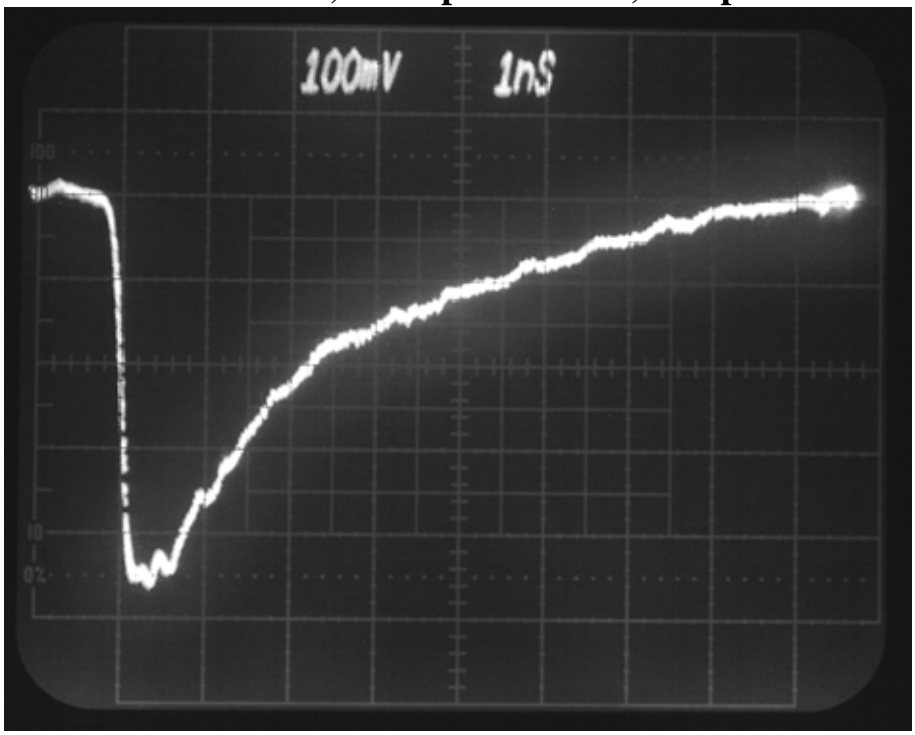
PBG5 channel 3 output using suicide T attenuator.
20000x attenuation, 2kV per division, 100ps per division



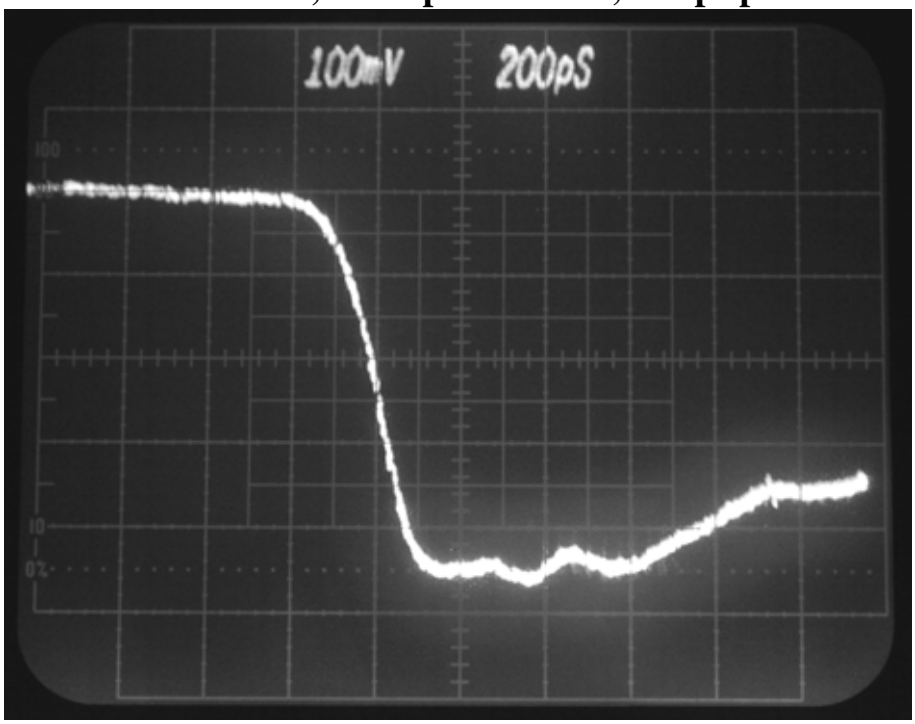
PBG5 channel 4 output using suicide T attenuator.
20000x attenuation, 2kV per division, 100ps per division



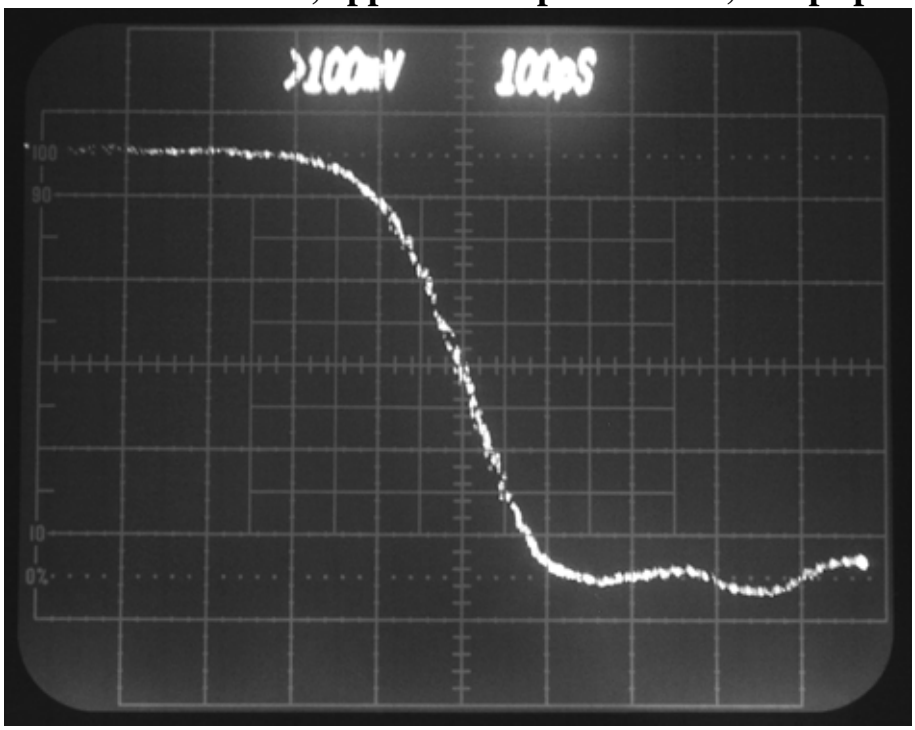
PBG7 output using special Kentech attenuator.
100000x attenuation, 10kV per division, 1ns per division

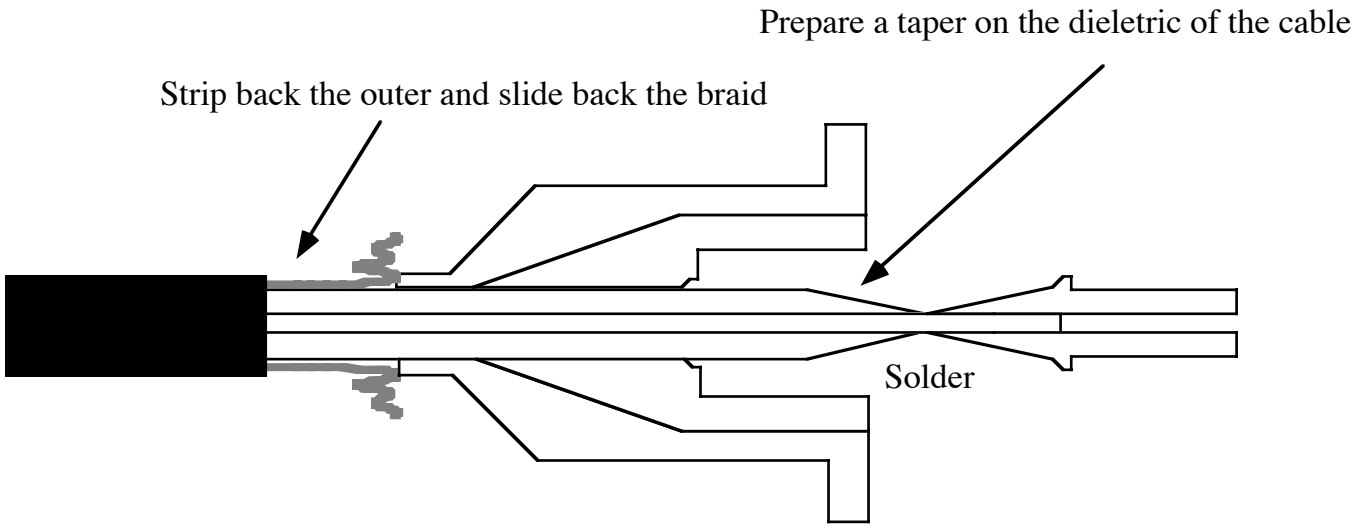


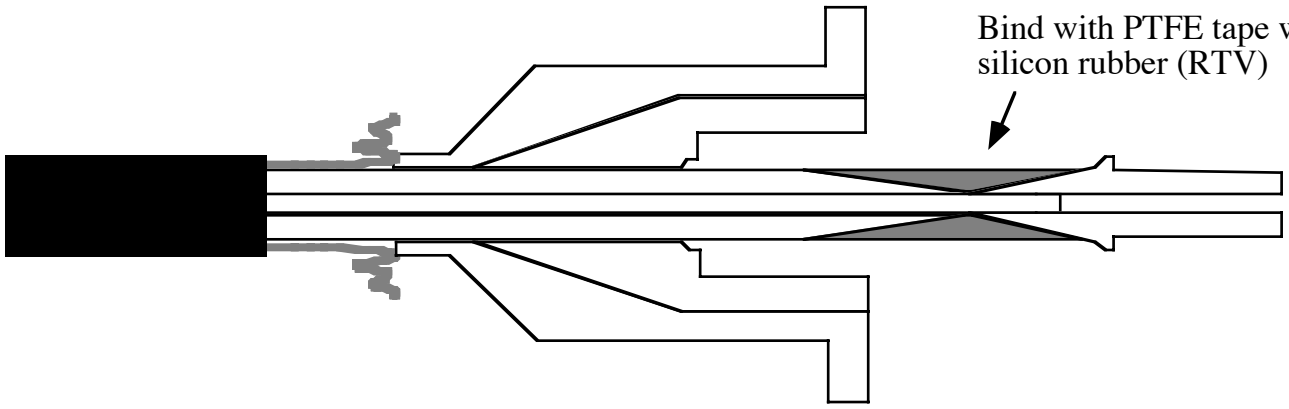
PBG7 output using special Kentech attenuator.
100000x attenuation, 10kV per division, 200ps per division

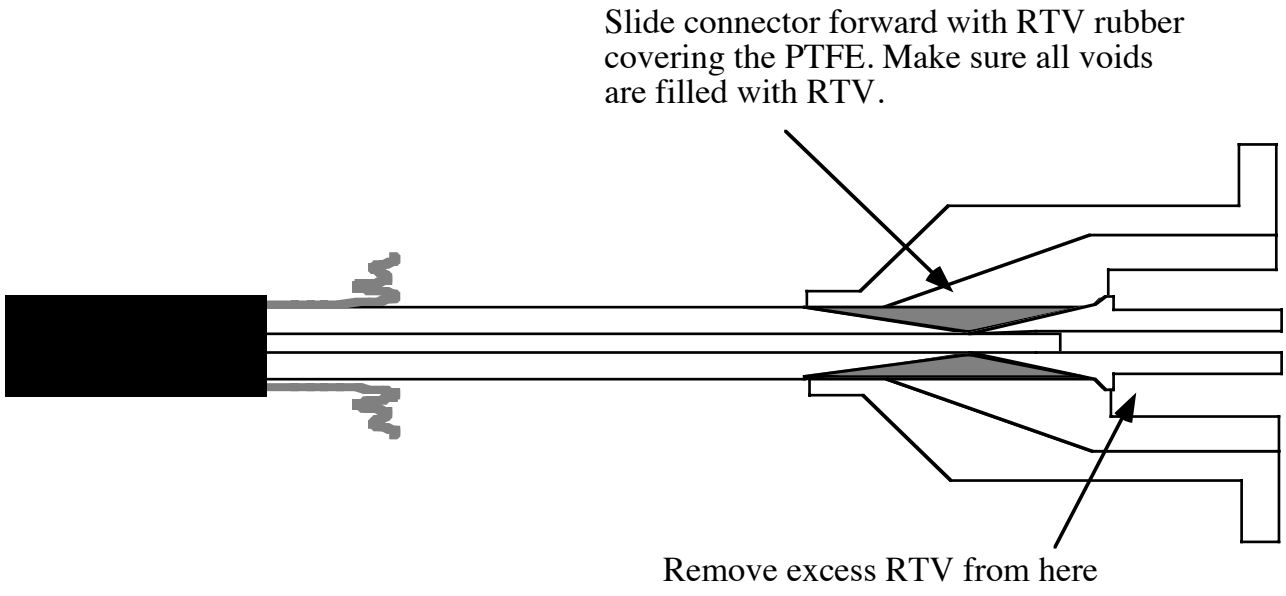


PBG7 output using special Kentech attenuator.
approx. 90000x attenuation, approx. 9kV per division, 100ps per division

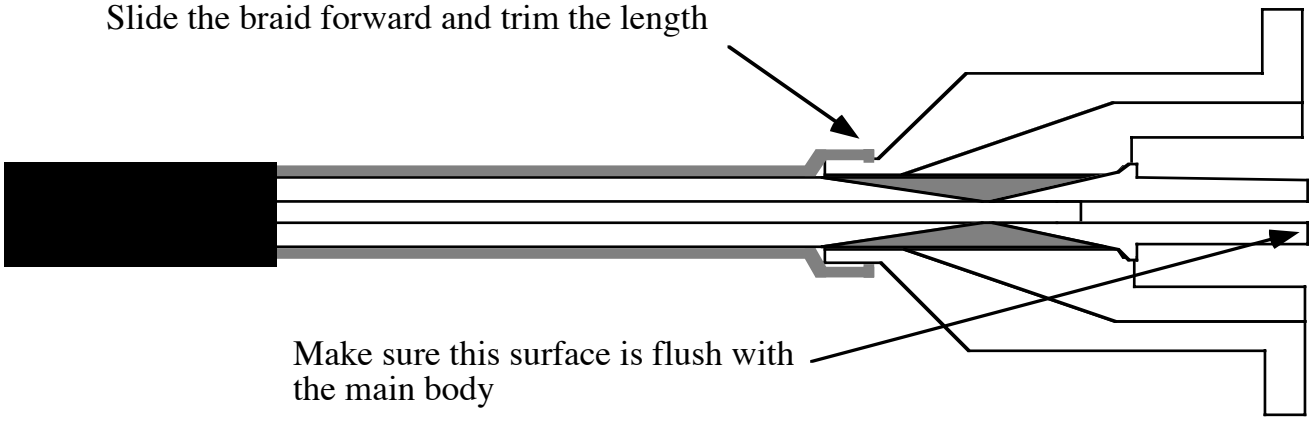



Prepare a taper on the dieletric of the cable
Strip back the outer and slide back the braid
Solder


Bind with PTFE tape with
silicon rubber (RTV)

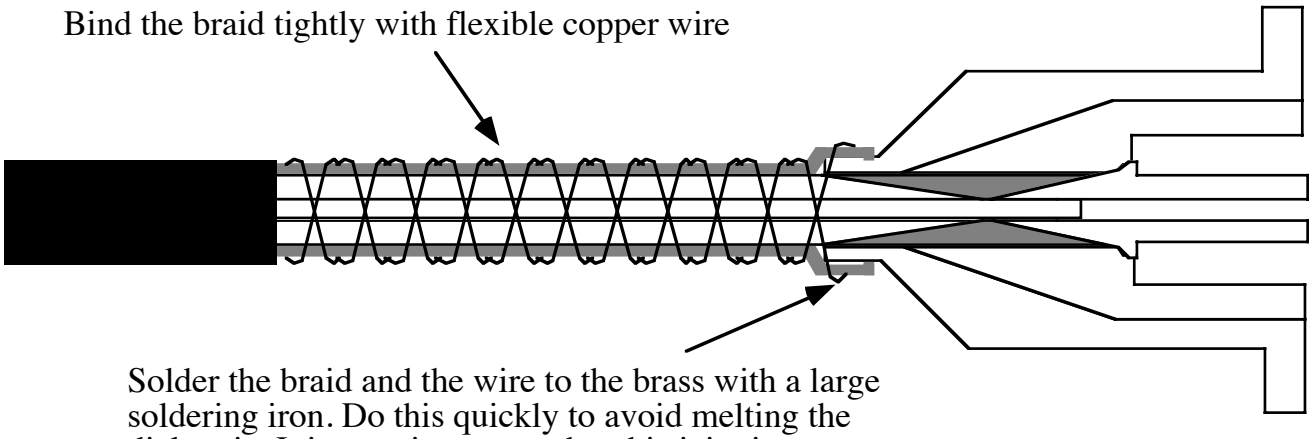

Slide connector forward with RTV rubber
covering the PTFE. Make sure all voids
are filled with RTV.
Remove excess RTV from here

Slide the braid forward and trim the length

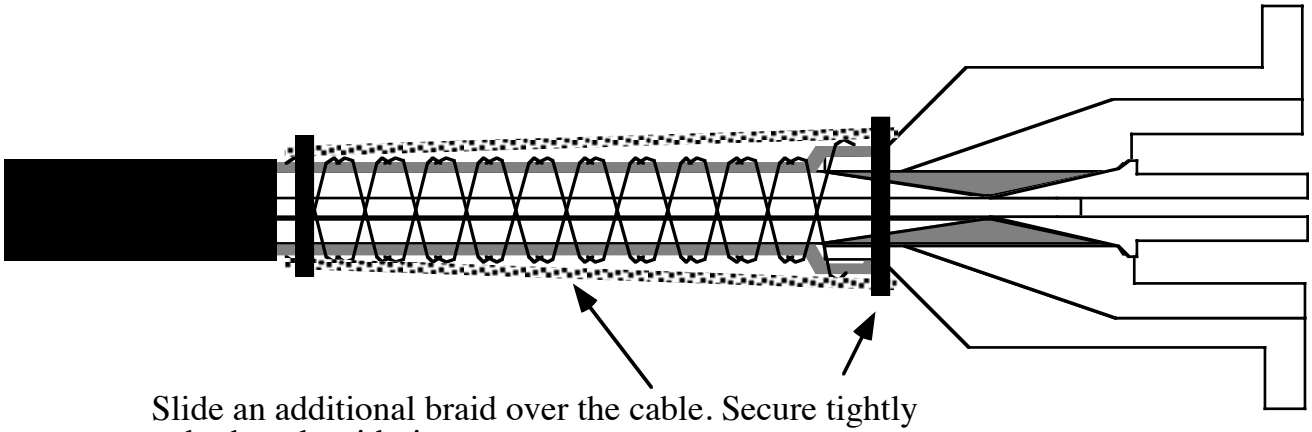


Make sure this surface is flush with the main body

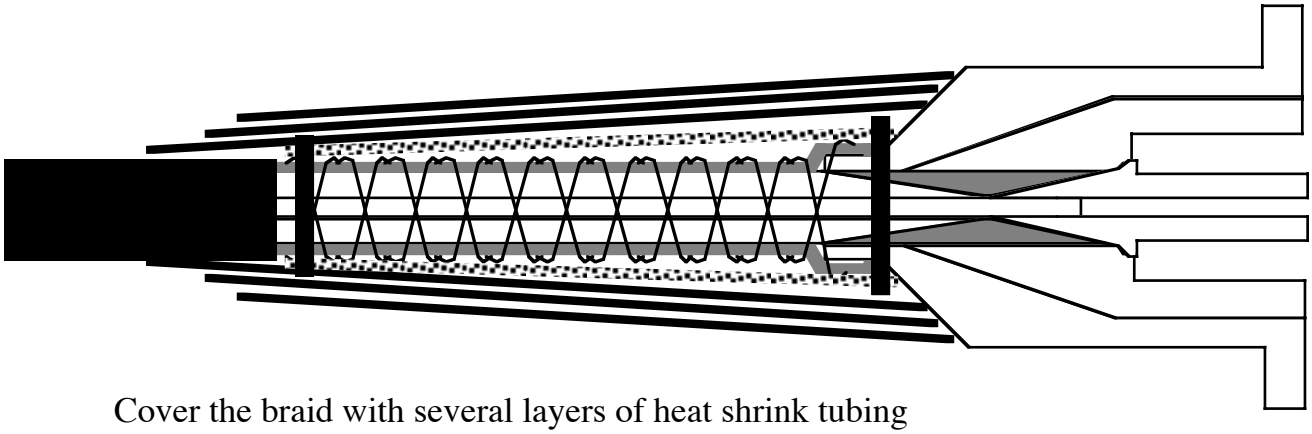
Bind the braid tightly with flexible copper wire



Solder the braid and the wire to the brass with a large soldering iron. Do this quickly to avoid melting the dielectric. It is very important that this joint is strong so the earth connection is secure.



Slide an additional braid over the cable. Secure tightly at both ends with tie wraps.



Cover the braid with several layers of heat shrink tubing

Notes on the use of

DEL4 four channel delay generator
Serial No. xxxxxx

11th March 2004

Specification

• Number of channels	4
• Maximum delay adjustment	20ns
• Incremental delay step	25ps
• Typical throughput delay at minimum setting	6ns
• Interstep error <± 0.5 steps, but reproducible.	
• Jitter effectively zero, mechanical device.	
• Characteristic impedance	50Ω
• Voltage handling	D.C. 30 volts.

With pulsed signals up to 30 volts the delay may be changed whilst the signal is propagating through the device. If the delay setting is not changed whilst the pulse is propagating, the pulse is limited to 1.8mamp coulombs. e.g.1.5kv for 2ns. 1.5kV is the maximum recomended voltage even for very short pulses.

- Fully functional controls via front panel keys and serial port.
- LCD display of status and functions.
- Serial port RS232, 9600 baud, requires simple text commands from a terminal or emulator.
- Nonvolatile memory
- Size 19” 3U rack mounting
- Power requirements 240V/110V 50/60Hz at approximately 50 watts.

Introduction

The Kentech Four Channel Delay Generator uses passive delay lines to form a compact unit designed for the critical timing adjustment of fast camera systems and other fast instrumentation. It has 4 independent channels each of which will delay an arbitrary input signal over an adjustment range of 20ns in 25ps steps. The unit consists of 4 sets of switched 50Ω calibrated delay lines together with a controlling microcomputer. The device has no inherent jitter, a risetime of better than 1ns and a high voltage capability for short pulses. The delay is set manually from the front panel or from an RS232 remote control interface.

The current delay settings are shown on an LCD display. The delay is achieved by the switching in and out of various sections of delay line by a set of matched relays. Care has been taken to give a reproducible risetime over the entire adjustment range and the through risetime is better than 0.8ns for all delay settings. The unit may be used to delay short, relatively high voltage trigger signals. Many Kentech high voltage pulsers are able to use this feature to provide highly stable relative timing between two or more output pulse channels. This will find such applications as the adjustment of interframe timing in fast framing cameras and triggering or pulse shaping in laser systems.

Use

In manual mode all that is required to operate the unit is to route the signals to be delayed via the four sets of two BNC connectors on the front panel of the delay generator. The front panel controls may then be used to adjust the relative delays added by the unit over a range of approximately 0 to 20ns in 25ps steps.

The delay data is stored in non volatile memory as a table of data with 100 entries. An entry contains 4 delay setings, one for each channel. Each entry can be edited and stored in EEPROM. The entry in the table currently used can be edited or incremented manually or by the RS232 interface to allow scanning of a range of different delay settings.

When the unit is not powered up the signal will be delayed by the minimum setting. This is typically 6.5ns.

Delaying a trigger signal

Although care has been taken to maintain a constant risetime, the shape of a fast rising signal will change slightly as different delay line sections are switched in and out. In order that the triggering of some piece of equipment is most accurately delayed the trigger threshold of the equipment to be triggered should be set at around half the trigger amplitude.

DEL4 V1.0 Software

The microprocessor used is a Hitachi H8/532 running a FORTH operating system and it is programmed in the FORTH programming language. It is not necessary to have any knowledge of the H8 or FORTH to operate the delay generator.

a) Run page

On power up or on entering LOCAL mode from remote, the unit will briefly display the "Kentech Instruments" banner and then the run page:-

```
Entry# =   0
Edit delays...    >
d1=   225 d2=   500
d3=   350 d4=   425
```

The cursor initially will be under Entry# as shown. From here one can either:-
1) Edit the entry number - press **right** to edit the entry number using **right** and **left** to select the appropriate digit then **up** or **down** to increment or decrement.
2) Move to delay edit page 1 - press **down** to get the cursor under Edit then **right** to enter the delay edit page 1.

The delays d1 to d4 are not directly editable from the run page.

b) delay edit page 1

The display will indicate that the current entry number and invite you to save changes made in delay edit page 2 (see below).

```
<Edit entry#   1...>
 Save= NO
```

The cursor initially will be under Entry# as shown. From here one can either:-
1) Move to delay edit page 2 - press **right**
2) Save changes previously made in delay edit page 2 into EEPROM - press **down** to get the

cursor under Save, then **right** to get it under NO, then use **up** to edit to YES. Finally press left, the data will be save and the cursor returned to Save.

Note that if you do not save changes previously made in delay edit page 2 into EEPROM here they will be lost when you subsequently power down the instrument or change entry number.

b) delay edit page 2

The display will show all four delay settings for this entry.

```
<Delay1 =   225ps
 Delay2 =   500ps
 Delay3 =   350ps
 Delay4 =   425ps
```

Press up or down to move the cursor under Delay for the channel of interest, then right to enter the delay editor which functions similarly to the entry number editor on the run page above. Finally press **left** one or more times to exit the delay editor, press **up** if necessary one or more times to move the cursor to Delay1 then left to return to delay edit page 1

Note that the changes you make on this page are in volatile memory only and will be lost when you subsequently power down the instrument or change entry number. If you want to keep them in non volatile memory you must use the SAVE function in delay edit page1.

f) REMOTE

The μP will enter REMOTE mode if it receives a character while displaying the run page. In REMOTE, the unit accepts commands in simple ASCII characters and transmits its responses. There is no handshake, this mode is designed to work with a simple terminal or terminal emulator. Baud rate is 9600, one start bit, no stop bits, no parity.

The character n below denotes a number. Do not use any punctuation, eg “,” or “.” in this number, use only numbers in the ranges indicated.

On entering REMOTE, the μP prints a “Kentech Instruments” banner, then waits for the user commands. The commands are:-

.ENTRY# {cr} to print entry number
n !ENTRY# {cr} to set entry number to n (range 0 to 100)

.DEL1{cr} to print out delay 1 in picoseconds
.DEL2{cr} to print out delay 2 in picoseconds
.DEL3{cr} to print out delay 3 in picoseconds
.DEL4{cr} to print out delay 4 in picoseconds

n !DEL1{cr} to set delay 1 to n picoseconds (range 0 to 20000)
n !DEL2{cr} to set delay 2 to n picoseconds (range 0 to 20000)
n !DEL3{cr} to set delay 3 to n picoseconds (range 0 to 20000)
n !DEL4{cr} to set delay 4 to n picoseconds (range 0 to 20000)

EE!ENTRY {cr} to store the changed delay settings for the current entry number into EEPROM (non volatile storage)
LOCAL {cr} to return to local mode ok

On returning to local mode, the "Kentech Instruments" banner is displayed once again on the LCD, quickly followed by the run page.