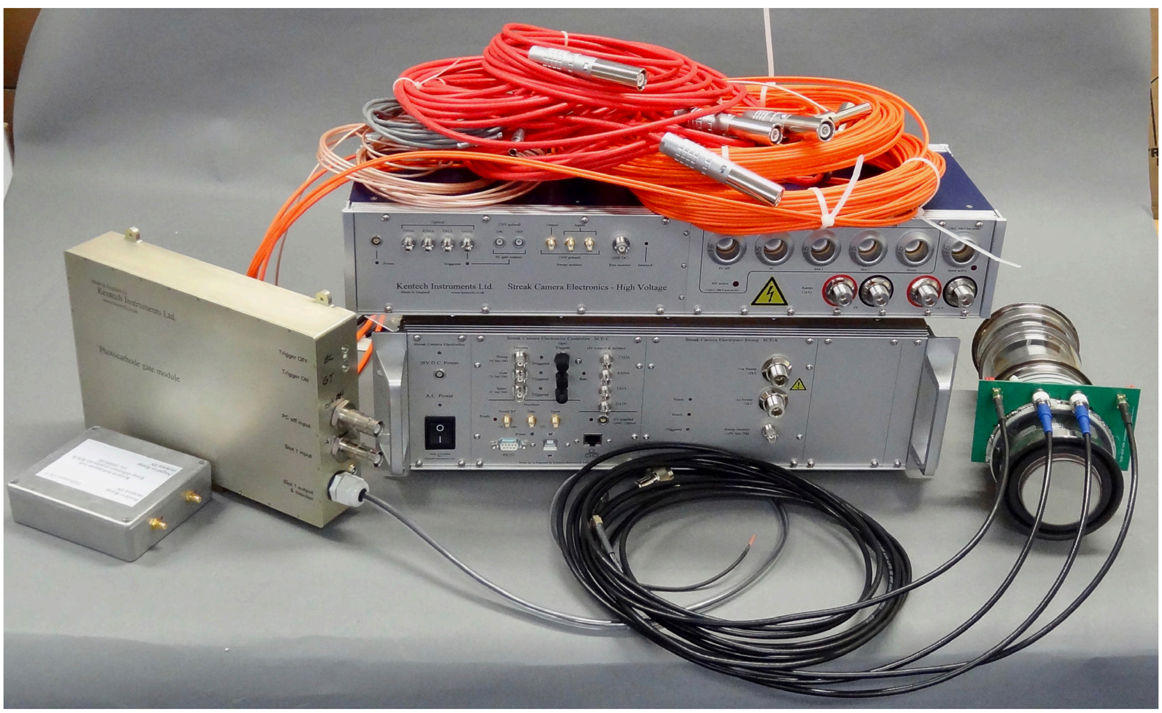
Kentech Instruments Ltd.

Remote Streak Camera Electronics System
RSCE

PLEASE READ THIS MANUAL CAREFULLY BEFORE USING THE SYSTEM.



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1. DISCLAIMER

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

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

2. SERIAL NUMBERS

There are three main components with serial numbers:

Rack controller

High Voltage Module

Gate module

3. ABBREVIATIONS

ADC or adc	Analogue to Digital Convertor
CPLD	Complex programmable logic device
CCD	Charge Coupled Device (camera)
Comms	Communications
cr	carriage return
DISC	Dim based X-Ray streak camera
DPCO	Double Pole Change Over
dv	desired value
EEPROM	Electrically programmable and erasable Read only memory, non-volatile
EHT or eht	Extra High Tension (high voltage)
EM	Electromagnetic
EPLD	Electrically programmable logic device
EPROM	Electrically programmable read only memory, non-volatile
FET	Field Effect Transistor
FPGA	Field Programmable Gate Array
FN	Foot Note
FO	fibre optic
GXD	Gated X-ray Diagnostic
HDISC	Neutron hardened version of DISC
HSLOS	Neutron Hardened Single Line of Sight Imager, also called SLOS2.
HV	High Voltage
hw	hardware
IBC	User's control system, also called UCS.
INT	Intensifier
lf	line feed
LFC	Large Format Camera, Gated X-ray Imager
LLNL	Lawrence Livermore National Laboratory
m	metres (meters US)
MAX	A phosphor and MCP combination
MCP	Micro Channel Plate
MCU	Main Control unit
mv	measured value
PCB	Printed circuit board
PCD	Photo Conductive Detector
PSU or psu	power supply unit
RAM	Random access memory, volatile.
RHIC	Radiation Hardened Instrument Controller
ro	read only
RSCE	Remote Streak Camera Electronics
rw	read and write
scope	Oscillosope
SLOS2	Alternative name for HSLOS
SOW	Statement of Works
SW	sweep
sw	software
sync.	synchronisation
UCS	Users Control System (to be provided by the user), also called IBC
W/E	Write Enable
wo	write only
w.r.t.	with respect to
#	number

4. BILL OF MATERIALS

Quantities are 1 off except where stated.

4.0.1 TOP LEVEL ITEMS

Rack controller
High Voltage Module
Gate module
Sweep difference monitor box.

4.0.2 EXTERNAL CABLES

The location of cables within the system is shown in **Figure 4 on page 16**

0070-0170 RSCE power lead 1 off

Note that when fielded with long cables the power cable loop resistance should be $<2\Omega$ otherwise the voltage drop at the HV module could be too great.
Twin screened
Test lead supplied is 2 metres long
Lemo FGA 0B 302 CLAD42 to same
Pin to pin correspondence

0070-0171 RSCE FO lead Rack to HV unit. 4 off or 2 off duplex

Multimode FO
OM4 50/125 µm/µm
ST to ST connectors
length 2 metres for testing

0070-0172 RSCE Sweep lead Rack to HV unit x 2 (Customer to supply)

Recommended cable LMR600
N type to N type

0070-0173 RSCE Sweep lead HV unit to tube, 2 off.

Coax-LMR200 or LMR195
N Types to TNC used on test setup.
Note test leads should be used for setting up the ramps but will help with setting up the sweep monitors.

0070-0175 RSCE Sweep monitor, 2 off

Coax-LMR200 or LMR195
SMA to SMA
Length ~ 4.1m

0070-0176 RSCE HV lead to tube, 3 off

Coax HiVolt HTV-30S-22-2
4.1 metres long
Lemo FFA.3Y.415.CTAC57 to free end, test to 20kV

0070-0177 RSCE HV lead HV unit to PC gate unit, 2 off.

Coax HiVolt HTV-30S-22 4 metres long
Lemo FFA.3Y.415.CTAC57 to HiVolt HC52P-HTV30S
Test to 20kV

0070-0178 RSCE PC gate unit trigger, 2 off

Coax RG316
Length 4m.
Lemo FFA.0S.250.CTL.C32 to Lemo FFA.00.250.CTA.C
Test to 1kV
Note that the plug into the HV unit is larger (0S) than the plug into the PC gate unit (00).

0070-0179 RSCE HV lead PC gate unit to tube, 1 off.
(Supplied attached to the PC gate module)

Coax RG179 (Note 75Ω cable for reduced capacitance)
0.35 metres long outside the PC gate unit
Hard wired into PC gate module
Lemo FFA.0S.403.CTA.C32 to free end
Insulate with 8mm OD PVC tubing, 1.5mm wall.
This is clamped in the cable gland on the PC gate unit.
If possible add heat shrink between HTS cable and PVC tubing.
Test to 4kV, inner to outer and, after fitting, short the connector pin to outer, ground the PC gate module case and test breakdown between outer and ground to 20kV
Note that although "hard wired" this cable is fairly easy to remove or replace as it is connectorised inside the PC module. The outer has to float to the Photocathode voltage, the inner is at the gated Slot 1 voltage.

A.C Power lead (US style)

4.0.3 EXTERNAL LEADS FOR BENCH TOP TESTING

Sweep leads from sweep module to HV module, 2 off. We used LMR600 cable, 13.411m (44 feet) long terminated with N type connectors. These have not been supplied.

5. HAZARDOUS MATERIALS

None of the materials used is very hazardous. The quantity of lead used is small and only used in hand built electronics and cable connectors. Much of the electronics is not hand built. Hand built electronics using lead free solder has resulted in low reliability and is consequently avoided. Some of the very specialised types of circuit used in this device are not amenable to machine building. Much of the aluminium used is coated with Alochrom or Iridite. Some of these coatings are not chromate free.

6. INTRODUCTION

This manual describes the operation and use of the RSCE (Remote Streak Camera Electronics) system. The system is designed as a general purpose electronics package for streak tubes. With 5 fully programmable potentials, plus a Gate off potential it will be able to drive many streak tubes. It offers photocathode gating, trigger and gate delay and a sweep system driven by an arbitrary waveform generator (AWG) which allows compensation for long sweep cables and sweep plate response. It is intended for applications where the tube is up to 50 feet (~15m) from the control electronics. It consists of three modules, a main control rack, a local (to the tube ~4m) high voltage unit and a close coupled gate unit (~0.5m).

6.1 SPECIFICATIONS OF THE SYSTEM

Electronics specification

The electronics is designed to meet the Statement of Works specification, see section **10 on page 69**

Connectors

Rack Unit

Power (28 V) output	Lemo EGA.0B.302.CLL
Mating connector	FGA.0B.302.CLAC42
Sweep output	2 x N type
Sweep monitor	BNC
Monitors on Control module	
Sweep RF, Gate & spare	3 x SMA
Triggers	3 x BNC
HV enabled (output)	Lemo ERA.0S.302.CLL
mating connector	Lemo FFA.0S.302.CLA
RS232 serial port	9 way D sub - female pins
Ethernet	RJ45
USB (service only)	Type B
Power (rear panel)	IEC
FO connectors	
3 x trigger + 4 x Comms to HV module	
	ST multi-mode

HV Module

Power (28 V) in	Lemo EGA.0B.302.CLL
Mating connector	FGA.0B.302.CLAC42.
Sweep input and output	4 x N type
High voltage outputs	
Photo-cathode OFF	Lemo ERA.3Y415.CTL
Photo-cathode	Lemo ERA.3Y415.CTL
SLOT 1	Lemo ERA.3Y415.CTL
SLOT 2	Lemo ERA.3Y415.CTL
Focus	Lemo ERA.3Y415.CTL
Spare	Lemo ERA.3Y415.CTL

HV mating connector	Lemo FFA.3Y.415.CTA
Bias Monitor output	BNC
Sweep monitor input x 2 + output	SMA
Gate ON output	Lemo PSA.0S.250.CTA
Gate OFF output	Lemo PSA.0S.250.CTA
FO comms	
TXDA	ST multi-mode
RXDA	ST multi-mode
TXCL	ST multi-mode
Gate	ST multi-mode

Gate Module

Photo-cathode (PC) OFF	HC52RB-A[1]
mating connector	HC52P-HTV30S[1]
SLOT 1	HC52RB-A[1]
mating connector	HC52P-HTV30S[1]
Gate ON	Lemo ERA.00.250.CTL
mating connector	Lemo FFA.00.250.CTA
Gate OFF	Lemo ERA.00.250.CTL
mating connector	Lemo FFA.00.250.CTA
Output to Photo cathode (PC)	Flying lead
	Internally this is on a Lemo ERA.0S.403.CLL
mating connector	Lemo FFA.0S.403.CTA
	Note that the body of this connector floats at the SLOT 1 voltage

6.2 FUNCTIONALITY

The system has several modes of operation but the important points to note are the electronic features that are present. These include the following:

1. Focussing for checking that the image of the cathode on the streak tube output is in focus.
2. Flat fielding, for measuring the relative sensitivity of various parts of the detector system. The image of the cathode can be swept linearly and slowly across the detector.
3. Sweep modes.
4. Sync. modes
5. Cathode gating; the cathode to SLOT 1 voltage can switched between an ON state and an OFF state.
6. Electrical or optical triggering.
7. Sweep ramps generated with an AWG to compensate for long cables and tube response.

Note in this manual it is assumed that the streak camera will streak from left to right. I.e. from the negative ramp to the positive ramp. Also the positive bias is the bias on the positive ramp and is usually negative for a normal sweep operation..

1 Available from hivolt.de GmbH & Co. KG

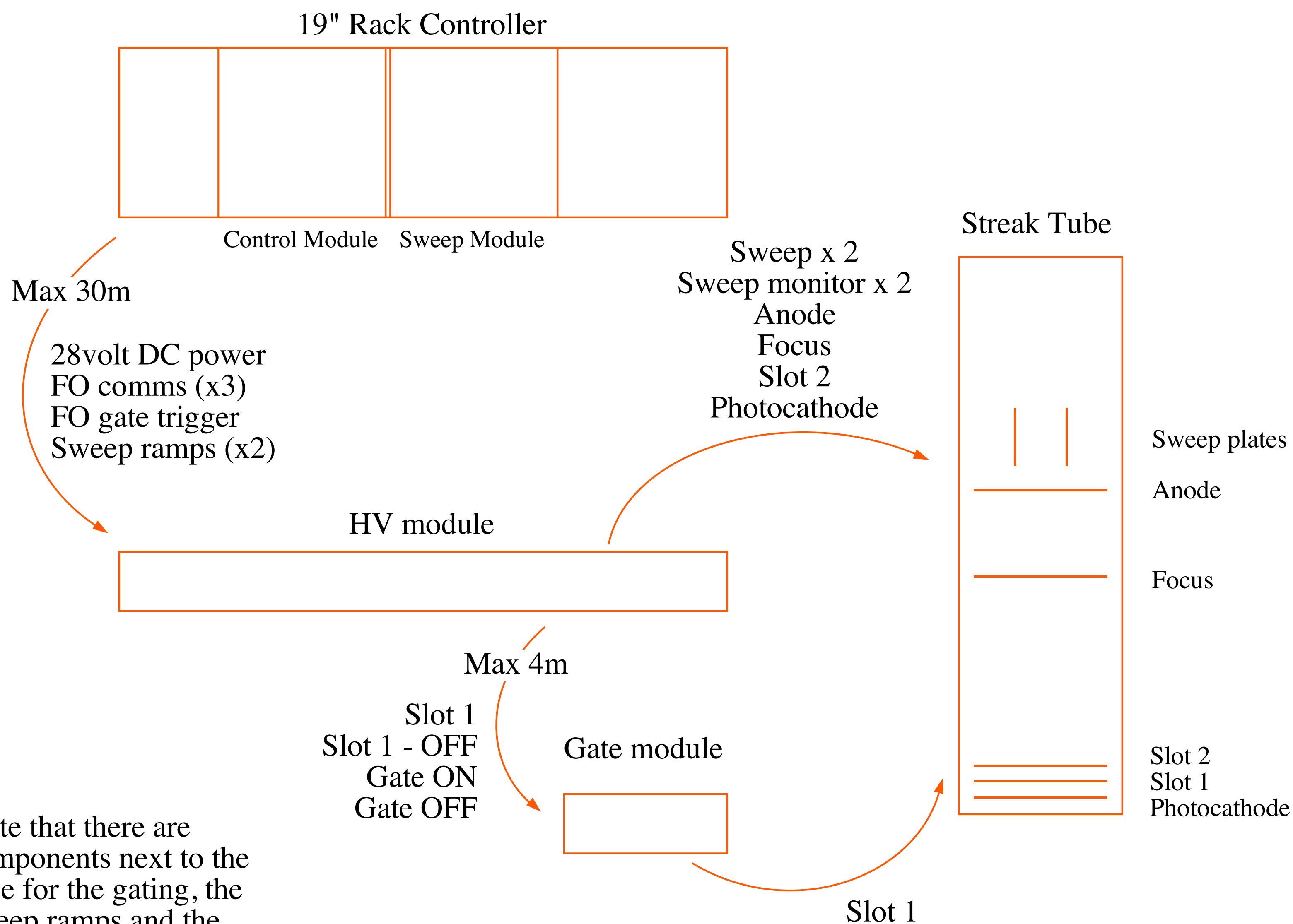
HV Module

Gate module

Control Rack

Ramp difference monitor box

Figure 1 The main components of the system



Note that there are components next to the tube for the gating, the sweep ramps and the sweep monitors. These are not shown here.

Figure 2 Overall layout

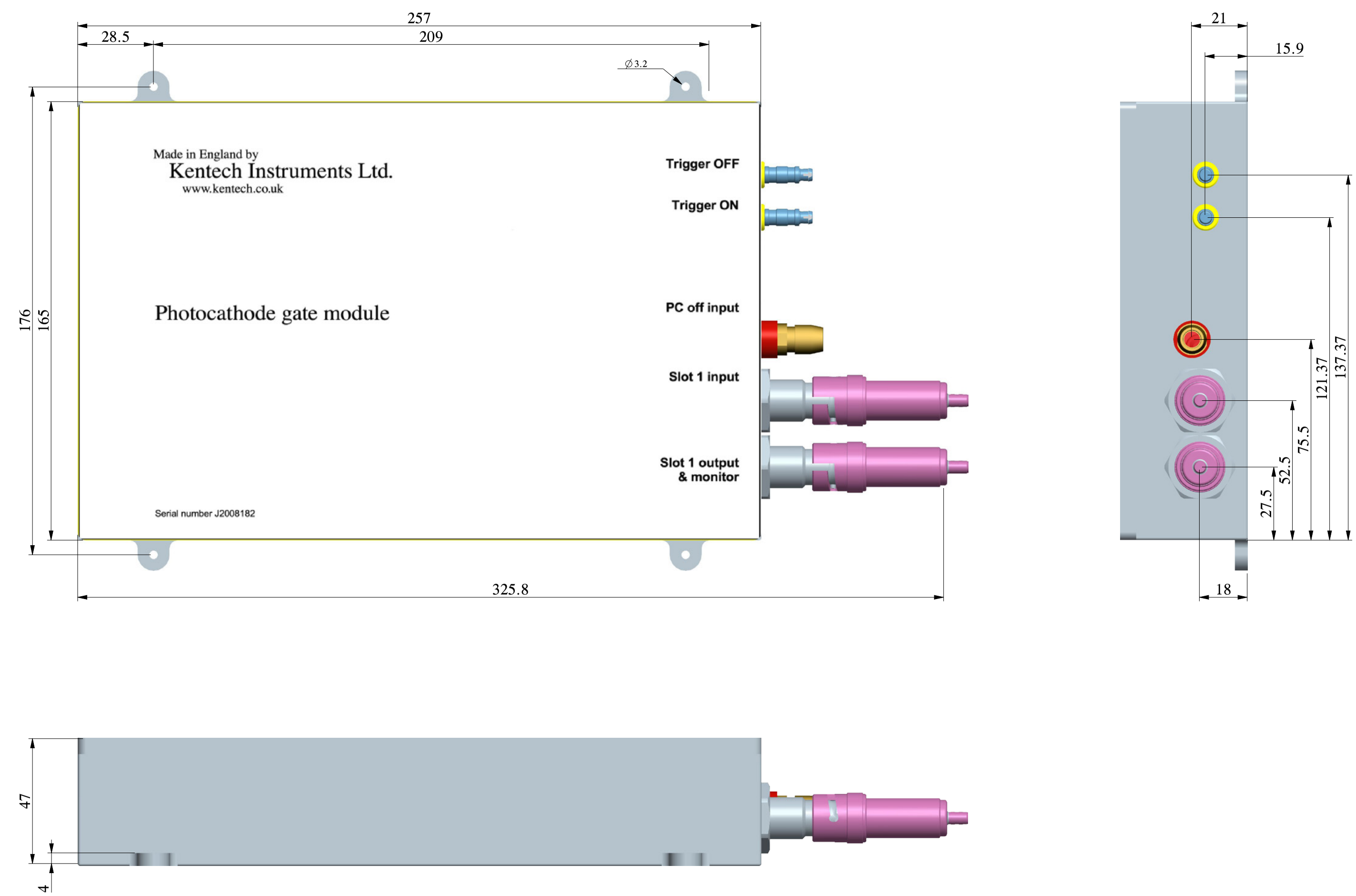


Figure 3 Dimensions and mount details for the Photocathode gate pulser

7. OVERALL DESCRIPTION

The RSCE system comprises 19 inch Rack unit, a custom size High Voltage (HV) module and a custom size gate module.

The gate module must be mounted close (~ 0.5m) to the users streak tube. The HV module should be within ~4m of the streak tube. The rack controller within 30m of the HV unit. These distances relate to the cable lengths. See **Figure 2 on page 12.**

This package is intended to be used with the user's streak tube and readout. No image readout trigger signals are provided.

The HV unit is controlled and monitored via a fibre optically isolated I^2C link.

If the system is to be used with an IBC, then this uses the protocol commands, defined in the software section of this manual, to issue requests to the remote task routine that is running on the controller. This will configure the camera system as necessary. The IBC can use protocol commands to monitor the status of the control and high voltage units. See section **9 on page 35.**

7.1 MECHANICS OF THE ELECTRONICS PACKAGES

The rack module is 3U high, 19 inch (84HP) wide and 400 mm deep. Power inlet on the rear, all other connections on the front panel. The EEPROM write protect button is on the rear panel.

The HV module is 88mm high (2U), 523mm wide and 175 mm deep. Connections are only on the front panel, 88mm x 523mm. The EEPROM write protect link is inside underneath the top cover. The Top cover and the smaller rear panel are connected to the interlock system. If either is removed the High voltages will be disabled. The smaller rear panel can be removed to insert zener diodes between the "Spare" output and the photocathode output.

The gate module is 257 mm long (plus connectors at one end), 165 mm wide (plus mount lugs) x 48 mm high. See **Figure 3 on page 13**.

7.2 FUNCTIONS OF EACH MODULE

The Rack Controller contains 3 modules, DC power, Control and Ramp generator.

7.2.1 POWER MODULE

This is a controllable 28 volt DC power module. Its output goes directly to power the HV module.

7.2.2 CONTROL MODULE

This contains the embedded processor that communicates with the power module, sweep module and HV module. It also interacts with the outside world over RS232 and Ethernet.

Within the control module there is also the AWG that generates a low voltage (<5V) arbitrary waveform signal that is fed to the sweep module for amplification.

The control module also generates trigger pulses. One is sent to the HV module to drive on the gate module trigger signals, another goes to the Sweep module to trigger the "hold up" pulser, see section **7.2.3 on page 15.**

7.2.3 SWEEP MODULE

This receives a low voltage waveform and trigger signal from the control module. It generates the positive and negative ramp waveforms and adds in a “hold up” pulse to keep the streak tube in a deflected state for longer than the AWG record length. These sweep waveforms are fed to the HV module.

7.2.4 HV MODULE

The HV module receives the sweep waveforms from the sweep module and adds in a bias voltage. The ramps are then balanced and sent to the streak tube.

In addition the HV module generates 6 high voltage potentials. The Photocathode OFF potential is always ~ 200 volts more negative than the Photocathode and does not have a separate control. If a lower voltage is required, zener diodes can be placed at the tube across the Photocathode and Slot 1 connections.

The Photocathode, Slot 1, Slot 2, Focus and Spare supplies are individually controllable. The first 4 of these are linked with chains of zener diodes to prevent large differences occurring between them, something that could otherwise happen during setting up or due to a wiring fault to the streak tube. The Photocathode, Slot 2 and Focus potentials are fed to the streak tube. The Photocathode OFF and Slot 1 potentials are fed to the Photocathode gate unit.

7.2.5 PHOTOCATHODE GATE MODULE.

The Photocathode gate unit receives the Photocathode OFF and Slot 1 potentials from the HV module. It delivers one of these to the output which is connected to the Slot 1 electrode on the streak tube. It uses a pair of high voltage switches to do this. The HV module sends trigger signals to control the switches in the Gate module.

7.3 COMMUNICATIONS

Control of the RSCE unit is over either Ethernet or a Serial RS232 port.
The ethernet port is at MAC address and uses Port 10001.
The RS232 port operates at 115200 baud. It uses no flow control, 8 data bits and 1 stop bit.
The USB port is only for software upgrades and servicing.

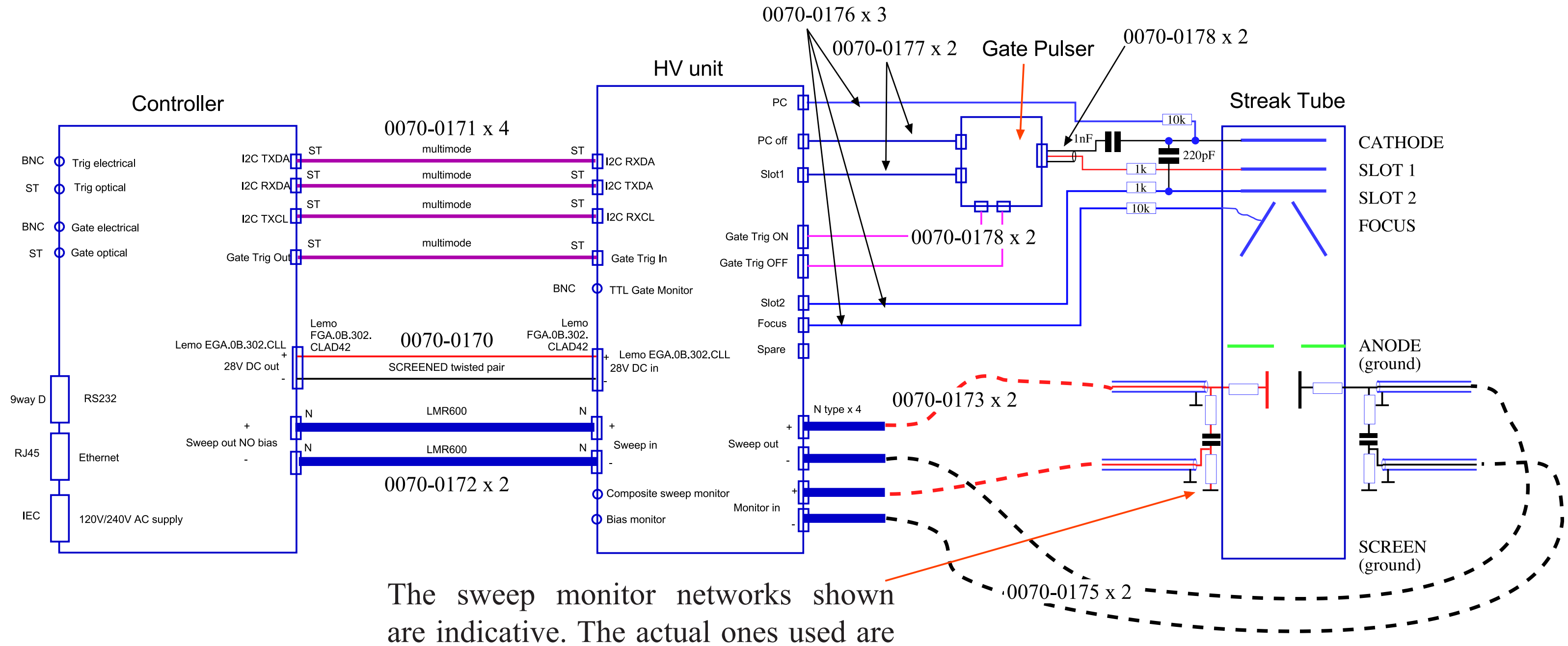
7.4 CONNECTIONS

7.4.1 CONNECTIONS BETWEEN THE RACK UNIT AND THE HV MODULE

There are just 5 connections, power and 4 optical multi-mode fibres. The fibres carry data (one for each direction) a clock and a fast gate signal to drive the photocathode gate pulser.

7.4.2 CONNECTIONS FROM THE HV UNIT AND THE GATE MODULE

There are 4 connections between the HV module and the photocathode gate module. The gate module drives the SLOT 1 electrode on a streak tube. The two high voltage connections to the gate module are the two voltage states the SLOT 1 electrode can be in. These are Photocathode OFF and SLOT 1. I.e. When the gate module is turning the tube ON, the SLOT 1 voltage passes through the gate module. When the tube is gated OFF, the gate module output is connected to Photocathode OFF.



The sweep monitor networks shown are indicative. The actual ones used are detailed at **Figure 7 on page 19**

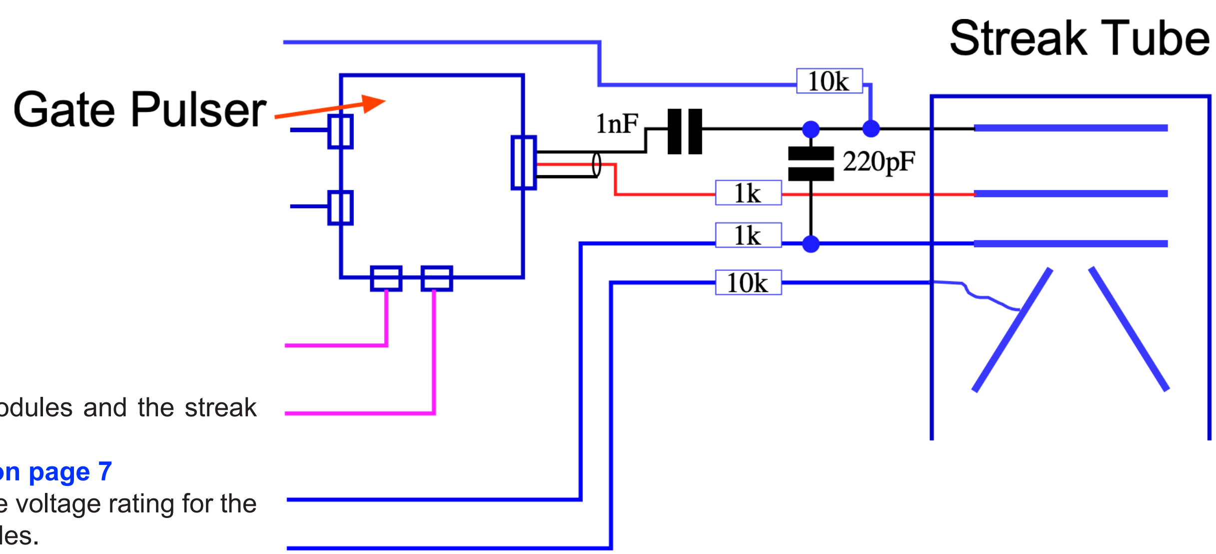
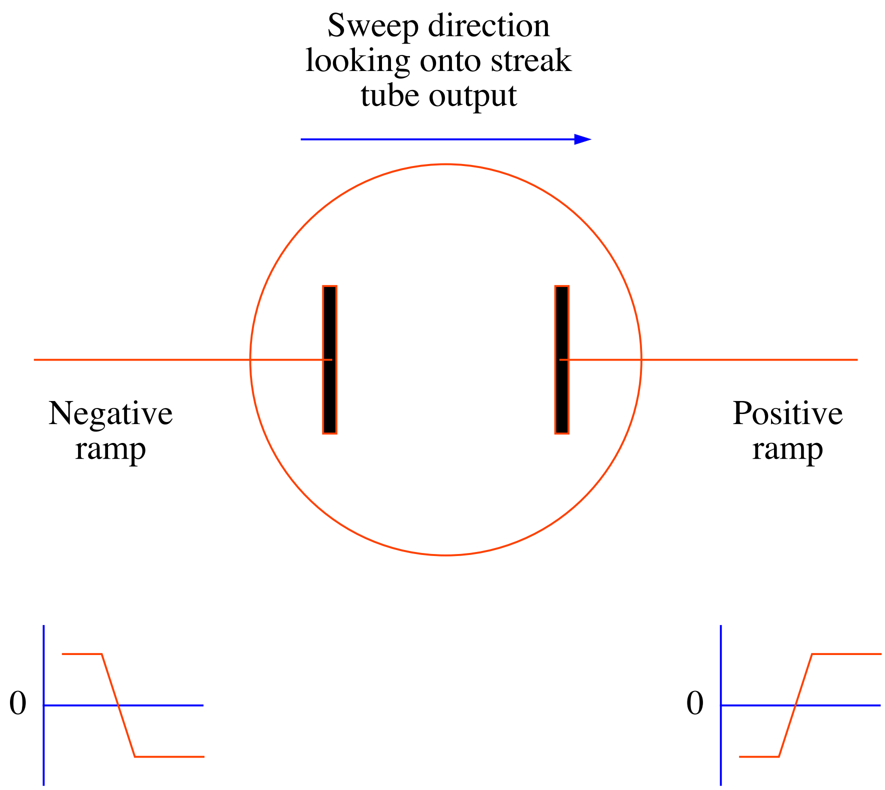


Figure 4 The connections between the various modules and the streak tube.
Cable part numbers are defined at **4.0.2 on page 7**
Capacitors should be should have suitable voltage rating for the relative potentials set on the tube electrodes.



The negative ramp requires a positive bias but the signal is called the negative bias as it biases the negative ramp

The positive ramp requires a negative bias but the signal is called the positive bias as it biases the positive ramp

The bias monitor produces 1/400th. of the the negative ramp bias (which is positive) minus the positive ramp bias (which is negative). So before deflection the monitor signal is positive.

Figure 5 Naming of the ramp and bias signals.
Deflection directions

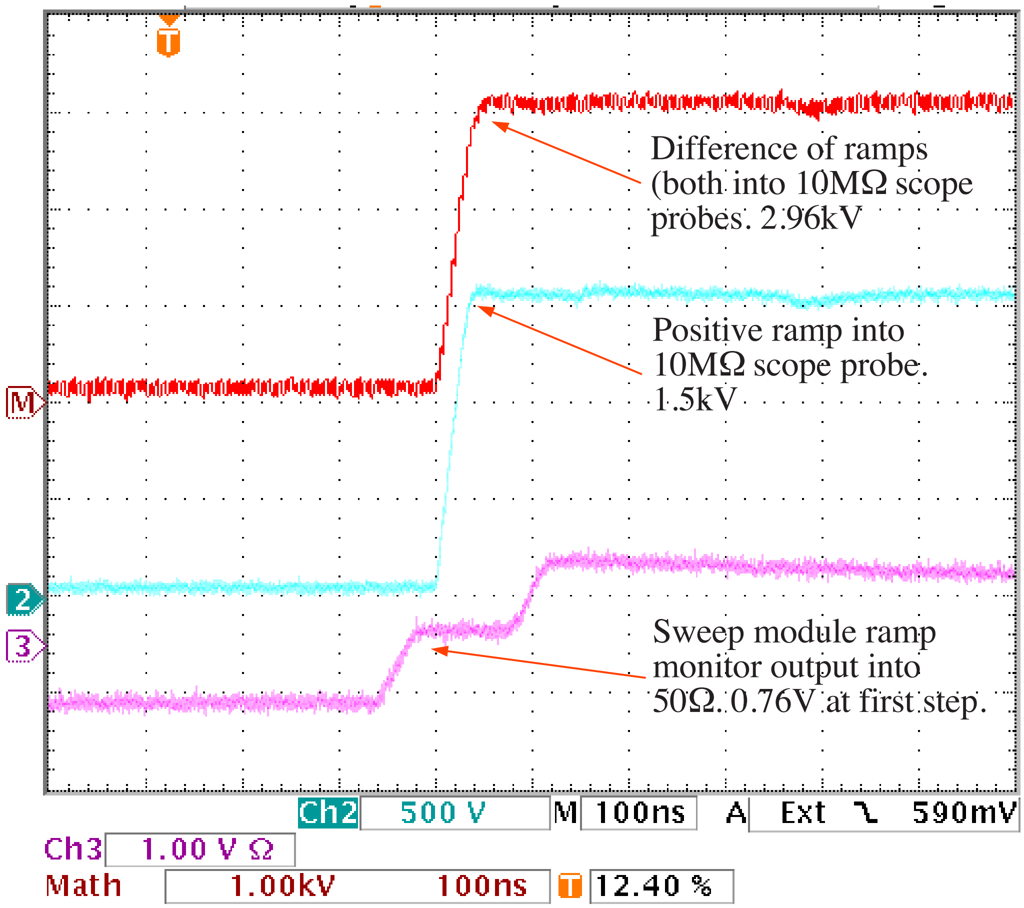


Figure 6 The sweep module monitors compared to the end of sweep leads signal. Red trace is ramp difference, Blue is positive ramp at the end of the sweep leads. Magenta is the sweep module monitor output, the step is due to the reflection from the 15m sweep leads. The second step has to make 2 transits of the sweep cable and so is not representative of the calibration which should be ~1/2000. The first step is 1/1973 of the positive ramp which has made a single transit of the sweep leads.

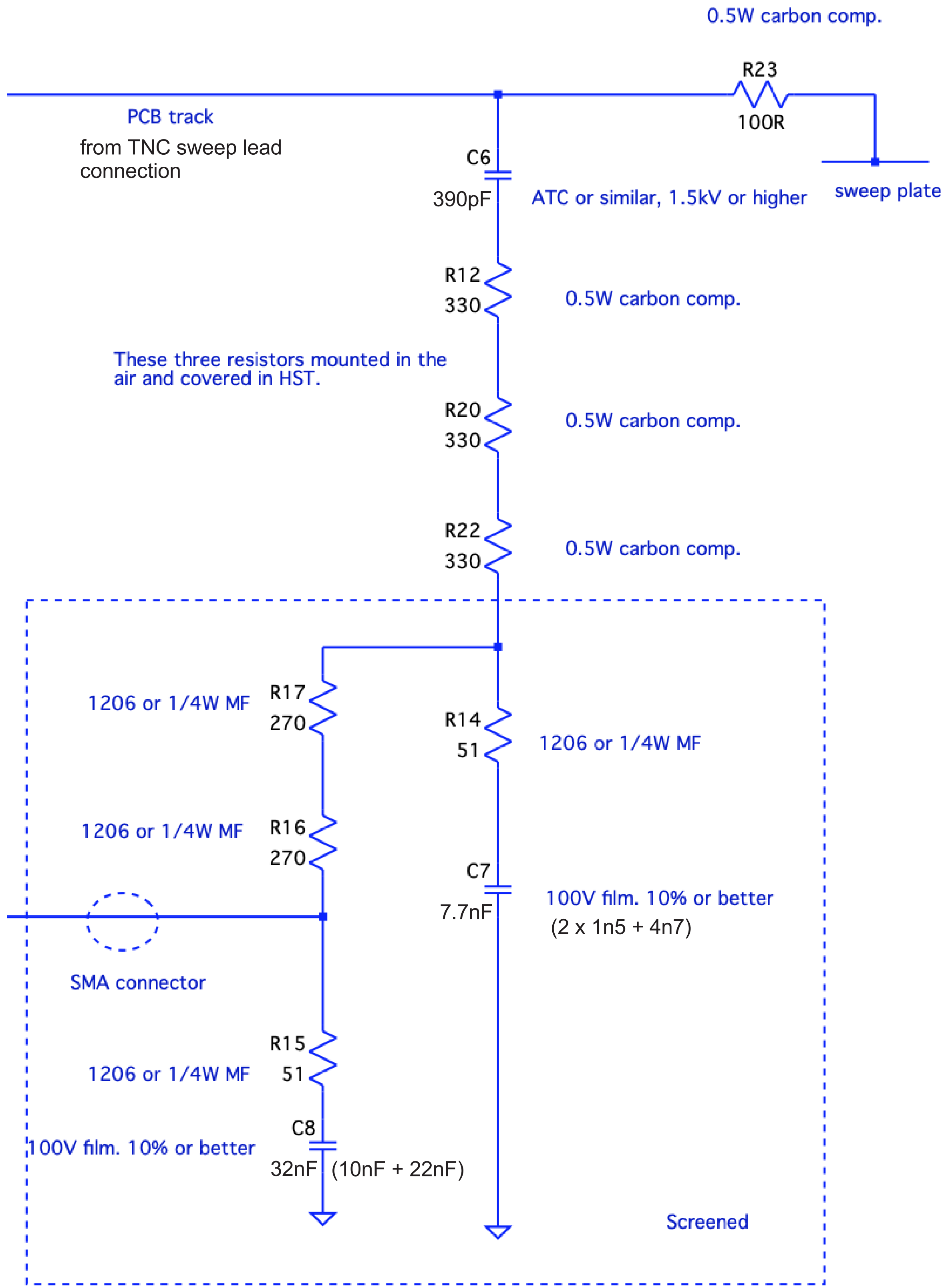


Figure 7 Sweep monitor circuit near the sweep plate.
There are two of these built as mirror images around the sides of the streak tube.

BOM for Sweep connection board 0020-0662

Item	References	Description	Manufacturer	Part #	Total	Kitted	Kitted
1	C6	390pF >1.5kV	ATC or similar		1		
2	C7	7.7nF film 100V 10% or better Used combination of 2 x 1n5 + 4n7					
3	C8	32nF film 100V 10% or better. Used combination 10nF + 22nF					
4	J1	SMA STRAIGHT, 50 OHM, PCB mount	ANY	ANY	2	Any	ANY
5	J4	TNC Connector, Straight Female Socket 50Ohm, PCB mount	Amphenol RF	122440	2	Degi-key	ARF2779-ND
6	J9	Custom connection to sweep plate connection.	defintion depends upon streak tube				
7	R12,20,22	330R Carbon Composition 0.5 watt					
8	R14, 15	51R Metal Film 0.25 watt					
9	R16, 17	270R Metal Film 0.25 watt					
10	R23	100R Carbon Composition 0.5 watt					

Note that all components are to be duplicated as a mirror image on the other half of the PCB. The quantities indicated here need to be doubled.

The SMA and TNC connectors could be replaced by 90° versions if more suitable. Or some other connector with similar ratings.

Figure 8 Bill of materials for the Sweep plate connection card used for testing the RSCE package.

Figure 9 Sweep monitor pcb mounted around the streak tube.
The conducting foil is wrapped around a plastic holder. The foil connects to the Phosphor ring and to te ground plane on the pcb (the underside of the circuit board shown). The monitor network is built in each corner.

Note that SLOT 1 refers to the a few things that should not be confused. Firstly it is the electrode on the streak tube, secondly it is the voltage connected to that electrode and thirdly it is one of the outputs of the HV module that is connected to the SLOT 1 electrode when the tube is ON.

7.4.3 CONNECTIONS TO THE STREAK TUBE

There are typically 4 high voltage connections to the streak tube. These control the focussing of the photoelectrons onto the phosphor. There are also connections to the two sweep plates and a ground.

This system also offers photocathode blanking. Whilst this does not require a further connection to the tube is does mean that connections are not quite so straightforward.

It is necessary to have resistors between the cabling and the streak tube electrodes and also a capacitor across the Photocathode to Slot 1 electrodes and a capacitor across the Photocathode to Slot 2 electrodes. The details are give in **Figure 4 on page 16**

These values are suitable for the dummy tube supplied. for other tubes it may be necessary to adjust the values slightly depending upon the internal capacitances within the tube.

7.4.4 CONNECTIONS TO THE OUTSIDE WORLD - MONITORS ETC.

All three units within the system have monitors.

7.4.4.1 CONTROL MODULE MONITORS

Sweep RF: This is a copy of the arbitrary waveform that is sent to the Sweep module for amplification.

Gate monitor: This delivers a pulse synchronised to the gate pulse that is sent to the HV module over the FO cable.

Spare: Unassigned

7.4.4.2 SWEEP MODULE MONITOR

Sweep monitor output. This is taken from one of the sweep outputs and divided down. It does not have the bias voltage superimposed on it. The division ration is nominally 1000:1. Note that when a fast sweep and long sweep leads are used this

monitor will show thr out and return edges separately, see . This is quite normal. For monitoring the sweep plate waveform use the monitors from the tube.

7.4.4.3 HV MODULE MONITORS

There are monitors for the Sweep and the Bias.

The Sweep monitor outputs the difference of the two monitors that are picked off at the streak tube sweep plate connections, with the bias voltage removed. The difference reflects the total voltage across the sweep plates. This signal is designed to drive a 50 Ω scope input. Note that the sweep monitor is derived at the vacuum interface to the streak tube. It does not indicate the voltage on the sweep plate. This is only really measurable by looking at swept images.

The output is ~ 1/1000th. of the plate to plate voltage. See section **7.5 on page 26**

The bias monitor is resistively coupled to the bias inputs to the sweep plates but is derived from the sweep feeds within the HV module where the bias is injected into the sweep plate feed. It is designed to drive a 10MΩ DMM or scope input.

The output is 1/400th. of the plate to plate voltage. The polarity indicated is the same polarity as the voltage on the negative ramp, i.e the voltage on the starting sweep plate.

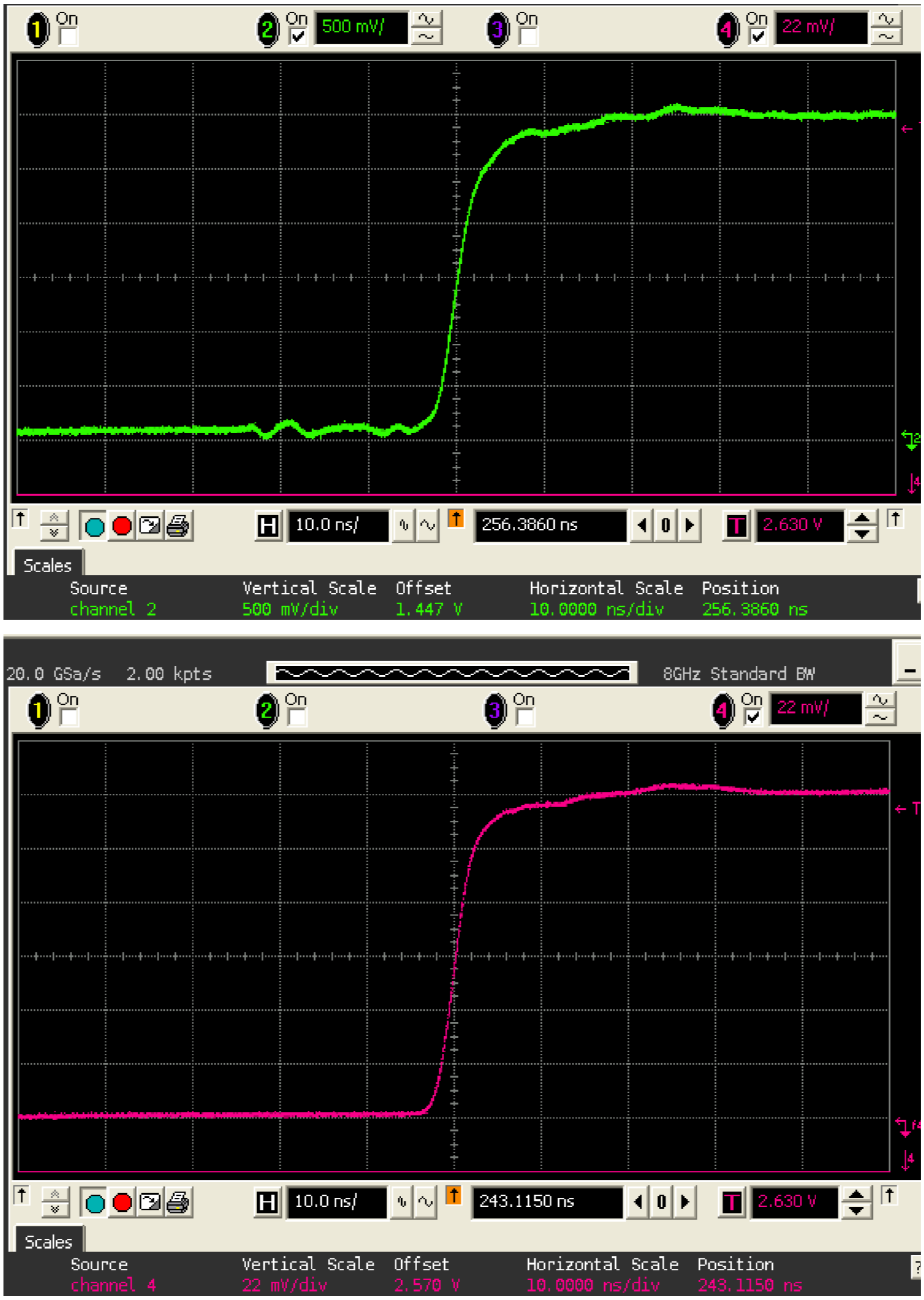


Figure 10 The sweep monitor noise.
Upper trace is the is from the difference unit in the HV module.
The lower trace is the difference generated in the scope.
(Agilent DSO 81004A)

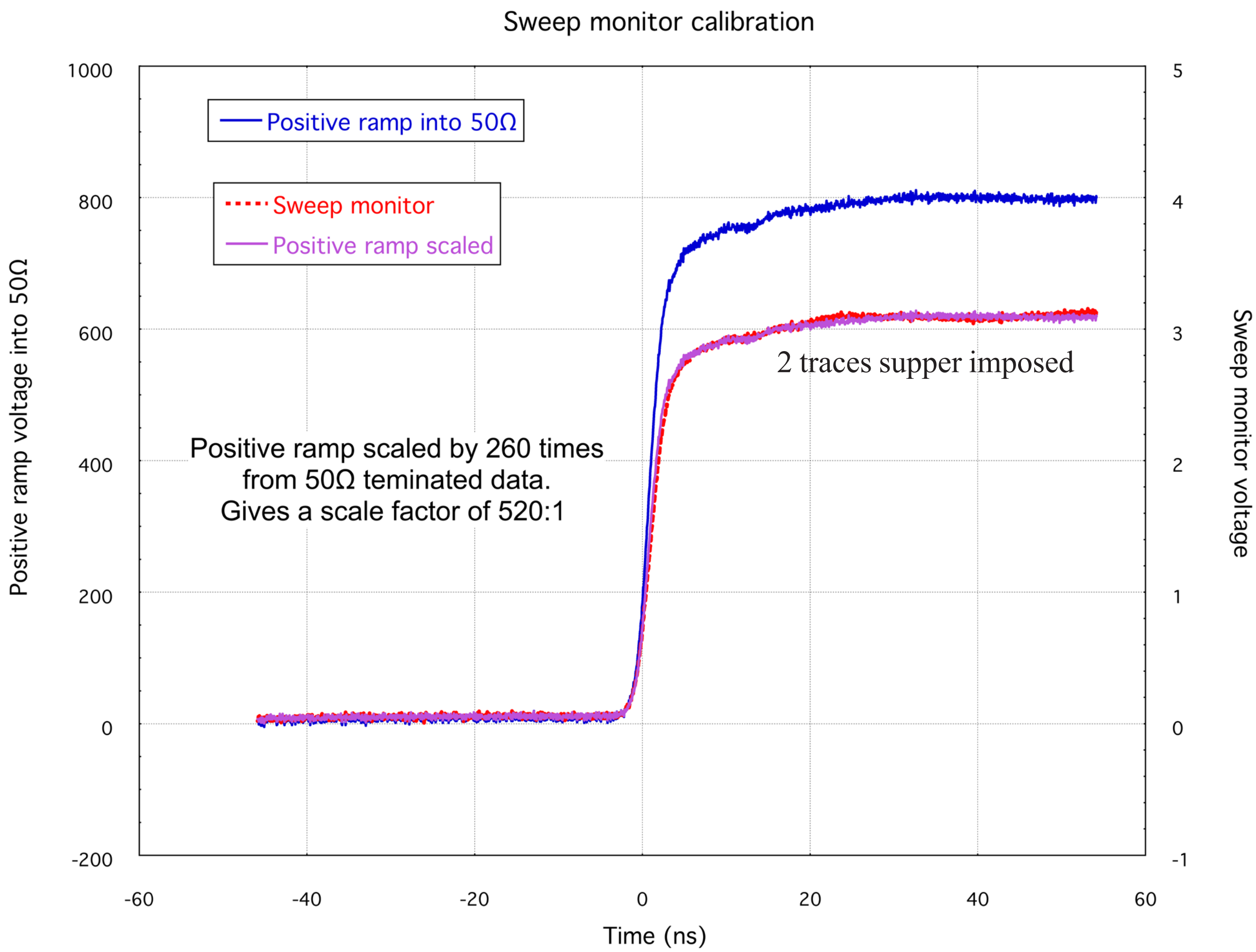


Figure 11 Sweep monitor calibration.
The attenuation ratio is 520:1 (allowing for the doubling of the ramp into an open circuit)

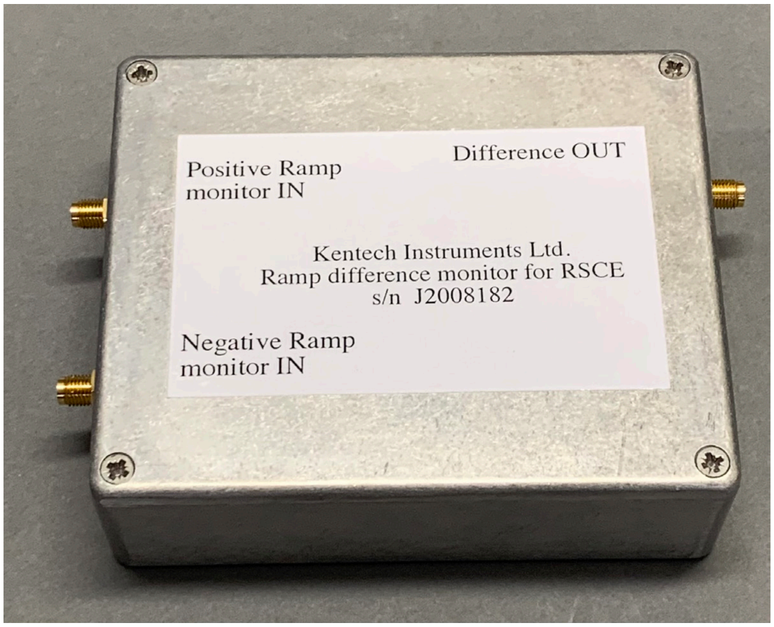
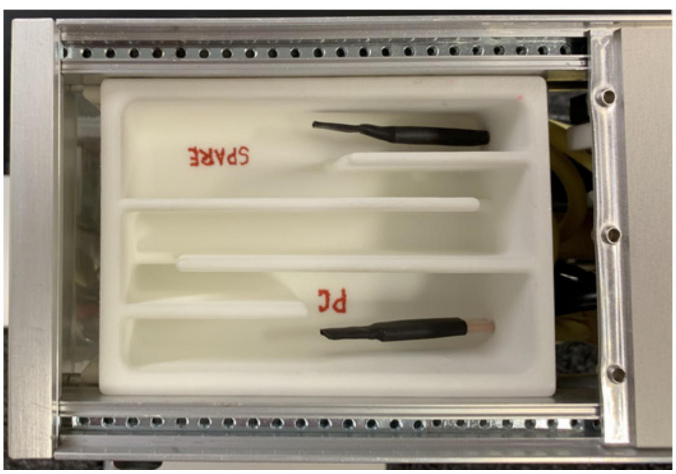


Figure 12 The external ramp difference box.
Use for fast sweeps when differencing on the scope is not available.

Rear panel left section. The top right screw activates the interlock

Remove the rear panel, 7 screws to reveal the zener box cover. The three screws on the right are not self retaining. If they are replaced make sure they are M2.5 Cap or Button head x 8mm long



Remove the cove to access the photocathode and spare power supply outputs. Remove the heat shrink tubing and connect the required zener chain between the leads. The chain should meander along the deep channel. The cover will push the zener chain into the middle of the channel. Replace the plastic cover and then the rear panel.

Figure 13 Accessing the zener box for the Spare output.

7.4.4.4 GATE MODULE MONITOR

The gate module switches float at ~-15kV. This limits the current available. The monitor can only drive ~ 10MΩ with a very small parallel capacitance, e.g. a scope probe. It will not drive a 50Ω cable even if terminated with 10MΩ as the cable capacitance will load the monitor. See section **8.3 on page 32**

7.5 SWEEP MONITOR CONNECTIONS AT THE STREAK TUBE

We have experimented with making a pick of sweep monitor from a sample streak tube. The circuit needs compensation and operates over several time scales. It cannot be DC coupled as the bias supplies have a high source impedance. It is also important that it does not load the ramp waveform too much.

We have found it necessary to fit a good ground plane around the streak tube in the vicinity of the sweep plates but also connected to the phosphor screen electrode. The pick off is made very close to the sweep plate connection where it goes through the glass tube wall. The test rig used a PCB that fitted around the tube body and connected to this ground plane and to the sweep electrode feed throughs.

The circuit is shown in **Figure 7 on page 19** . The fitting of the test PCB to the sample streak tube is shown in **Figure 9 on page 21**

7.5.1 CHECKING THE SWEEP MONITOR

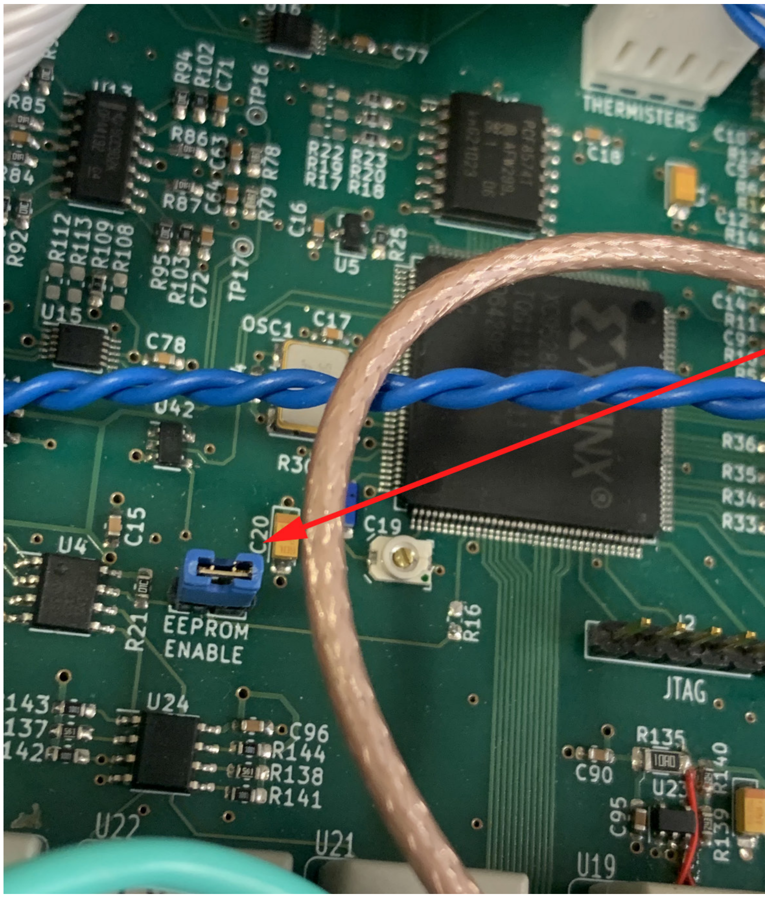
For fast sweeps, rising in a few ns, it is hard to characterise the ramp directly with scope probes. However, the ramp can be run into a 50Ω attenuator and into a suitable scope. This delivers half the voltage that would be produced at a sweep plate. The sweep monitor from the sweep plate can be compared to this. The comparison is very good. The voltage calibration can also be found. For slower ramps there is a problem with the behaviour of the ramp balancer on time scales where refections are occurring. Both sweep leads need to be terminated in the same manner for the ramp balancer to be benign. An alternative is to remove the ramp balancer from the circuit by not putting the sweep leads though the HV module.

Note that as the sweep leads are not terminated at the tube there are always reflections. With long sweep leads these will not return to the sweep plates during the sweep. For slow sweep speeds the reflections are so small they cannot be measured. However, with much shorter sweep leads the user should be aware of this issue. Ideally for fast sweeps, the sweep lead round trip time should be longer than the sweep duration.

7.5.2 BIAS VOLTAGE DURING SWEEP SETTING UP

When setting up ramp waveforms the bias is not needed and indeed can be a nuisance to have to deal with, particularly is scope probes are being used. The easiest way to switch them off is to disconnect the power to the HV module prior to turning the system on. The system will detect the absence of the HV module but will still permit operation in Standby mode. The sweep leads can still go though the ramp balancer and the waveforms will still see any perturbations due to the bias insertion circuits but there won't be any bias.

Once a waveform is deemed satisfactory the optimum bias voltage for both normal and sync. modes needs to be worked out. Generally this involves using the tube deflection sensitivity to set the most linear part of the ramp at screen centre. This will give the normal operating bias. The sync. bias is less critical and is possibly the same for every sweep speed for a particular tube and focus voltage set. This will set all start points at the same screen position.



Insert link to enable writing to the HV calibration EEPROM.

Figure 14 Above the write protect link for the HV module EEPROM.
Do not modify the stored data without fully understanding the ramifications.

Rear panel buttong to enable writing the calibration and control data.

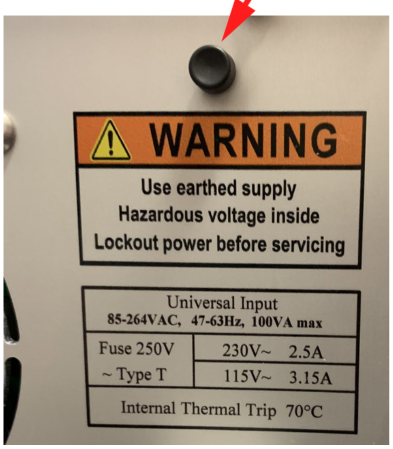


Figure 15 Left the write enable button for the Control module EEPROM.
This is on the rear panel above the power inlet.

7.5.3 EXTERNAL SWEEP MONITOR DIFFERENCING BOX.

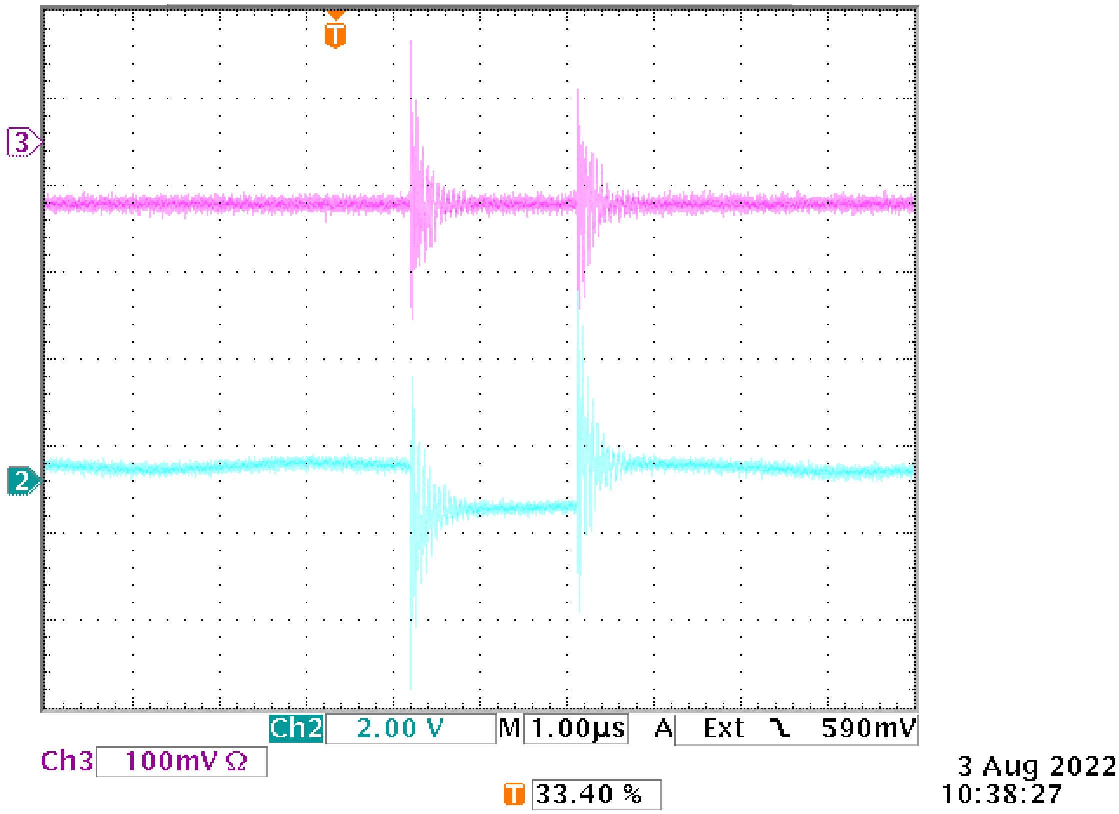
The ramp balancer generates a lot of EM noise inside the HV module and for fast ramps this is picked up by the circuit that differences the two ramp monitors from the tube. Consequently for fast ramps (≤10ns rise), see **Figure 10 on page 23,** the external difference combiner box should be used, see **Figure 12 on page 24,** or the monitor signals from the tube should be differenced in a scope. A future revision may be able to fit this inside the HV module but on the first unit there is insufficient space available. The difference circuit is completely passive and does not require power.

7.6 RUNNING THE ELECTRONICS

The electronics can safely be powered up as no high voltages will be switched on until specific commands are sent to the control unit. All connections between the modules should be made before powering up as the software checks for the existence of other parts of the system at boot up and only then.

7.7 ACCIDENTAL DISCONNECT OF HV MODULE

The system monitors whether it can communicate with the HV module. If communications fail the system will switch off power to the module. This prevents the situation arising whereby the HV outputs are on but communications to change or adjust them is lost.



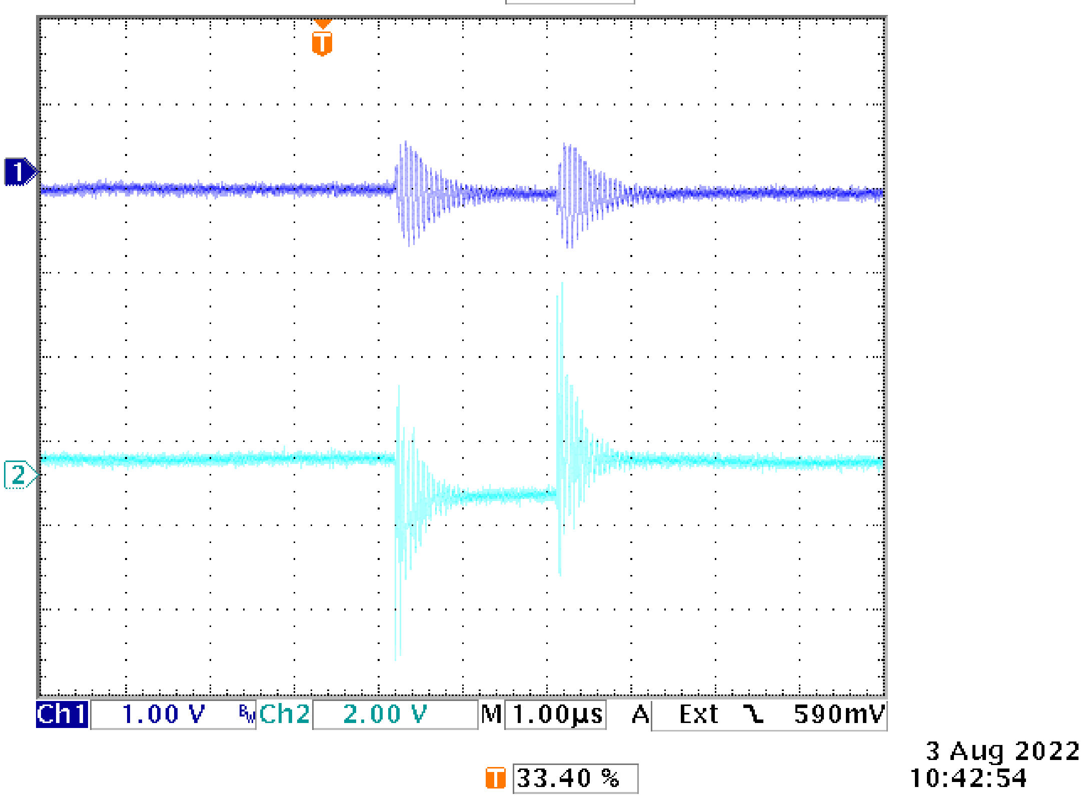


Figure 16 Gate monitor signals for timing information.
Upper is monitor inot 50Ω (upper magenta trace) compared to a scope probe near the output cable (light blue).
Lower is monitor into a 10MΩ scope probe (Upper dark blue trace) compared to a scope probe near the output cable (light Blue).

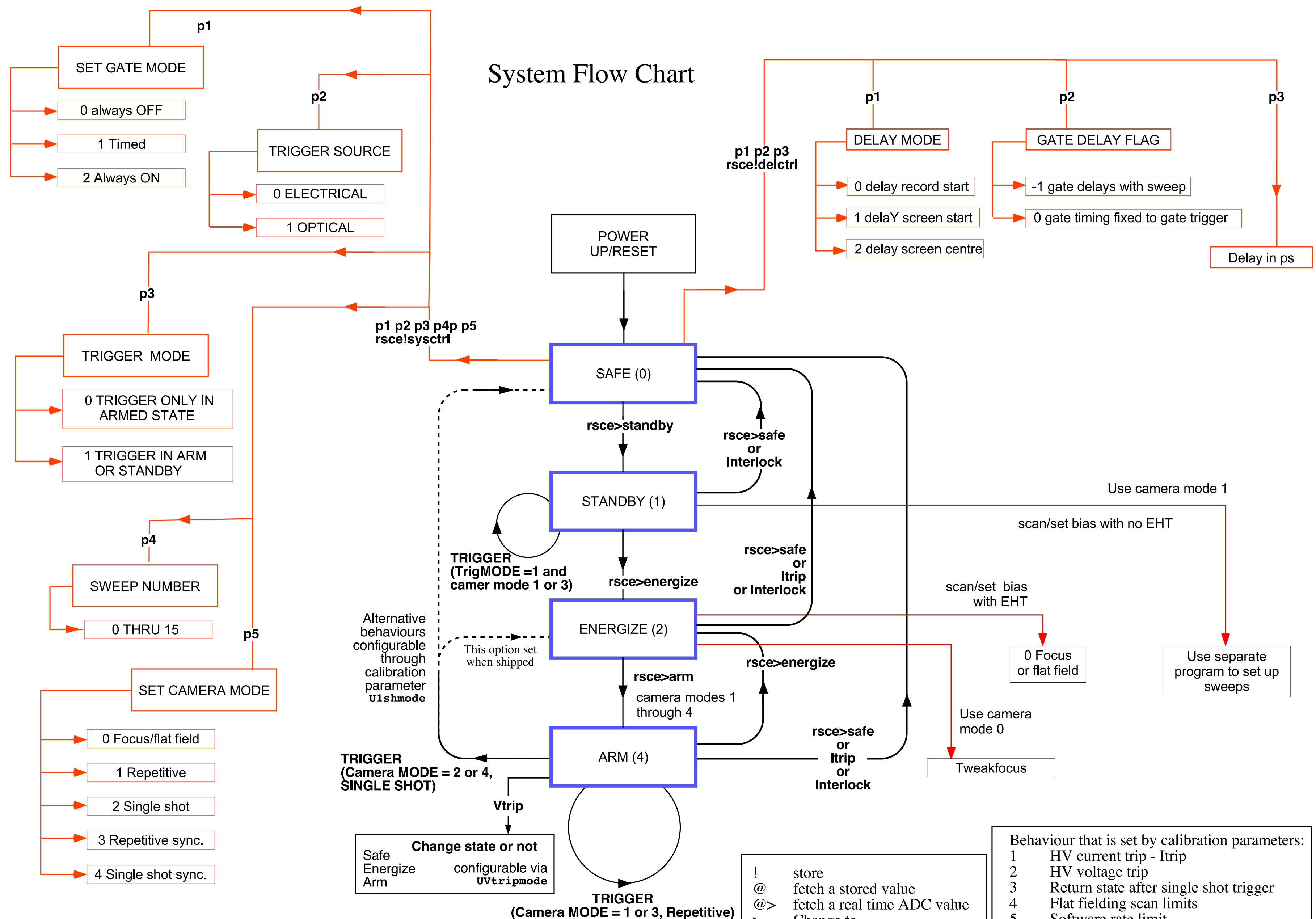


Figure 17 System flow chart

8. STREAK CAMERA OPERATION

8.1 PRINCIPAL OF OPERATION

It is assumed that the user is already familiar with streak cameras. No general details will be given here.

8.2 THE ELECTRON OPTIC FOCUSSING

The RSCE package can drive different streak tubes as the focus voltages are programmable and there are several of them. Some tubes will not require all the voltages. There is also a "Spare" high voltage output which can be used if one of the others fails. It may not be suitable as an alternative photocathode supply or Photocathode OFF supply if the gating feature is to be used.

8.2.1 SPARE OUTPUT

The outputs other than the "Spare" output are linked to each other with zener diode chains to limit the maximum voltage excursion between them. This helps protect the streak tube in the event of a power supply failure but also any failure in tube connections or breakdowns etc.

As the use of the "Spare" output is not specified it is not connected with zeners to the other supplies in the "as shipped" condition.

However, there is provision for the user to add a zener chain between it and the Photocathode supply.

The rear panel of the HV module has a small section that can be removed and behind this is a plastic box inside which the two HV feeds can be accessed. The rear panel is connected to the interlock system so that the high voltages will be disabled if left on when the panel is removed. See **Figure 13 on page 25.**

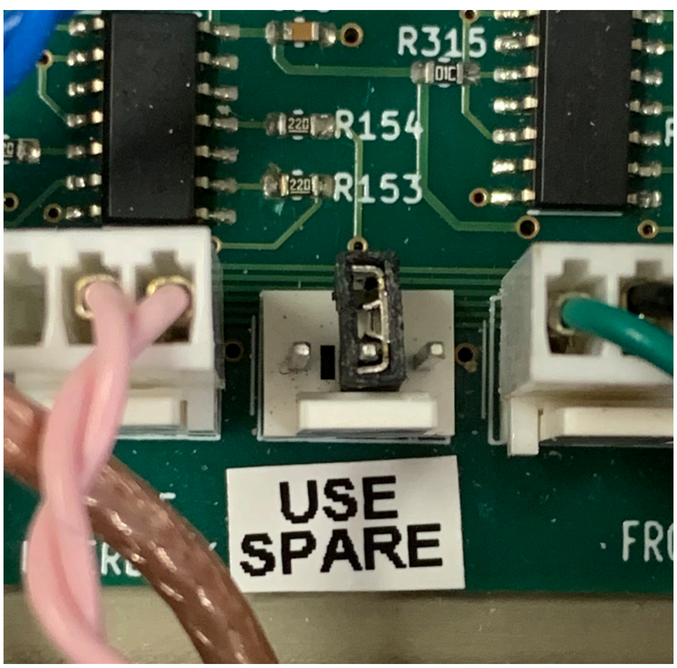


Figure 18 Showing the position if the "Use Spare" connector.
For use with the Spare output.
To access the connector remove the top cover of the HV module. The connector is at front right.
Do **NOT** remove the cover with power applied.

When considering what zener diodes to fit, remember that the supplies are all negative and zener diodes forward conduct with a voltage drop of < 1volt. Zener diodes are normally used reverse biased. If it is necessary to hold off a certain voltage in both polarities, then zeners need to be fitted with some in each direction. Strings of zeners can easily be made than deliver a sharp response at several kV.

We have found that sometimes zeners have a soft "knee" and others should be selected. We recommend the BZT03C270 (a 270 volt device but other voltages are available) and have found these exhibit low leakage below their zener voltage. They may need to be selected if a very specific voltage is required. The surface mount equivalents ones are not as good.

The Spare output has its own interlock which must be set up to allow use of the spare output. See section **8.4.3 on page 34.**

8.3 CATHODE GATING

Cathode gating is achieved by switching the voltage on the SLOT 1 electrode of the streak tube (or mesh in some tubes) between two voltages. The ON state will be a voltage closer to ground than the photocathode. The OFF voltage will be further from ground than the photocathode. The OFF voltage is linked by a fixed amount to the photocathode voltage and will move with it. It is not proportional to the cathode voltage. The ON voltage is set as the SLOT 1 voltage and is adjustable to set the tube focus in the ON condition.

The photocathode gate module is supplied with these two voltages and outputs one or other of them to the SLOT 1 electrode. The switch is actually two switches, each connects the output to one of the two inputs. Only one of the switches is on at a time. The switches are driven from the two inputs that are fed from the HV module. The switches have to float at ~ -15kV, consequently the switches are AC coupled to their trigger inputs. To achieve prolonged connection to either voltage, the relevant switch has to be repeatedly triggered. This can result is some fluctuations that are subsequently removed with smoothing capacitors.

There is a monitor output on the unit. However, as the switch that is floating at high voltage, the monitor is capacitively coupled. It is not possible to draw much current from it. The monitor is designed to drive a high impedance scope probe of 10MΩ and delivers ~ 1 volt. Into 50Ω it will deliver ~ 100mV. This monitor is designed for timing purposes only and will delivery a differential of the SLOT 1 voltage, i.e. two oscillatory bursts, one for ON and one for OFF. See **Figure 16 on page 29.**

If the gate is set to OFF (not TIMED) then only the drive to the gate module drives the switch that connects the Slot 1 electrode to the PC OFF power supply. The trigger is generated by the software and is not timed to any gate signals or the sweep. Similarly if the gate is set to ON then only the drive to the gate module drives the switch that connects the Slot 1 electrode to the SLOT 1 power supply. In this case the HV module triggered LED will be on constantly. In gate mode the LED is only on when the unit it triggered.

8.4 SWEEP ELECTRONICS

8.4.1 INTRODUCTION

The sweep module has to drive long cables and yet deliver a linear ramp at the streak tube. To do this an arbitrary waveform generator is used. This is built into the control module. The output is sent to the sweep module where it is amplified and then split into a positive and negative pair. A "hold-up" pulse is also added to it so that the sweep plates can remain in the deflected stated after a sweep for ~1ms. The two ramps are sent from the sweep module to the HV module over the long cables. Within the HV module the biases are added, the biases are monitored, a continuity check is performed and then the ramps are "balanced". Balancing can reduce small timing errors between the two ramps. Note that mistimed ramps can cause defocusing of the streak tube. The outputs are then fed from the HV module to the streak tube. The continuity check can also determine that the sweep leads between the Sweep module and the HV module are connected the correct way around. Continuity of connections between the HV module and the streak tube are not monitored.

In normal use the positive going ramp starts with a negative bias and vice versa. The image will be swept from the sweep plate that has the positive bias (-ve ramp) to the plate that has the -ve bias (+ve ramp).

Generally within this manual we will use screen left to indicate the starting side of the sweep and screen right, the finishing side. This defines left and right. Remember that positive bias means the bias on the positive ramp; it does not mean that the bias is positive. The bias polarity can be positive or negative for either sweep plate.

The ramp voltages are sent to the tube and are then reflected back to the sweep module. This allows the ramp voltage to double up at the streak tube. For this to work nicely the ramp generator has to be reverse terminated so that the reflection is absorbed in the ramp generator and not sent out again to the tube.

To ensure good reverse termination the high voltage amplifier in the sweep module has to be driven hard ON at the time the reflection arrives back at the module. To achieve this the last 500ns (~ the round trip time of the cabling from the sweep module to the tube and back) of the possible sweep period is not available to the user but instead is used to hold the amplifier ON.

With different length sweep leads other possibilities may arise.

8.4.2 SWEEP WAVEFORMS

The arbitrary waveform generator requires 4096 two byte words to generate the waveform. The AWG generates a waveform using 400ps sampling. So 4096 words each every 400ps give a record length of 1.638μs. This includes the 500ns period not available to the user. Also only 4032 words are actually saved to EEPROM. This makes little difference as they are not available anyway.

Whilst Kentech supplies software commands for configuring the system and also for uploading data for the arbitrary ramps it may be that the user needs to consider how to generate the ramp data. Some basic functions are included to tweak individual samples, read samples and read and write waveforms.

It is fairly easy to generate a list of 2 byte words.

Kentech will be able to provide some Python code to help with this. The linearity of the ramps on the sweep plates is only really measurable by looking at the swept images on the specific tube being used. Even if the ramps are very linear at the outside of the tube, the inductance of the internal tube connections to the deflector plates may well affect the sweep linearity, especially at the faster speeds.

8.4.2.1 LEDs

There are 12 LEDs on the Rack controller. There are 5 on the HV module.

There purpose is as follows:

Power panel	1	AC power
	2	28 volt power to the HV module
Control module	1	Module power
	2	Sweep triggered
	3	Gate triggered
	4	Spare triggered - this input is not configured.
	5	Rate rate exceeds software limit.

	6	Ready - can be triggered
	7	HV enabled - high voltages may not have reached their set values.
Sweep module	1	Module power
	2	Ready - can be triggered
	3	Triggered
HV module	1	Module power
	2	Triggered - gate trigger OFF = tube held OFF, ON = tube held ON and FLASH = tube gate triggered.
	3	Interlock - illuminated if the interlock latch is set.
	4	HV ON (excluding Spare output)
	5	Spare output ON

Interlock - this indicates the state of the interlock latch not the current state of the interlock.
Triggered LEDs flash to indicate the system has been triggered. They do not indicate the state of the trigger latches.

The HV and Spare LEDs indicate that the HV is on. They will flash during the ramp up phase and then become steady when the voltages are steady. The rate limit LED is illuminated if the software rate limit is enabled and the set rate limit is exceeded. This works in both standby and arm modes with repetitive triggering. Either the gate or the sweep trigger can cause the rate limit LED to come on. See section **9.8 on page 39.**

8.4.3 INTERLOCKS

There are interlocks on the HV module. It is split into two parts. One is just for the Spare output. This detects the presence of a high voltage plug in the output socket with a micro switch on the connector. This is used to deliver an interlock. The other interlock receives a signal from two series wired micro switches, one on the top cover and one on the small rear panel covering the box where it is possible to link the Spare output to the Photocathode output with zener diodes.

In normal use it is expected that the Spare output will not be used. In order not to have to fit a plug into the output connector, the interlock can be defeated by having no link on the “USE SPARE” connector. This will allow all the supplies except the SPARE output to operate and will not be sensitive to the presence of a connector in the Spare output socket.

To use the Spare output, the link has to be fitted to the “USE SPARE” connector and this will integrate the Spare output interlock system into the main interlock system.

The “USE SPARE” connector has three pins. The link should be fitted from the centre pin to either of the outer pins. The unit is supplied with a link piece connected to just the centre pin.

Note that the hardware checks the “USE SPARE” link continuously and will inhibit the Spare supply if this link is made after boot up time. The software will not allow operation of the Spare channel unless the USE SPARE link is read as present at boot up time.

9. SOFTWARE INTERFACE

9.1 VERSIONS AND REVISIONS

Revisions/versions:

Currently on version 0 as of 5th. July 2022

9.2 INTRODUCTION

There are several modes for several different functions of the system. These are most easily understood by reference to **Figure 17 on page 30**. Within this figure the core operating states of the system can be appreciated along with how the system moves form one to another and some of the operations and parameters than can be selected at each stage.

9.3 COMMAND LEVELS

There are four levels of commands:

Level 1 is for day to day use with a set up system.

Level 2 is for setting up the tube focus, timing and performing flat field tests.

Level 3 is for setting up system behaviour and sweep waveforms.

Engineering is for testing the unit only.

Levels 1 and 2 use a defined protocol with a strictly limited vocabulary and format of command and response. This is designed for easy interfacing with a suitable interface program. See section **9.11 on page 42.**

Level 3 runs in "debug" mode. Here the system uses the Forth interpreter and replies with "OK" after commands are entered.

9.4 NON VOLATILE MEMORY

There are many parameters that need to be stored in non volatile memory. These include the basic calibration data for the various measurement systems, the system behaviour when certain conditions are encountered, the user parameters for use with a particular streak tube, etc.

There are two EEPROMs available to the user but only one should generally be adjusted. The other is in the HV module and this should not be changed unless the user is very clear about what they are doing. It is possible to do serious damage to a streak tube and possibly to the RCSE system if the parameters in there are changed inappropriately.

The specification of the system requires that it should be testable at up to 20kV for a short period of time. Consequently the electronics has this capability. Overriding the HV module calibration data could result in excessive voltages being accessible in day to day use. This EEPROM is write protected by a board link in the HV module.

The second available EEPROM is in the Control module. Some information stored in this is unlikely to need changing frequently and so is protected by a write enable control. The control button is on the rear panel of the rack controller above the power inlet. It is not labelled.

Other parameters such as ramp waveforms may need more regular changing and are not write protected. The commands for saving the system state to the EEPROMs are in the sections below where it will also be indicated whether the write enable button needs to be depressed during the write cycle. See section **9.15 on page 63.**

9.5 OPERATING STATE

There are four defined system operating states. These are:-

0 SAFE
28V remote power is ON if the HV unit is found
(i.e. connected and working) during the power up sequence, otherwise it is OFF.
The sweep pulser and sweep bias are off.
The focus supplies are inhibited and all HV control adcs set to zero.
Triggering is disabled

1 STANDBY
28V remote power is ON if the HV unit is found at power up, otherwise it is OFF
The sweep pulser and sweep bias are ON.
The focus HV is inhibited and all control adcs set to zero[2].
The requested sweep data is loaded into the waveform buffer.
Triggering is disabled or enabled depending on the trigger mode.

2 ENERGISE
28V remote power is ON
The sweep pulser and sweep bias are ON
The focus HV supplies are ON and set to the requested focus values.
Triggering is disabled

3 ARM
28V remote power is ON
The sweep pulser and sweep bias are ON
The focus module HV supplies are ON
Triggering is enabled.

9.5.1 USE WITHOUT THE HV MODULE POWERED OR PRESENT

The rack controller may be operated for testing and setup purposes without the HV unit connected. If the HV unit is not found at power up the 28V supply is disabled and only SAFE and STANDBY states are available. Note that by setting the trigger mode = 1, the sweep module is active and the ramps can be investigated in the STANDYBY state. If the sweep leads are connected to the HV module (even though the module is inactive) the sweeps can be passed all the way to the streak tube. The sweep monitors on the HV unit can be used. Note that the bias monitors cannot be used as they are amplified.

2 In addition the unit will be in the STANDBY state after ENERGIZE has been requested but the high voltages have not yet reached their steady state. The HV active LEDs will flash as the voltages are ramped up.

9.6 SYSTEM OPERATIONAL VARIABLES

The operation of the RSCE system in the above operating states is also influenced and controlled by the operational variables. Operational variables are volatile and will have default values unless correctly configured after a reset or power cycling. See **Figure 17 on page 30**

The following parameters are set with the command **rsce!sysctrl**, see section **9.11 on page 42**

0	Gate Mode	Defines the gate pulser behaviour
1	Trigger Source	Defines the trigger source
2	Trigger Mode	Defines the trigger behaviour
3	Sweep#	Selects a set of sweep data
4	Camera Mode	Defines the operating mode

9.6.1 GATE MODE - PARAMETER 0

The gate mode determines the behaviour of the gate pulser in camera modes 1 through 4. In camera mode 0 “focus” the tube is on DC regardless of the gate mode setting.

There are three Gate modes:

0. Off mode - the tube is always off - held off by the SLOT 1 voltage.
1. Timed mode. The on time is set by the hardware, edge triggered by the gate input. The gate on time will be linked to the gate trigger plus a programmable delay. The gate off time is linked to the gate on time plus the programmed gate width. See gate delay flag at section **9.7.2 on page 39**
2. On mode - tube is always on

Gate Mode#	Mode
1.	Off
2.	Timed
3.	On - default

9.6.2 TRIGGER SOURCE - PARAMETER 1

The trigger source flag selects either electrical or optical triggering.

Trigger Source	Behaviour
0	All inputs electrical - default
1	All inputs optical

9.6.3 TRIGGER MODE - PARAMETER 2

The trigger mode determines the behaviour of the trigger in the STANDBY operating state.

This allows the operation of the ramp generator and sweep bias to be checked without applying the focus voltages to the streak tube.

Trigger Mode	Behaviour
0	Trigger enabled in ARMED state only
1	Trigger enabled in ARMED and in STANDBY - default

9.6.4 SWEEP NUMBER - PARAMETER 3

The sweep data is stored in EEPROM in an area known as the sweep table. This is divided into 16 sweep records numbered 0 through 15. Each entry in a sweep record consists of the sweep waveform and a set of sweep control data. The sweep table has the capacity for 16 different data sets (0 through 15), each set defining one sweep speed. The sweep control data includes a set of focus voltages, i.e. there is a independent set of voltages for each sweep#. The focus voltages need to be stored with the sweep data as the deflection sensitivity is dependent on them. The focus voltages may be slightly dependent upon the sweep speed due to dynamic defocusing In addition each sweep # includes a set of bias voltages for both normal and sync. operation..

The default sweep number at power on is 0.

9.6.5 CAMERA MODES - PARAMETER 4

The camera mode defines the mode of operation of the RSCE.

There are five modes, a focus mode, 2 normal modes and 2 synchronisation modes:-

0. Focus/Flat field mode in which the focus of the streak tube may be check and modified, The focus supplies are operative but the fast sweep pulser is inhibited.
1. Repetitive (OPERATE) mode in which the camera may be repetitively triggered when armed.
2. Single shot (OPERATE) mode in which the camera may be triggered once after arming.
3. Repetitive SYNC mode in which the sweep starts on screen and in which the camera may be repetitively triggered when armed.
4. Single shot SYNC mode in which the sweep starts on screen and in which the camera may be triggered once when armed.

Note that there is no reduced scan mode set up although in principal this is possible.

Mode#	Mode
0	Focus/Flat field
1	Repetitive - default.
2	Single shot
3	Repetitive Sync
4	Single shot Sync

9.7 DELAY CONTROL

The following delay control parameters are set with rsce!delctrl, see section **9.11 on page 42**:

0. Delay mode - which point in the sweep record is used to set the sweep delay
1. Gate delay flag - whether or not the gate is also delayed
2. Sweep delay - the amount of delay.

9.7.1 DELAY MODE - PARAMETER 0

The delay mode defines the point of the sweep waveform that is delayed by the sweep delay

Delay Mode#	Behaviour
0	delay record start
1	delay screen start
2	delay screen centre

Note that sweep waveforms are stored in EEPROM with minimum delay (i.e. at the beginning of the sweep record) and the delays are then increased if necessary to accommodate the delay mode. Delays of the ramps are achieved by moving the ramp data within the waveform buffer (the section of RAM to where the waveform record is downloaded). This gives 400 ps resolution. In addition there is 400 ps of fine analogue delay. These two delay systems are integrated into the delay commands and are transparent to the user.

If mode 2 is chosen and a repetitive event it timed to screen centre at a slow sweep, then the sweep speed can be increased and the event will remain at screen centre. One can zoom in on the event.

9.7.2 GATE DELAY FLAG - PARAMETER 1

The gate delay flag controls how the photocathode gate is delayed.

With the flag set to TRUE (-1) the timing of the gate signal is delayed with the sweep delay.

With the flag set to FALSE (0) the timing of the gate signal is fixed and the user needs to adjust the timing of the applied gate trigger signal. (This is a requested feature.)

Note that the gate ON duration is a calibration parameter stored along with the ramp data; it has units with 10 ns steps.

9.7.3 SWEEP DELAY - PARAMETER 2

This specifies the sweep delay to be applied in picoseconds. The range is 0 through 600,000.

9.8 SOFTWARE RATE LIMIT

If the software rate limit flag is TRUE (-1), the trigger will be inhibited for a fixed time after every shot. The time, in milliseconds, is set by the software trigger inhibit time variable and is a calibration parameter.

If the software rate limit flag is FALSE (0), no inhibit is applied. However, note that there is a hardware rate limit of ~5 Hz. The rate LED will only illuminate if the rate limit system is enabled, the system is in a repetitive mode and the rate limit is exceeded by either the sweep or gate trigger rate. It will operate in both standby and arm modes assuming the trigger mode is set = 1 (Trigger in arm and standby modes)

This flag and the variable are set with Level 3 commands. See section **9.14.5 on page 63.**

9.9 POWER UP SEQUENCE

After power cycling or a reset, the rack controller applies 28V power to the HV module and attempts to communicate with it. Then it leaves the system in the SAFE state.

The results of this process should be read using the following two commands:

1. The rack controller hardware status read command **rs@hrdw**. This will return the software version number, the HV module detected flag, the sweep module serial no., the control module serial no., and the Kentech job number. If the HV detected flag is returned as zero, this indicates no optical communications were received from the HV module. If this is unintentional it should be investigated before proceeding.
2. The HV unit hardware status read command **rs@hvhw**. This will return the HV unit detected flag, the HV unit serial no., the state of the "Use Spare" link, connection status of the +ve ramp input and the connection status of the –ve ramp input. Note that the parameters after the first are valid only if the HV unit detected flag is TRUE (-1).

The connection status of the ramp connections between the Sweep module and the HV module are returned as numerical code:

Code returned	Connection status
1	Connected to +ve sweep output
0	Not connected
-1	Connected to –ve sweep output

So the +ve ramp parameter should return 1 and the -ve ramp parameter a -1.

The state of the HV module can be verified with the RSCE status read command **rs@stat**
Amongst other parameters this command returns:

sv_remstate - this is the currently set value of the system state (rs@stat returned value r1)

dv_remstate - the system state last requested (rs@stat returned value r2)

State	Description
-1	not used in RSCE
0	safe
1	standby
2	energise
3	not used in RSCE
4	arm

A change of state can be requested by the IBC/user.

If the change is allowed the desired state will appear immediately in dv_remstate, then after a delay as the hardware responds it will appear in sv_remstate.

The activity of the remote task which performs the changes of state is also returned. Possible values which may be seen are (rs@stat returned value r3):

Activity	Description
6	Changing to STANDBY
7	Changing to ENERGIZED
9	Changing to ARM

12	Idle
0	Off
10	Updating

This is not useful for normal operation of the system but it can be useful to read it for diagnostic purposes. After the power up sequence the system state should eventually be SAFE. At this point there is no focus high voltage supply to the tube and the trigger is disabled.

The IBC/user should now set the operational variables using the Level 1 commands **rs!sys**c and **rs!delc**

rs!sysc sets: Sweep#, Trigger Mode, Camera Mode, Gate Mode, Trigger Source

rs!delc sets Delay Mode, Gate delay flag, Delay

9.10 COMMS FAILURE

The state of the FO communication between the Control module and the HV module is continuously monitored. This is required as otherwise the high voltages could be ON but with lost comms there would be no way to turn them off.. A "watch dog" counter in the HV module is reset every 320 ms by a command from the control module. If, within 5 seconds, the counter is not reset and exceeds a certain value the HV module sets a watch dog latch and turns the high voltages off. In addition the control module reads a register in the HV module every 320 ms and if it receives the wrong value it will switch to the Safe state. Of course switching to the Safe state with failed comms means that only the control module is in this state, hence the requirement for the HV module to be able to turn off the high voltages autonomously.

In the rsce@hvhardware command (see **on page 45**) are three returned parameters that reflect the state of the comms. r6 looks to see if the watch dog latch is set, r7 looks to see if the comms is working OK and r8 gives the number of times the comms failure has occurred. If there is an intermittent comms fault i is possible that the watch dog counter will get reset but that comms is still failing at times, this counter will indicate the failure level.

If the comms failure latch is set or the watch dog latch is set, the system will be fixed in the SAFE state until the power is recycled and the comms failure is corrected. By remaining in the Safe state it is possible to continue attempting to communicate with the HV module in order to fix the issue.

9.11 LEVEL 1 OPERATIONAL COMMANDS

For day to day use with a set up system.

Name **rsce>safe**

Explanation Request system change to SAFE state

Format **rs_rqsf or safe**

returned value 1 r1 0 = command completed, -1 = unable

Notes Executes in STANDBY, ENERGIZE and ARM states
Returns “unable” if executed in SAFE state

Name **rsce>standby**

Explanation Request system change to STANDBY state

Format **rs_rqsb**

returned value 1 r1 0 = command completed, -1 = unable

Notes Executes in SAFE state, ENERGIZE state in focus mode (Camera mode 0).
Returns “unable” in STANDBY state
Returns “unable” in ENERGIZE state other than in focus mode (Camera mode 0),
Returns “unable” in ARMED state

Name **rsce>energize**

Explanation Request system change to ENERGIZE state

Format **rs_rqen**

returned value 1 r1 0 = command completed, -1 = unable

Notes Executes in STANDBY state if hv_detect flag is true,
ARM state if hv_detect flag is true. (See rsce@hvhardware)
Returns unable in any state if hv_detect flag is false, in SAFE state or in ENERGIZE state.

Name **rsce>arm**

Explanation Request system change to ARM state

Format **rs_rqar**

returned value 1 r1 0 = command completed, -1 = unable

Notes Executes in ENERGIZE state other than in focus mode
Returns unable in SAFE state, in STANDBY state, in ENERGIZE state in focus mode or in ARM state.
Note that the change from STANDBY to ENERGIZE takes several tens of seconds while the focus supplies are raised slowly to their requested levels. Use **rsce@status** to check that the machine state equals the requested state.

Name **rsce!syscrtl**

Explanation Store write mode settings

Format **p1 ……. p5 rs!sysc**

parameter 1	p1 = gate mode,	0 through 2
parameter 2	p2 = Trigger source,	0 through 1
parameter 3	p3 = Trigger mode	0 through 1

parameter 4	p4 = Sweep#,	0 through 15
parameter 5	p5 = Camera mode	0 through 4
returned value 1	r1 0 = command completed, -1 = unable	

Notes Executes in SAFE state
Returns unable in STANDBY state, in ENERGIZE state, in ARM state
See section **9.6 on page 37**

Name	**rsce@sysctrl** **********	

Explanation read mode settings

Format	**rs@sysc** **********	
returned value 1	r1 = Gate mode	0 through 2
returned value 2	r2 = Trigger source,	0 through 1
returned value 3	r3 = Trigger mode	0 through 1
returned value 4	r4 = Sweep	0 through 15
returned value 5	p5 = Camera mode	0 through 4

Notes Read back of values set with rsce!sysctrl

Name	**rsce@status**	

Explanation Read status

Format	**rs@stat**	
returned value 1	r1 = machine state	
	r2 = requested state	
	r3 = remote task activity	
	r4 = trigger latch	0 = not triggered, -1 = triggered
	r5 = current trip latch	0 = OK, -1 = tripped
	r6 = voltage trip latch	0 = OK, -1 = tripped
	r7 = interlock latch	0 = OK, -1 = interlock compromised
	r8 = comms fail latch	0 = OK, -1 = comms failed

Notes The trigger latch signal here is the logical OR of the sweep trigger, gate trigger and HV trigger latches

---

Name	**rsce!delctrl**	

Explanation write delay settings

Format	**p1 ……. p3 rs!delc**	
parameter 1	p1 = delay mode	0 through 2
parameter 2	p2 = gate delay flag	True/False -1/0
parameter 3	p3 = delay in ps	0 through 1 600 000
returned value 1	r1 0 = command completed, -1 = unable.	

Notes Executes in SAFE state
0 = command completed, -1 = unable.
Returns unable in STANDBY state, in ENERGIZE state, in ARM state

---

Name	**rsce@delcrtl**	

Explanation Read delay settings

Format	**rs@delc**	
returned value 1	r1 = Delay mode	0 through 2

returned value 2	r2 = Gate delay flag	true/false	-1/0
returned value 3	r3 = Delay in ps	0 through 1 600 000	

Notes Read back of values set with rsce!delctrl

Name **rsce@trigger**

Explanation Read trigger latches

Format **rs@trig**

returned value 1	r1 = Sweep trigger latch	(0 = not triggered)
	r2 = Gate trigger latch	(0 = not triggered)
	r3 = HV trigger latch	(0 = not triggered)

Name **rsce0trigger**

Explanation Reset trigger latches

Format **rs0trig**

returned value 1 r1 0 = command completed, -1 = unable

Notes Executes in any state

Name **rsce@interlock**

Explanation Read intelock latches and current state

Format **rs@intk**

returned value 1	r1 = eht interlock current state	(-1 = fail)
	r2 = spare interlock current state	(-1 = set)
	r3 = eht interlock latch	(-1 = fail)
	r4 = spare interlock latch	(-1 = set)

Notes 0 indicates interlock OK. -1 indicates interlock fail.
If the current status is OK, the latches will be cleared by a change of state from SAFE to STANDBY.

Name **rsce@hivtrip**

Explanation Read high voltage trip latches

Format **rs@hitp**

returned value 1	r1 = Spare	
	r2 = Photocathode	
	r3 = SLOT 1	(-1 = tripped)
	r4 = Slot2	(-1 = tripped)
	r5 = Focus	(-1 = tripped)
	r6 = not used	
	r7 = not used	
	r8 = not used	

Name **rsce@lovtrip**

Explanation Read low voltage trip latches

Format **rs@lotp**

returned value 1	r1 = Spare	(-1 = tripped)
	r2 = Photocathode	(-1 = tripped)
	r2 = SLOT 1	(-1 = tripped)

	r4 = Slot2	(-1 = tripped)
	r5 = Focus	(-1 = tripped)
	r6 = not used	
	r7 = not used	
	r8 = not used	

Name	**rsce0trip**
Explanation	Reset high and low voltage trip latches and current trip
Format	**rs0trip**
returned value 1	r1 0 = command completed, -1 = unable
Notes	Executes in any state

Name	**rsce@hardware**
Explanation	Read Rack hardware status
Format	**rs@hrdw**
returned value 1	r1 = Kentech job number from rack controller
	r2 = trigger control unit serial number
	r3 = sweep unit serial number
	r4 = HV unit detected flag
	r5 = software version
	r6 = reserved
	r7 = reserved
	r8 = reserved

Name	**rsce@hvhardware**
Explanation	Read HV hardware status
Format	**rs@hvhw**
returned value	r1 = HV unit detected flag, -1 = detected, 0 = not found
	r2 = HV unit serial no.
	r3 = spare in use flag
	r4 = Pos sweep cable status
	r5 = Neg sweep cable status
	r6 = watchdog fail latch 0 = OK, -1 = fail
	r7 = comms 0 = OK, -1 = fail
	r8 = comms fail #

Notes

Parameters r2 through r8 are only valid if the HV module detected flag is true
Values r2 through r5 are only valid at power up. They are not continuously read.
The "spare in use" flag will be true if there is a plug is in the "Spare HV" output socket and the "Use Spare" link was installed at boot time. See section **8.4.3 on page 34**.

For r4 and r5

Code returned	Connection status
1	Connected to +ve sweep output
0	Not connected
-1	Connected to –ve sweep output

So they would normally read 1 & -1 respectively.

for r6 though r8 see section **9.10 on page 41**

Name **rsce@>temp**

Explanation Read measured temperatures in °C.

Format **rs@>tmp**

returned value 1
r1 = Processor module T1
r2 = Processor module T2
r3 = Sweep module T1
r4 = HV unit T1
r5 = HV unit T2
r6 = reserved
r7 = reserved
r8 = reserved

Name **rsce@Vtube**

Explanation Read the set value of streak tube focus voltages

Format **rs@vtbe**

returned value 1
r1 = Spare
r2 = Photocathode
r3 = SLOT 1
r4 = Slot2
r5= Focus
r6 = Bias
r7 = not used
r8 = not used

Notes SLOT 1 voltage is the power supply output and does not reflect the state of the photocathode blanking pulser.

Name **rsce@>Vtube**

Explanation Read measured streak tube focus voltages

Format **rs@>vtb**

returned value 1
r1 = Spare
r2 = Photocathode
r3 = SLOT 1
r4 = SLOT 2
r5= Focus
r6 = Nbias
r7 = Pbias
r8 = not used

Notes SLOT 1 voltage is the power supply output and does not reflect the state of the photocathode blanking pulser.

Name **rsce@>Itube**

Explanation Read measured streak tube focus currents

Format **rs@>itb**

returned value 1
r1 = Spare

r2 = Photocathode
r3 = SLOT 1
r4 = SLOT 2
r5 = Focus
r6 = not used
r7 = not used
r8 = not used

Notes Measures load current plus the current into 1GΩ sense resistor
Range 0 through 4095 where a count ~ 10nA

Name **rsce@>rcdiags**

Explanation Read measured diagnostic values rack controller

Format **rs@>rcd**

returned value 1 r1 = 28V supply current im mA
r2 = 12V supply current in mA
r3 = Hold up pulser supply in volts
r4 = Sweep pulser supply in volts
r5 = Sweep temperature in C
r6 = Dacrate count (used for factory diagnostics)
r7 = qso count (used for factory diagnostics)
r8 = reserved

Name **rsce@>hv1diags**

Explanation Read measured diagnostic values HV unit set 1

Format **rs@>hv1**

returned value 1 r1 = HV temperature 1
r2 = HV temperature 2
r3 = +ve sweep sense ADC
r4 = -ve sweep sense ADC
r5 = Bias ref monitor
r6 = EHT ref monitor
r7 = reserved
r8 = reserved

Name **rsce@>hv2diags**

Explanation Read measured diagnostic values HV unit set 2

Format **rs@>hv2**

returned value 1 r1 = 22V unregulated monitor
r2 = 28V input monitor
r3 = 200V supply monitor
r4 = Bias psu1 monitor
r5 = Bias psu2 monitor
r6 = reserved
r7 = reserved
r8 = reserved

9.12 LEVEL 2 COMMANDS TO ADJUST THE FOCUS & FLAT FIELD

Commands to adjust the focus of the system in situ and executing flat filed measurements.

Name		**rsce_focus**
Explanation	Setup camera focus condition	
Format		**p1 rs_fcus**
parameter 1		p1 = bias voltage for focus, range -800V to +800V
returned value 1		r1 0 = command completed, -1 = unable

Notes: Will execute only in focus/flatfield mode
This command is normally only used for static focusing of a streak tube when it is necessary to have the image on screen, often in the centre
The polarity used is the polarity on the positive ramp plate, consequently the bias monitor will indicate the opposite polarity.
If p1>0 the beam will be moved towards the right side of the screen, i.e. away from the start plate.

Name		**rsce_flatarm**
Explanation	Arm the camera system in flat field mode	
Format		**p1 rs_farm**
parameter 1		p1 = pause in ms per step for flat field 1 though 1000 ramge
returned value 1		r1 0 = command completed, -1 = unable

Notes: Will execute only in focus/flatfield mode
The step is 1 volt with smoothing.
Restores sweep bias to flatfield start condition. This is **not** the bias voltage set with rsce_focus, but the bias set with Level 3 commands, see section **9.14.1 on page 61**

Name		**rsce_flattrig**
Explanation	Trigger the camera system in flat field mode	
Format		**rs_ftrg**
returned value 1		r1 = sweep bias voltage on termination
returned value 2		r2 0 = command completed, -1 = unable

Notes: Will execute only in focus/flatfield mode
This command will not send a return value for several seconds until the flat field sweep has terminated. It will terminate prematurely if any further serial character is received.
As a guide a step of 10ms with a start and end bias of ±700 volts takes ~16.5 seconds.
To monitor the sweep in real time use the bias monitor output on the HV module.
Note that this has the opposite polarity to the bias voltages reported here.

The start and end bias voltages can be changed with Level 3 commands, see section **9.14.1 on page 61**

Name		**rsce_incvcathode**
Explanation	Add an increment to the cathode voltage	
Format		**p1 rs_+vpc**
parameter 1		p1 = voltage increment, range +/-1000V

returned value 1	r1 = revised cathode voltage setting
returned value 2	r2 0 = command completed, -1 = unable

Notes Will execute only in focus/flatfield mode
Changes only the RAM value, will be lost on power up unless sweep control data is saved.
A positive increment will make the output larger but actually more negative.

Name	**rsce_incvSLOT 1**

Explanation Add an increment to the SLOT 1 voltage

Format	**p1 rs_+vs1**
parameter 1	p1 = voltage increment, range +/-1000V
returned value 1	r1 = revised SLOT 1 voltage setting
returned value 2	r2 0 = command completed, -1 = unable

Notes Will execute only in focus/flatfield mode
Changes only the ram value, will be lost on power up unless sweep control data is saved.
A positive increment will make the output larger but actually more negative.

Name	**rsce_incvslot2**

Explanation Add an increment to the slot2 voltage

Format	**p1 rs_+vs2**
parameter 1	p1 = voltage increment, range +/-1000V
returned value 1	r1 = revised slot2 voltage setting
returned value 2	r2 0 = command completed, -1 = unable

Notes Will execute only in focus/flatfield mode
Changes only the RAM value, will be lost on power up unless sweep control data is saved.
A positive increment will make the output larger but actually more negative.

Name	**rsce_incvfocus**

Explanation add an increment to the focus voltage

Format	**p1 rs_+vfc**
parameter 1	p1 = voltage increment, range +/-1000V
returned value 1	r1 = revised focus voltage setting
returned value 2	r2 0 = command completed, -1 = unable

Notes Will execute only in focus/flatfield mode
Changes only the RAM value, will be lost on power up unless sweep control data is saved.
A positive increment will make the output larger but actually more negative.

Name	**rsce_incvspare**

Explanation add an increment to the spare voltage

Format	**p1 rs_+vsp**
parameter 1	p1 = voltage increment, range +/-1000V
returned value 1	r1 = revised focus voltage setting
returned value 2	r2 0 = command completed, -1 = unable

Notes Will execute only in focus/flatfield mode.
Changes only the ram value, will be lost on power up unless sweep control data is saved.
A positive increment will make the output larger but actually more negative.

9.12.1 COMMAND RESTRICTION BY STATE

Not all commands can be used in all states. The following is a list of states and the Level 1 and Level 2 commands that **cannot** be used for the state. This is a SOW request.

State	Commands that cannot be used
SAFE (0)	rsce>safe
	rsce>energize
	rsce>arm
	rsce_focus
	rsce_flatarm
	rsce_flattrig
	rsce_incvcathode
	rsce_incvSLOT1
	rsce_incvSLOT2
	rsce_incvfocus
	rsce_incvspare
STANDBY (1)	rsce>standby
	rsce>arm
	rsce!sysctrl
	rsce!delctrl
ENERGIZE (2) + Cammode≠0	rsce>energize
	rsce!sysctrl
	rsce!delctrl
	rsce_focus
	rsce_flatarm
	rsce_flattrig
	rsce_incvcathode
	rsce_incvSLOT1
	rsce_incvSLOT2
	rsce_incvfocus
	rsce_incvspare
ENERGIZE (2) + Cammode=0	rsce>energize
	rsce>arm
	rsce!sysctrl
	rsce!delctrl

State	Commands that cannot be used
ARM (4)	rsce>standby rsce>energize rsce>arm rsce!sysctrl rsce!delctrl rsce_focus rsce_flatarm rsce_flattrig rsce_incvcathode rsce_incvSLOT1 rsce_incvSLOT2 rsce_incvfocus rsce_incvspare

9.13 LEVEL 3 COMMANDS

These commands talk directly to the Forth interpreter using the Forth programming language and can be used manually with a terminal emulation program such as Hyperterminal.

A good general guide to Forth programming is Programming Forth by Stephen Pelc which is available on line in pdf format. However it is not necessary to have an in depth knowledge of Forth to use these commands.

Level 3 commands are only accessible in DEBUG mode. Debug mode is enabled/disabled using:-

+debug - change into debug mode

-debug - change into normal mode

Strictly +debug is a level 1 or 2 command but not included as it allows access to Level 3 commands and takes the unit out of the limited vocabulary mode.

In debug mode, the standard short form protocol commands can be used as in level 1 & 2 modes, but in debug mode the rack controller will also recognise the long form name of the function.

If any Forth macros are added the long form should be used.

For example the hardware status read command rc@hrdw will respond as before, but the system will also respond to the long form rc@hardware.

It will be observed that the returned parameters from rc@hardware are not formatted and printed, they are left on the data stack. The stack can be non destructively printed using the stack print command [.S] or the parameters can be printed one by one using the print command [.], which prints one parameter and drops it from the stack. Note that the returned parameters are in reverse order as the last returned parameter is at the top of the stack and will be the first one printed.

9.13.1 DECODED COMMANDS

Several of the Level 1 & 2 commands have new versions under level 3 with parameter decoding. For example

rsce.sysctrl - a decoded version of rsce@sysctrl

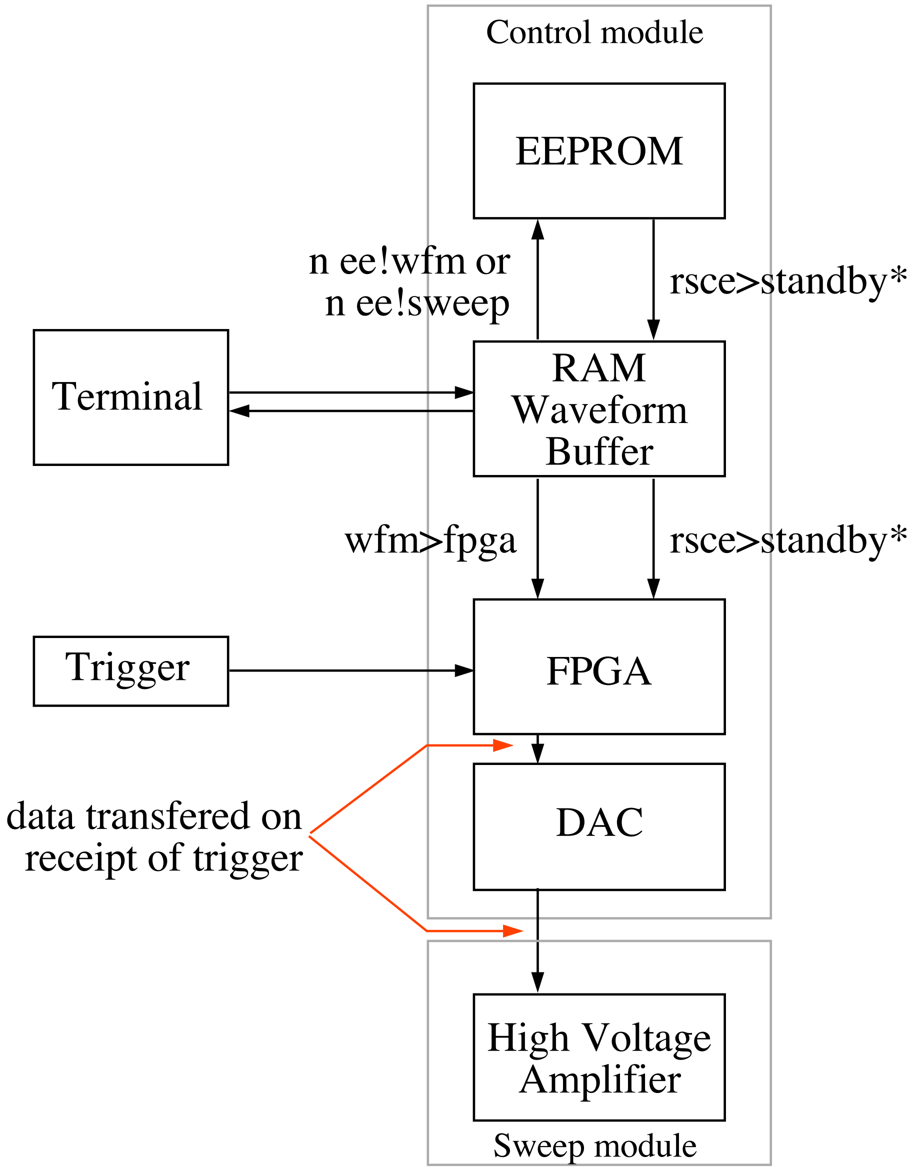
```
rsce.sysctrl
mode = repetitive
sweep# = 0
trigmode = trigger in arm and standby
trigsource = electrical
gatemode = on  ok
```

rsce.status - equivalent to rsce@status

```
rsce.status
comms fail latch = -1
interlock latch = -1
hv_vtripl =0
hv_itripl =0
trig_l = -1
remtask state = Idle
Requested state = Safe
Remote state = Safe  ok
```

rsce.hardware - equivalent to rc@hardware

```
rsce.hardware
SW version = 0
HV unit detected = true
SW module # = 1
```



* When the state is changed to STANDBY the waveform in the EEPROM is copied to the waveform buffer. This will overwrite any changes made with “**tweak**” or “**!sample**”.

The **tweak** and **!sample** functions can be used in both the safe and standby states.

Note that **!sample** does not update the FGPA so if the command is executed in standby mode while viewing the waveform it will be necessary to execute the **wfm>fpga** command to see changes to the waveform.

Figure 19 The structure of the waveform generation

TC module # = 1
Job no. = 2008182 ok

rsce.hvhardware - equivalent to rc@hvhardware

comms fail # = 2
commsok = true
wdog fail latch = true
-ve ramp input = open circuit
+ve ramp input = open circuit
use spare? = true
HV unit # = 1
HV unit detected = true ok

rsce.interlock

rsce.interlock
spare latch = 0
eht latch = -1
spare current = 0
eht current = -1 ok

rsce.trigger   - etc

rsce.trigger
hvtrig_l = 0
gttrig_l = 0
swptrig_l = 0 ok

rsce.>temp

rsce.>temp
Processor T2 = 38
Processor T1 = 36
Sweep T1 = 30
HV T2 = 49
HV T1 = 31 ok

rsce.>Vtube

rsce.>Vtube
>vpbias = 3
>vnbias = 3
>vfocus = 37
>vslot2 = 52
>vSLOT 1 = 86
>vcath = 8
>vspare = 25 ok

rsce.>Itube

rsce.>Itube
>ifocus = 27
>islot2 = 27
>iSLOT 1 = 27
>icath = 26
>ispare = 28 ok

rsce.>rcdiags

rsce.>rcdiags
qso_fcount = 1021
dacrate = 25000
sw_temp = 30
Vsweep = 2
Vhold = 1
12V current = 1389
28V current = 324 okrsce.>hv1diags
rsce.>hv2diags

```
safe {safe;0 }
 ok
2 0 1 0 0 rsce!sysctrl  ok-1
. 0  ok
rsce>standby  ok-1
. 0  ok
rsce>energize  ok-1
. 0  ok
rsce.sysctrl
mode = focus
sweep# = 0
trigmode = trigger in arm and standby
trigsource = electrical
gatemode = on  ok
rsce.status
interlock latch = 0
hv_vtripl =0
hv_itripl =0
trig_l = -1
remtask state = Idle
Requested state = Energized
Remote state = Energized  ok
tweakfocus

use q and w choose param then decrement/increment with 1 2 3 4 5 6
s to save
c to copy
v to paste
z to undo paste


SW#  VPC    VS1    VS2    VFO    VSP
  0  15000  13989  13500  13000  12000
^^^^^

SW#  VPC    VS1    VS2    VFO    VSP
  0  15000  13989  13500  13000  12000
     ^^^^^

SW#  VPC    VS1    VS2    VFO    VSP
  0  15000  13989  13500  13000  12000
            ^^^^^

SW#  VPC    VS1    VS2    VFO    VSP
  0  15000  13989  13500  13000  12000
                   ^^^^^

SW#  VPC    VS1    VS2    VFO    VSP
  0  15000  13989  13500  13000  12000
                          ^^^^^

SW#  VPC    VS1    VS2    VFO    VSP
  0  15000  13989  13500  13000  12000
                                 ^^^^^

SW#  VPC    VS1    VS2    VFO    VSP
  0  15000  13989  13500  13000  12000
                          ^^^^^

SW#  VPC    VS1    VS2    VFO    VSP
  0  15000  13989  13500  13000  12000
                   ^^^^^

SW#  VPC    VS1    VS2    VFO    VSP
  0  15000  13989  13500  13000  12000
            ^^^^^

SW#  VPC    VS1    VS2    VFO    VSP
  0  15000  13989  13500  13000  12000
     ^^^^^

SW#  VPC    VS1    VS2    VFO    VSP
  0  15000  13989  13500  13000  12000
^^^^^

SW#  VPC    VS1    VS2    VFO    VSP
  1  15000  14000  13500  13000  12000
^^^^^

SW#  VPC    VS1    VS2    VFO    VSP
  0  15000  13989  13500  13000  12000
^^^^^

SW#  VPC    VS1    VS2    VFO    VSP
  0  15000  13989  13500  13000  12000
     ^^^^^

SW#  VPC    VS1    VS2    VFO    VSP
  0  14900  13989  13500  13000  12000
     ^^^^^

SW#  VPC    VS1    VS2    VFO    VSP
  0  15000  13989  13500  13000  12000
     ^^^^^

SW#  VPC    VS1    VS2    VFO    VSP
  0  15000  13989  13500  13000  12000
^^^^^ ok-1
```

Figure 20   An example of setting up and using TWEAKFOCUS

9.13.2 TUBE FOCUSSING - TWEAKFOCUS

The focus voltages can be set up by putting the system into focus mode (camera mode 0) and the ENERGIZE state. The voltages may be varied using Level 2 commands.

An alternative is to use the TWEAKFOCUS Level 3 command. This command is provided to simplify the task of focusing the streak tube. With the system in the ENERGIZE (2) state and with the camera mode set as FOCUS (0) this command runs a routine to adjust the voltage outputs from the focus supply. The parameters that can be modified are the current sweep#, Photocathode voltage, SLOT 1 voltage, SLOT 2 voltage, Focus voltage and Spare voltage.

Each sweep record in the sweep table contains a set of focus voltages and they are saved to EEPROM in the sweep tables with either **n ee!swpctrl** or **n ee!sweep** where **n** is the sweep table number (0 through 15). See section **9.15 on page 63.** The sweep rate will depend upon the focus voltages so it is necessary to set up the focus voltages for each sweep rate. Often the focus voltages will be unchanged between sweep speeds, so there is a function to copy the focus voltages from one sweep record to another.

To set the focus voltages the camera mode should be focus/flat field (0) and the state should be ENERGIZE. If the focussing is to be done with a static image at tube centre then the bias voltage will have to be changed to zero with the command **rsce_focus.**

TWEAKFOCUS is activated by typing TWEAKFOCUS (cr).

The following keys are used to operate the function:

W or Q changes the selected parameter be adjusted. W to the right and Q to the left.
1 or 2 decrements/increments the set value by 1
3 or 4 decrements/increments the set value by 10
5 or 6 decrements/increments the set value by 100
c or C will copy all the focus voltages of the selected sweep# to a clipboard
v or V will paste the clipboard into the focus voltages for the selected sweep#
s or S will save the parameters in the sweep control block of the selected sweep# in EEPROM
z or Z will undo the last paste operation.
ESC will exit the routine

On exit the voltages will remain as they have been adjusted, but note that this data is volatile. It will be lost if the system power is cycled or the state is moved from SAFE to STANDBY (as this will download a sweep control table from EEPROM), unless it is explicitly saved in EEPROM using s or S within the TWEAKFOCUS command. An alternative is to use **n ee!swpctrl** to save the sweep control table for the record being adjusted (record = n).

Note that this part of the EEPROM is not write protected.

On exit from TWEAKFOCUS a parameter is returned on the stack. This is 0 for success and -1 for fail. Note that in the event of a fail, the routine is exited immediately.

If TWEAKFOCUS returns a non zero value it means the system state is not in ENERGIZE, and/or the camera mode is not FOCUS.

Note that if the bias voltage is adjusted with **rsce_focus** while tweaking the focus and then the new focus voltages are saved with **n ee!sweep**, the bias voltage will not be overwritten. This is intentional as the bias voltage always has to be adjusted to focus the tube.

An example session of adjusting the focus voltages is shown in **Figure 20 on page 55.**

Note that a set of focus voltages is required for each sweep record, hence the copy and paste commands.

9.13.3 TWEAKFOCUS AND SPARE OUTPUT

Tweakfocus works by changing the voltage in a table and then copying the table value to the output DACs. Consequently is works in real time on the outputs. If the Spare output is not enabled ("Use Spare" link is absent in HV module) then the table is updated but this can't be copied to the output DACs. If the tweaked spare voltage is required, it will be necessary to save the tweaked voltage in EEPROM and reboot the machine. The "Use Spare" link is only read at boot up time.

9.13.4 THE SWEEP TABLE DATA

The sweep table has 16 sweep records. Each sweep is represented in the EEPROM as a record of 8192 bytes. Each record contains a "sweep control table" and a "sweep waveform".

The sweep waveform which will be used by the AWG is kept as 4032 two byte sample values (11 bits used).

The remaining 128 bytes (that make up a sweep record) are used to store a block of parameters this is the "sweep control table". There is one sweep control table for each of the 16 sweeps that are stored.

Parameters in the sweep control table are:

swp_gt_del	- the gate delay in units of 10ns
swp_gt_pw	- the gate width in units of 10ns
swp_hu_f	- hold up pulser flag, true (-1) = enable, false (0) = disable
swp_lhs_ps	- time in ps from start of record to screen left
swp_cen_ps	- time in ps from start of record to screen centre
swp_bias	- bias in volts to use in repetitive and single shot modes
swp_sync	- bias in volts to use in repetitive sync and single shot sync modes
swp_vcath	- photocathode voltage in volts
swp_vslot1	- SLOT 1 voltage in volts
swp_vslot2	- SLOT 2 voltage in volts
swp_vfocus	- focus voltage in volts
swp_vspare	- spare voltage in volts

To set any of these parameters use the standard form, e.g. for the sweep hold up flag:

```
-1 swp_hu_f !
```

The value can also be read, e.g.

```
swp_hu_f @ .
```

Carriage returns have been omitted. The "@'"fetches the value, the "." prints it.

9.13.5 CHANGING THE SWEEP WAVEFORM

When a sweep speed is selected the sweep waveform is copied from the sweep table in EEPROM to the waveform buffer RAM in the AWG.

The waveform buffer is 4096 two byte samples long, which is longer than the 4032 sample record in the sweep table. The deficiency of samples at the end of the waveform buffer is made good by duplicating the last sample of the record in the sweep table. So this should always be enough to deflect beyond screen right.

The position of the sweep table record when copied into the waveform buffer depends on the user delay setting and the delay mode. The samples are 400ps apart, and this is used as a means to vary the coarse delay. Any deficiency of samples at the start of the waveform buffer is made good by padding with zero samples. There is a fine delay hardware function that fills in the 400ps steps. The user delay is specified in ps and the system uses the two delay modes appropriately.

The way the user delay in ps is interpreted depends on the user delay mode, see section **9.7.1 on page 39**.

With trigger mode 1 selected and in camera mode repetitive, the sweep waveforms can be characterised and adjusted in the STANDBY state without high voltages present on the streak tube (other than the sweep bias). The sweep waveform can be adjusted in the waveform buffer, then this can be copied to the user sweep table.

The sweep waveform should be adjusted at minimum delay. The system can add subsequently add delay to the waveform in the user sweep table relative to the sweep trigger as it copies the waveform to the AWG described above, but it can't remove delay, so the ramp data should be at the beginning of the record.

The following commands are provided to define and edit the sweep waveform:

xxx SETALL	Sets all 4096 samples in sample buffer to xxx
ZERO	Sets all samples to generate a zero waveform
+RAMP	Produces a rising linear ramp over all samples
-RAMP	Produces a falling linear ramp over all samples
xx %WFM	Scale the waveform by xx % and send to the output[3]
xx TWEAK	Interactively tweak individual samples
x n !SAMPLE	Set sample at address n (0 through 4095[3]) to x (0 through 2047[3]) (note this does not write the waveform to the FPGA)
n ?SAMPLE	Print value of sample address n
?WFM	Print the waveform buffer as a formatted list of DAC values
TXWFM	Transmit current waveform in binary from buffer to terminal
RXWFM	Receive a binary waveform from terminal to buffer.
?SUMWFM	Print the checksum of the waveform modulus 2^16
WFM>FPGA	Copy the waveform buffer to the FPGA and output to the DAC on receipt of a trigger

Note that **WFM>FPGA** is needed in conjunction with the **!SAMPLE** command. **Figure 19 on page 53** shows how the data is manipulated.

Any sweep waveform set up in this way is volatile and will be lost at power down unless explicitly saved in EEPROM. Further, a change from SAFE state to STANDBY state will overwrite the waveform buffer with the data in the EEPROM at the sweep table specified by the rsce!sysctrl command. The waveform buffer can be saved to EEPROM with the command

n ee!wfm

where **n** = the sweep record to be used.

The EEPROM used for sweep data and user variables is not write protected, i.e. there is no need to operate any write protect button.

3 Note that the data has a maximum value of 2047 and is an integer. The address must be inside the permitted range. No error messages are issued for incorrect data.

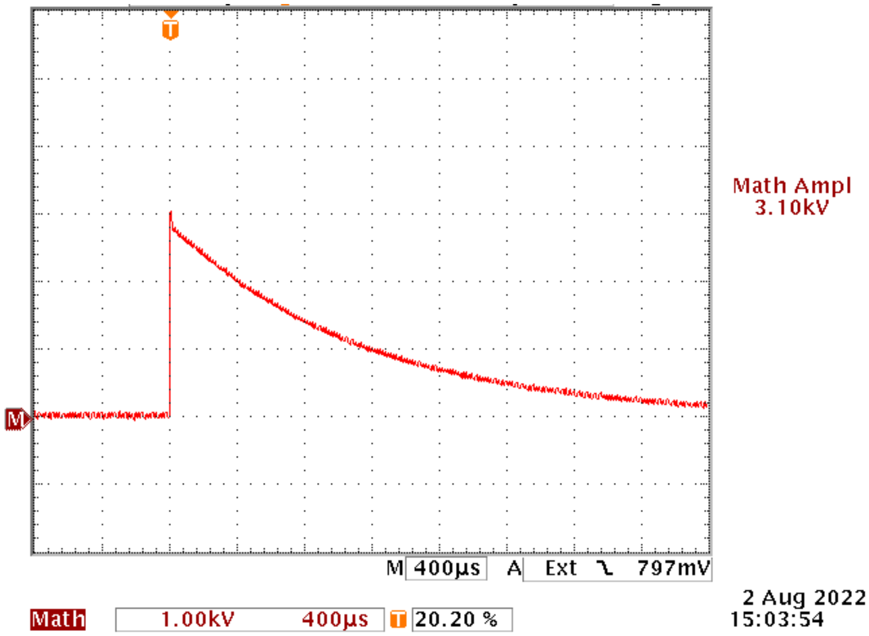


Figure 21 Sweep plate difference voltage with the hold up pulser switched OFF; 400µs per division and 1kV per division. Tested with 15m sweep leads

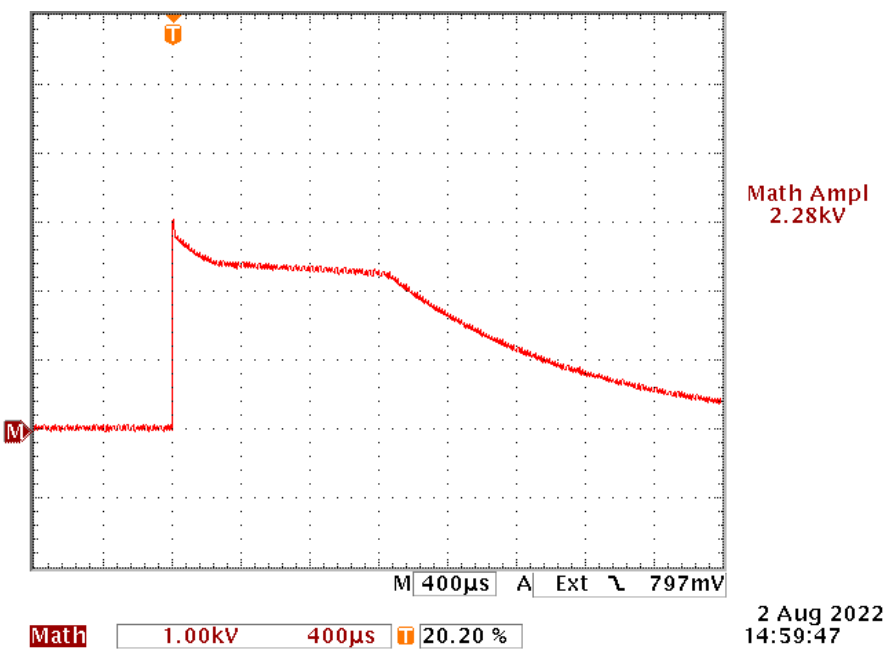


Figure 22 Sweep plate difference voltage with the hold up pulser switched ON; 400µs per division and 1kV per division. Tested with 15m sweep leads

9.13.6 CHANGING THE SWEEP CONTROL TABLES

The sweep control table parameters other than focus voltages should also be setup at this stage.

The 12 parameters in a sweep control table can be modified under Level 3 commands simply by saving a new value in the variable and then saving the table into the relevant sweep record with **n ee!swpctrl** where **n** is the record number (i.e. the sweep number). However, the focus voltages are more easily set up with either Level 2 commands or with TWEAKFOCUS, see section **9.13.2 on page 56**

There are also tweakers for the gate delay and gate width.

Tweak_pw
Tweak_delay

Both take values from 0 through 512 in 10ns steps

The controls for each of these commands are the same. On launch two numbers are presented, the former is the increment and the latter the current value the parameter is set to.

Use the keys “1” & “2” respectively to decrease and increase the increment

Use the keys “3” & “4” to respectively to subtract or add the increment to the current value.

The “ESC” key will exit the routine.

The block of sweep control table parameters can be saved to EEPROM with

n ee!swpctrl

where **n** = the sweep record to be used, see section **9.15 on page 63**.

The waveform and control data from the sweep table, defined by the user variable sweep# (normally set within the rsce!sysctrl command), is read by the system on transition from the SAFE to STANDBY states and used to setup the system appropriately.

9.13.7 SWEEP HOLD UP PULSER

At the end of the ramp the sweep plates will be brought back to their initial state by the bias supply. The supply has a high source impedance and so will take a long time to recharge long sweep cables. However, shorter sweep cables will recharge more quickly. There is a hold up pulser in the Sweep module that holds the voltage difference on the plates high (and in the deflected state) for ~ 1.2ms. The pulse is not equal and opposite (as the ramps are) due to loading by the sweep monitor on the sweep module that loads the positive ramp more than the negative. Imbalance after the sweep is not a important.

The hold up pulser can be enabled and disabled and there is a flag (swp_hu_f) in the sweep control table to reflect this. It should be set up in the usual way when setting up a ramp, see **9.13.4 on page 57.**

The two long time history waveforms are shown in **Figure 21 on page 59**.

9.13.8 SWEEP BIAS VOLTAGES AND SWEEP DELAYS

The above does not allow the setting of the sweep bias voltages for sweep modes (Camera modes 1 though 4). These must be explicitly set by loading the required value into the appropriate variable prior to saving the sweep control data with **n ee!swpctrl or n ee!sweep**.

The required voltages will depend on the streak tube and sweep speed. Generally the bias voltage has to be large enough to hold the start point off screen. Also if the ramp has any non linearities, then the bias voltage can be used to set the most linear part at screen centre.

The voltages have to be obtained empirically for each streak tube used.

The bias voltage used in sync. mode is often zero. This puts the sweep start at screen centre. However,, a more useful place is at the left hand side of the screen. I.e. the starting side, as this gives a longer temporal record. Sync. modes help with timing of the sweep trigger. If an undeflected image appears, the trigger was too late or absent. If no image appears the trigger was to early or no signal was received. Assuming no errors this can give a binary search procedure for the correct trigger timing. It is good practice to check for error occasionally otherwise the binary search can be lead astray.

The sweep delays also have to be set. These need to be measured for a particular sweep set up and streak tube. The delay to sweep centre is just the time it takes the ramp to get to be equal but opposite to the bias voltage, i.e. the plate voltage is zero.

If the streak tube deflection sensitivity is well known, then the time to any point on the screen can be measured and the time to screen left can be set.

9.14 BEHAVIOUR CONTROLLED BY CALIBRATION VARIABLES

In the following several calibration variable may be changed. In all cases they are changed by the following procedure:

Type the following;

x variable_name ! cr

where x is the new value and there is a space before the "!" which represents "store"in Forth.

The new value is in volatile memory and should be saved to EEPROM by the appropriate ee! command.

9.14.1 FLAT FIELD RANGE

The flat field routines available under level 2 commands require the start and end bias voltages to be set. These are stored in two variables:

ffstartbias

ffendbias

The end bias must always be more positive than the start bias.

The factory default values are -700 and +700 volts respectively but these may not be suitable for all streak tubes.

The variables are changed in the usual way:

x ffstartbias ! cr

y ffendbias ! cr

Where x and y are the starting and ending bias voltages in volts (integers) in the range -800 to +800 Note that the step in the flat fielding sweep is 1 volt and the pause per step is in the range 1 to 1000 ms.

The values stored here are in volatile RAM. To save to EEPROM use the command

ee!tc_cal cr

Note that the write protect button will need depressing for this.

9.14.2 CURRENT TRIP BEHAVIOUR

There is a current trip on each of the HV outputs. The spare output current trip is only active when the “USE SPARE” link is fitted in the HV unit. The same trip level is applied to all outputs and is in arbitrary units 0 though 4095. The trip is enabled or disabled according to the variable

Uitrip_en

It takes values, True (-1) = enable, False (0) = disable.

There are two different levels applied, these are defined by the variables

itripl_startup
itripl_steady

itripl_startup is the value loaded for the soft start of the HV module and will be the higher of the two values.

After soft start has finished there is a programmable delay before the lower value **itripl_steady** is loaded and used. A delay is necessary as it takes time for voltages in the Gate module to stabilise.

The delay is defined in milliseconds by the variable

Tsettle

All four variables are stored in the control unit calibration variables. It is unlikely that they will need changing. They can be saved to EEPROM with **ee!tc_cal**, this needs the write protect button depressed.

9.14.3 ONE SHOT MODE BEHAVIOUR

It can bee seen in **Figure 17 on page 30** that following a single shot trigger the system can return either to the ENERGIZE state or to the SAFE state. Which, is controlled by the variable

U1shmode
0 = after a trigger the state returns to SAFE
1 = after a trigger the state returns to ENERGIZE

This variable is stored in the control unit calibration. This can be saved to EEPROM with **ee!tc_cal**, this needs the write protect button depressed.

9.14.4 VOLTAGE TRIP BEHAVIOUR

The system has over and under voltage trips which are active in the ARM state. The action following a voltage trip is defined by the control unit calibration variable

UVtripmode
0 = set trip latch and change state to SAFE - volts go off
1 = set trip latch and change state to ENERGIZE
  volts stay on but triggers will be disabled by change to ENERGIZE
2 = set trip latch but leave voltages on and do not change state.

There is a high trip level and a low trip level for each high voltage output except the Photocathode OFF supply which is closely linked to the Photocathode supply.

These 10 variables are stored in the control unit calibration variables; units are volts.

U_dHiVcath
U_dHiVSLOT 1
U_dHiVslot2

U_dHiVfocus
U_dHiVspare
U_dLoVcath
U_dLoVSLOT 1
U_dLoVslot2
U_dLoVfocus
U_dLoVspare

These values are offsets which are added to the desired value for each output stored in the sweep table to give an absolute level for the trip. Therefore the low trip levels must be negative numbers.

When a focus potential is set, the active trip values are calculated using these offsets and applied.

9.14.5 CALIBRATION PARAMETERS FOR SOFTWARE RATE LIMIT

The hardware has a ~ 5Hz trigger rate limit. In addition there is a software rate limit option.

This is enabled by setting the rate limit flag (U_swlim_en) to True (-1).

-1 U_swlim_en !

In addition there is a variable to set the duration of the trigger inhibit after a trigger is received.

This time (in ms) is set by the control unit calibration variable:

xx U_Tinhibit !

Where xx is the time in ms. Changes to these parameters are volatile unless stored with a ee!user command. This is not write protected.

If either of these parameters is changed they are not acted upon unless the system moves from SAFE to STANDBY.

9.15 SUMMARY OF COMMANDS FOR SAVING TO EEPROM

There are two EEPROMs and several commands for saving different parts of the overall calibration and set up to the EEPROMs.

The commands can only be executed in debug mode and all take the form:

ee!xxxx where xxxx defines which group of parameters is to be saved. Some have a preceding parameter, i.e. **n ee!xxx**

9.15.1 LIST OF ee! COMMANDS

ee!hv_cal will store data to the EEPROM in the HV module - this needs the write protect link in the HV module being set. Do not use this command unless you are very sure you know what you are saving and why. We recommend these default stored values are left unchanged.

All other ee! commands are for the rack controller EEPROM.

ee!tc_cal	write protected
ee!sw_cal	write protected.
ee!user	NOT write protected
n ee!swpctrl	NOT write protected
n ee!wfm	NOT write protected
n ee!sweep	NOT write protected

ee!tc_cal for saving calibration data

ee!sw_cal saves the sweep module calibration

ee!user This is useful for saving a set up as default that otherwise would require the execution of the control commands for the system and the delay (rsce!sysctrl & rsce!delctrl).

It saves the following parameters:

U_swlim_en	true to enable software rate limit
Ugatemode	0 = always off
	1 = timed
	2 = always on
Utrigmode	0 = all triggers only enabled in armed state
	1 = all triggers enabled in standby and armed
Utrigsource	0 = electrical trigger
	-1 = opto trigger
Ucammode	0 = focus/flatfield
	1 = repetitive
	2 = single shot
	3 = repetitive sync
	4 = single shot sync
Usweep#	0 through 15
Udelmode	0 = delay record start
	1 = delay screen start
	2 = delay screen centre
U_>>gtdel_en	true to shift gate del with sweep del
Udelay	delay in ps

n ee!swpctrl Saves all the current sweep control table parameters to entry n (0 through 15) in the sweep table

n ee!wfm saves the contents of the current waveform buffer to entry n (0 through 15) in the sweep table

n ee!sweep saves all the current sweep data to entry n (0 through 15) in the sweep table i.e. it does **n ee!swpctrl** and **n ee!wfm**

These three commands are show in **Figure 23 on page 65.**

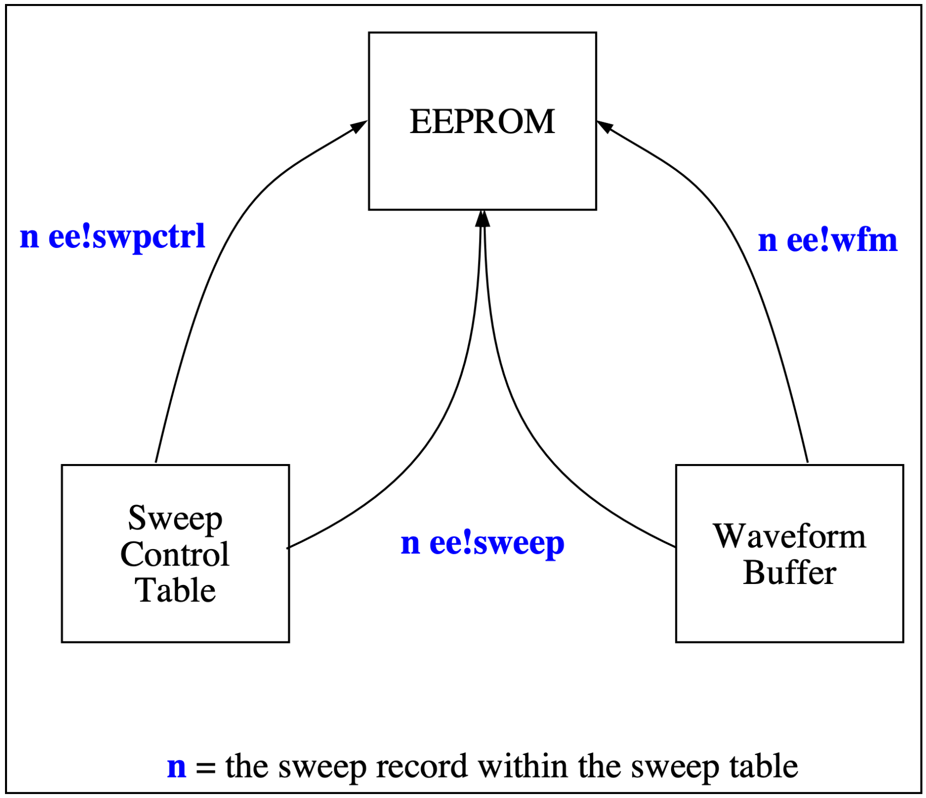


Figure 23 The commands for saving the 2 parts of a weep record to the EEPROM

```
********************************
MPE ROM PowerForth for Cortex-M3
v1.00 [build 0706] 27 Jun 2022, 11:48:52
********************************
11192 bytes free

  ok
engineer  ok
HV_TEST
*** CAUTION 20kV withstand test***
Press Y to continue
Press any key to abort
    0 sv= 0 Vcath=19 Icath =27 Vslot1=88 Islot1 =27 Vslot2=53 Islot2 =27 Vfocus=39 Ifocus =28 Vspare=26 Ispare =28
  500 sv= 500 Vcath=548 Icath =27 Vslot1=488 Islot1 =27 Vslot2=515 Islot2 =27 Vfocus=508 Ifocus =31 Vspare=519 Ispare =28
 1000 sv= 1000 Vcath=1058 Icath =78 Vslot1=1006 Islot1 =27 Vslot2=981 Islot2 =27 Vfocus=1037 Ifocus =35 Vspare=999 Ispare =59
 1500 sv= 1500 Vcath=1500 Icath =154 Vslot1=1500 Islot1 =156 Vslot2=1543 Islot2 =163 Vfocus=1500 Ifocus =153 Vspare=1502 Ispare =152
 2000 sv= 2000 Vcath=1999 Icath =214 Vslot1=1999 Islot1 =199 Vslot2=1999 Islot2 =203 Vfocus=2003 Ifocus =201 Vspare=2000 Ispare =200
 2500 sv= 2500 Vcath=2534 Icath =262 Vslot1=2503 Islot1 =215 Vslot2=2501 Islot2 =284 Vfocus=2507 Ifocus =243 Vspare=2500 Ispare =245
 3000 sv= 3000 Vcath=2999 Icath =304 Vslot1=3000 Islot1 =323 Vslot2=3008 Islot2 =318 Vfocus=3000 Ifocus =303 Vspare=3002 Ispare =304
 3500 sv= 3500 Vcath=3501 Icath =361 Vslot1=3502 Islot1 =357 Vslot2=3501 Islot2 =344 Vfocus=3501 Ifocus =357 Vspare=3500 Ispare =352
 4000 sv= 4000 Vcath=3993 Icath =406 Vslot1=4004 Islot1 =403 Vslot2=4004 Islot2 =386 Vfocus=4006 Ifocus =401 Vspare=4001 Ispare =398
 4500 sv= 4500 Vcath=4500 Icath =465 Vslot1=4502 Islot1 =456 Vslot2=4511 Islot2 =458 Vfocus=4500 Ifocus =456 Vspare=4502 Ispare =454
 5000 sv= 5000 Vcath=5001 Icath =513 Vslot1=5003 Islot1 =510 Vslot2=5000 Islot2 =500 Vfocus=5001 Ifocus =505 Vspare=5001 Ispare =502
 5500 sv= 5500 Vcath=5503 Icath =552 Vslot1=5505 Islot1 =552 Vslot2=5501 Islot2 =551 Vfocus=5507 Ifocus =551 Vspare=5501 Ispare =549
 6000 sv= 6000 Vcath=5999 Icath =572 Vslot1=6003 Islot1 =612 Vslot2=6010 Islot2 =611 Vfocus=5999 Ifocus =672 Vspare=6002 Ispare =602
 6500 sv= 6500 Vcath=6505 Icath =651 Vslot1=6503 Islot1 =656 Vslot2=6500 Islot2 =655 Vfocus=6500 Ifocus =679 Vspare=6501 Ispare =654
 7000 sv= 7000 Vcath=7006 Icath =616 Vslot1=7007 Islot1 =704 Vslot2=7001 Islot2 =700 Vfocus=7009 Ifocus =724 Vspare=7002 Ispare =704
 7500 sv= 7500 Vcath=7505 Icath =615 Vslot1=7504 Islot1 =756 Vslot2=7500 Islot2 =756 Vfocus=7498 Ifocus =943 Vspare=7504 Ispare =747
 8000 sv= 8000 Vcath=8006 Icath =619 Vslot1=8005 Islot1 =807 Vslot2=8002 Islot2 =812 Vfocus=7997 Ifocus =1042 Vspare=8001 Ispare =804
 8500 sv= 8500 Vcath=8508 Icath =443 Vslot1=8508 Islot1 =863 Vslot2=8502 Islot2 =868 Vfocus=8507 Ifocus =1050 Vspare=8502 Ispare =849
 9000 sv= 9000 Vcath=9008 Icath =422 Vslot1=9006 Islot1 =908 Vslot2=9001 Islot2 =908 Vfocus=8997 Ifocus =1424 Vspare=9005 Ispare =899
 9500 sv= 9500 Vcath=9508 Icath =401 Vslot1=9506 Islot1 =955 Vslot2=9501 Islot2 =960 Vfocus=9499 Ifocus =1564 Vspare=9502 Ispare =951
10000 sv= 10000 Vcath=10032 Icath =135 Vslot1=10010 Islot1 =988 Vslot2=10002 Islot2 =1016 Vfocus=10008 Ifocus =1777 Vspare=10001 Ispare =992
10500 sv= 10500 Vcath=10521 Icath =881 Vslot1=10504 Islot1 =1060 Vslot2=10501 Islot2 =1038 Vfocus=10494 Ifocus =1307 Vspare=10504 Ispare =1059
11000 sv= 11000 Vcath=11020 Icath =666 Vslot1=11007 Islot1 =1116 Vslot2=11000 Islot2 =1124 Vfocus=10997 Ifocus =1594 Vspare=11005 Ispare =1094
11500 sv= 11500 Vcath=11520 Icath =330 Vslot1=11513 Islot1 =1152 Vslot2=11500 Islot2 =1144 Vfocus=11496 Ifocus =2033 Vspare=11498 Ispare =1148
12000 sv= 12000 Vcath=12021 Icath =247 Vslot1=12006 Islot1 =1216 Vslot2=12000 Islot2 =1198 Vfocus=11996 Ifocus =2226 Vspare=12004 Ispare =1199
12500 sv= 12500 Vcath=12524 Icath =148 Vslot1=12506 Islot1 =1255 Vslot2=12500 Islot2 =1259 Vfocus=12499 Ifocus =2376 Vspare=12502 Ispare =1249
13000 sv= 13000 Vcath=13029 Icath =27 Vslot1=13015 Islot1 =1307 Vslot2=13003 Islot2 =1300 Vfocus=13000 Ifocus =2616 Vspare=13002 Ispare =1293
13500 sv= 13500 Vcath=13529 Icath =27 Vslot1=13506 Islot1 =1363 Vslot2=13501 Islot2 =1360 Vfocus=13501 Ifocus =2709 Vspare=13506 Ispare =1354
14000 sv= 14000 Vcath=14037 Icath =27 Vslot1=14007 Islot1 =1404 Vslot2=14001 Islot2 =1424 Vfocus=14003 Ifocus =2824 Vspare=14002 Ispare =1409
14500 sv= 14500 Vcath=14536 Icath =27 Vslot1=14522 Islot1 =1453 Vslot2=14506 Islot2 =1472 Vfocus=14501 Ifocus =2926 Vspare=14502 Ispare =1451
15000 sv= 15000 Vcath=15037 Icath =27 Vslot1=15007 Islot1 =1515 Vslot2=15001 Islot2 =1513 Vfocus=15001 Ifocus =3013 Vspare=15008 Ispare =1501
15500 sv= 15500 Vcath=15546 Icath =28 Vslot1=15509 Islot1 =1552 Vslot2=15501 Islot2 =1570 Vfocus=15504 Ifocus =3117 Vspare=15501 Ispare =1556
16000 sv= 16000 Vcath=16043 Icath =27 Vslot1=16027 Islot1 =1609 Vslot2=16006 Islot2 =1624 Vfocus=16000 Ifocus =3238 Vspare=16003 Ispare =1606
16500 sv= 16500 Vcath=16542 Icath =28 Vslot1=16509 Islot1 =1657 Vslot2=16501 Islot2 =1669 Vfocus=16502 Ifocus =3308 Vspare=16512 Ispare =1656
17000 sv= 17000 Vcath=17058 Icath =27 Vslot1=17011 Islot1 =1698 Vslot2=17002 Islot2 =1709 Vfocus=17008 Ifocus =3421 Vspare=17002 Ispare =1705
17500 sv= 17500 Vcath=17546 Icath =27 Vslot1=17509 Islot1 =1761 Vslot2=17511 Islot2 =1776 Vfocus=17502 Ifocus =3522 Vspare=17504 Ispare =1753
18000 sv= 18000 Vcath=18047 Icath =27 Vslot1=18010 Islot1 =1812 Vslot2=18003 Islot2 =1792 Vfocus=18002 Ifocus =3625 Vspare=18014 Ispare =1803
18500 sv= 18500 Vcath=18552 Icath =28 Vslot1=18515 Islot1 =1874 Vslot2=18502 Islot2 =1816 Vfocus=18504 Ifocus =3688 Vspare=18505 Ispare =1851
19000 sv= 19000 Vcath=19023 Icath =28 Vslot1=19011 Islot1 =2112 Vslot2=19034 Islot2 =1962 Vfocus=18973 Ifocus =3578 Vspare=19005 Ispare =1945
19500 sv= 19500 Vcath=19516 Icath =28 Vslot1=19510 Islot1 =2728 Vslot2=19498 Islot2 =2116 Vfocus=19459 Ifocus =3008 Vspare=19503 Ispare =1940
20000 sv= 20000 Vcath=19589 Icath =654 Vslot1=19677 Islot1 =2800 Vslot2=19730 Islot2 =2300 Vfocus=19558 Ifocus =2752 Vspare=19999 Ispare =2000
20500 sv= 20000 Vcath=20008 Icath =1362 Vslot1=19981 Islot1 =2393 Vslot2=19810 Islot2 =2000 Vfocus=19928 Ifocus =2281 Vspare=20000 Ispare =2001
21000 sv= 20000 Vcath=20008 Icath =1333 Vslot1=19978 Islot1 =2384 Vslot2=19826 Islot2 =1968 Vfocus=19926 Ifocus =2316 Vspare=20004 Ispare =2018
21500 sv= 20000 Vcath=20010 Icath =1329 Vslot1=19978 Islot1 =2394 Vslot2=19826 Islot2 =1988 Vfocus=19924 Ifocus =2274 Vspare=20004 Ispare =2019
22000 sv= 20000 Vcath=20010 Icath =1316 Vslot1=19975 Islot1 =2400 Vslot2=19821 Islot2 =1987 Vfocus=19926 Ifocus =2312 Vspare=20002 Ispare =1997
22500 sv= 20000 Vcath=20009 Icath =1315 Vslot1=19975 Islot1 =2394 Vslot2=19825 Islot2 =1971 Vfocus=19925 Ifocus =2285 Vspare=20003 Ispare =2001
23000 sv= 20000 Vcath=20008 Icath =1306 Vslot1=19975 Islot1 =2386 Vslot2=19828 Islot2 =1973 Vfocus=19925 Ifocus =2316 Vspare=19997 Ispare =1988
23500 sv= 20000 Vcath=20007 Icath =1306 Vslot1=19975 Islot1 =2392 Vslot2=19833 Islot2 =1974 Vfocus=19926 Ifocus =2322 Vspare=20004 Ispare =1988
24000 sv= 20000 Vcath=20008 Icath =1294 Vslot1=19977 Islot1 =2392 Vslot2=19833 Islot2 =1985 Vfocus=19926 Ifocus =2326 Vspare=20004 Ispare =2012
24500 sv= 20000 Vcath=20009 Icath =1282 Vslot1=19976 Islot1 =2403 Vslot2=19832 Islot2 =1996 Vfocus=19927 Ifocus =2323 Vspare=20003 Ispare =2008
25000 sv= 20000 Vcath=20008 Icath =1285 Vslot1=19975 Islot1 =2408 Vslot2=19822 Islot2 =1984 Vfocus=19926 Ifocus =2306 Vspare=20003 Ispare =1990
25500 sv= 20000 Vcath=20008 Icath =1281 Vslot1=19974 Islot1 =2384 Vslot2=19822 Islot2 =1979 Vfocus=19926 Ifocus =2315 Vspare=20004 Ispare =1992
26000 sv= 20000 Vcath=20008 Icath =1275 Vslot1=19976 Islot1 =2384 Vslot2=19844 Islot2 =1980 Vfocus=19927 Ifocus =2354 Vspare=20002 Ispare =2004
26500 sv= 20000 Vcath=20007 Icath =1276 Vslot1=19976 Islot1 =2400 Vslot2=19844 Islot2 =1984 Vfocus=19927 Ifocus =2361 Vspare=20000 Ispare =1992
27000 sv= 20000 Vcath=20009 Icath =1263 Vslot1=19976 Islot1 =2421 Vslot2=19847 Islot2 =2002 Vfocus=19927 Ifocus =2339 Vspare=20003 Ispare =1994
27500 sv= 20000 Vcath=20009 Icath =1260 Vslot1=19976 Islot1 =2386 Vslot2=19852 Islot2 =1977 Vfocus=19927 Ifocus =2361 Vspare=20004 Ispare =2001
28000 sv= 20000 Vcath=20009 Icath =1251 Vslot1=19976 Islot1 =2385 Vslot2=19851 Islot2 =1972 Vfocus=19928 Ifocus =2360 Vspare=20003 Ispare =1996
28500 sv= 20000 Vcath=20008 Icath =1255 Vslot1=19976 Islot1 =2408 Vslot2=19853 Islot2 =1991 Vfocus=19927 Ifocus =2380 Vspare=20004 Ispare =1998
29000 sv= 20000 Vcath=20008 Icath =1251 Vslot1=19975 Islot1 =2402 Vslot2=19856 Islot2 =1986 Vfocus=19926 Ifocus =2356 Vspare=20001 Ispare =2000
29500 sv= 20000 Vcath=20008 Icath =1238 Vslot1=19976 Islot1 =2396 Vslot2=19860 Islot2 =1970 Vfocus=19927 Ifocus =2338 Vspare=20003 Ispare =1993
30000 sv= 20000 Vcath=20008 Icath =1232 Vslot1=19975 Islot1 =2424 Vslot2=19854 Islot2 =1989 Vfocus=19926 Ifocus =2385 Vspare=19996 Ispare =1996
30500 sv= 20000 Vcath=20009 Icath =1233 Vslot1=19974 Islot1 =2416 Vslot2=19862 Islot2 =1971 Vfocus=19926 Ifocus =2360 Vspare=20003 Ispare =2000
31000 sv= 20000 Vcath=20008 Icath =1228 Vslot1=19974 Islot1 =2400 Vslot2=19862 Islot2 =2002 Vfocus=19926 Ifocus =2368 Vspare=20002 Ispare =1986
31500 sv= 20000 Vcath=20009 Icath =1232 Vslot1=19975 Islot1 =2396 Vslot2=19869 Islot2 =2005 Vfocus=19926 Ifocus =2368 Vspare=20004 Ispare =2000
32000 sv= 20000 Vcath=20008 Icath =1227 Vslot1=19975 Islot1 =2402 Vslot2=19869 Islot2 =1984 Vfocus=19927 Ifocus =2384 Vspare=20003 Ispare =1990
32500 sv= 20000 Vcath=20008 Icath =1222 Vslot1=19975 Islot1 =2408 Vslot2=19873 Islot2 =2010 Vfocus=19926 Ifocus =2361 Vspare=20003 Ispare =1984
33000 sv= 20000 Vcath=20008 Icath =1213 Vslot1=19975 Islot1 =2400 Vslot2=19874 Islot2 =1975 Vfocus=19926 Ifocus =2392 Vspare=20003 Ispare =1992
33500 sv= 20000 Vcath=20008 Icath =1205 Vslot1=19976 Islot1 =2402 Vslot2=19880 Islot2 =1988 Vfocus=19925 Ifocus =2360 Vspare=20004 Ispare =1997
34000 sv= 20000 Vcath=20008 Icath =1211 Vslot1=19976 Islot1 =2408 Vslot2=19860 Islot2 =1994 Vfocus=19926 Ifocus =2368 Vspare=20004 Ispare =1995
34500 sv= 20000 Vcath=20008 Icath =1201 Vslot1=19976 Islot1 =2400 Vslot2=19876 Islot2 =2009 Vfocus=19927 Ifocus =2376 Vspare=20004 Ispare =1985
35000 sv= 20000 Vcath=20007 Icath =1203 Vslot1=19978 Islot1 =2426 Vslot2=19878 Islot2 =1980 Vfocus=19927 Ifocus =2409 Vspare=20004 Ispare =1986
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38500 sv= 20000 Vcath=20008 Icath =1172 Vslot1=19976 Islot1 =2437 Vslot2=19888 Islot2 =1985 Vfocus=19927 Ifocus =2390 Vspare=20005 Ispare =1997
39000 sv= 20000 Vcath=20007 Icath =1176 Vslot1=19978 Islot1 =2424 Vslot2=19884 Islot2 =1988 Vfocus=19927 Ifocus =2400 Vspare=20002 Ispare =2006
39500 sv= 20000 Vcath=20008 Icath =1176 Vslot1=19976 Islot1 =2443 Vslot2=19888 Islot2 =1994 Vfocus=19927 Ifocus =2380 Vspare=20000 Ispare =2010
40000 sv= 20000 Vcath=20009 Icath =1172 Vslot1=19975 Islot1 =2457 Vslot2=19884 Islot2 =1976 Vfocus=19926 Ifocus =2412 Vspare=20000 Ispare =2012
```

```
40500 sv= 20000 Vcath=20008 Icath =1168 Vslot1=19977 Islot1 =2424 Vslot2=19888 Islot2 =2002 Vfocus=19928 Ifocus =2384 Vspare=20004 Ispare =1988
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45000 sv= 20000 Vcath=20007 Icath =1142 Vslot1=19975 Islot1 =2452 Vslot2=19898 Islot2 =2003 Vfocus=19928 Ifocus =2380 Vspare=20004 Ispare =2009
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57500 sv= 20000 Vcath=20008 Icath =1113 Vslot1=19978 Islot1 =2454 Vslot2=19909 Islot2 =1984 Vfocus=19929 Ifocus =2425 Vspare=20000 Ispare =1989
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61000 sv= 20000 Vcath=20007 Icath =1112 Vslot1=19977 Islot1 =2456 Vslot2=19909 Islot2 =1970 Vfocus=19928 Ifocus =2420 Vspare=20002 Ispare =1996
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65000 sv= 20000 Vcath=20007 Icath =1100 Vslot1=19978 Islot1 =2456 Vslot2=19907 Islot2 =1996 Vfocus=19928 Ifocus =2420 Vspare=20000 Ispare =1988
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70000 sv= 20000 Vcath=20009 Icath =1103 Vslot1=19977 Islot1 =2502 Vslot2=19898 Islot2 =1993 Vfocus=19928 Ifocus =2446 Vspare=20004 Ispare =2002
70500 sv= 20000 Vcath=20007 Icath =1102 Vslot1=19977 Islot1 =2496 Vslot2=19894 Islot2 =2000 Vfocus=19928 Ifocus =2420 Vspare=20002 Ispare =1993
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75500 sv= 20000 Vcath=20007 Icath =1104 Vslot1=19977 Islot1 =2468 Vslot2=19896 Islot2 =1991 Vfocus=19929 Ifocus =2428 Vspare=20002 Ispare =1992
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76500 sv= 20000 Vcath=20008 Icath =1102 Vslot1=19976 Islot1 =2468 Vslot2=19896 Islot2 =1996 Vfocus=19929 Ifocus =2440 Vspare=20000 Ispare =1994
77000 sv= 20000 Vcath=20008 Icath =1102 Vslot1=19978 Islot1 =2461 Vslot2=19895 Islot2 =2006 Vfocus=19930 Ifocus =2393 Vspare=20003 Ispare =2007
77500 sv= 20000 Vcath=20007 Icath =1103 Vslot1=19978 Islot1 =2455 Vslot2=19892 Islot2 =1992 Vfocus=19928 Ifocus =2406 Vspare=20003 Ispare =1984
78000 sv= 20000 Vcath=20008 Icath =1096 Vslot1=19978 Islot1 =2470 Vslot2=19896 Islot2 =1994 Vfocus=19928 Ifocus =2406 Vspare=20004 Ispare =1997
78500 sv= 20000 Vcath=20007 Icath =1099 Vslot1=19977 Islot1 =2464 Vslot2=19892 Islot2 =1996 Vfocus=19929 Ifocus =2411 Vspare=19999 Ispare =1986
79000 sv= 20000 Vcath=20007 Icath =1104 Vslot1=19977 Islot1 =2476 Vslot2=19892 Islot2 =1981 Vfocus=19929 Ifocus =2412 Vspare=20002 Ispare =1993
79500 sv= 20000 Vcath=20007 Icath =1100 Vslot1=19976 Islot1 =2476 Vslot2=19898 Islot2 =1966 Vfocus=19929 Ifocus =2426 Vspare=20002 Ispare =1994
80000 sv= 20000 Vcath=20007 Icath =1102 Vslot1=19978 Islot1 =2464 Vslot2=19890 Islot2 =1974 Vfocus=19929 Ifocus =2433 Vspare=20002 Ispare =1986
 ok
safe {safe;0 }
 ok
cold RSCE controller
Kentech Instruments 2022
```

Figure 24 A Log of the use of the HV_test routine to check operation at 20kV for 1 minute

9.16 ENGINEERING COMMANDS

These commands are for testing the unit only. Under no circumstances should the unit be connected to a streak tube when using these commands. These commands enable access to voltages higher than the 16kV that the system will normally run to. Testing up to 20kV is possible but the equipment is not rated for 20kV for more than 1 minute. At 20kV the power output of several supplies will cause overheating. After this routine is used the system must be re-booted to turn background tasks back on and to reset certain parameters.

MISS USE OF THESE COMMANDS CAN RESULT IN PERMANENT DAMAGE TO THE UNIT AND A STREAK TUBE IF CONNECTED.

The unit normally has a 16kV maximum voltage.

These commands allow going beyond this for testing only.

To execute the test type the following in debug mode.

engineer *(cr)*

HV_test *(cr)*

These commands will cause the Photocathodes, SLOT 1, SLOT 2, Focus and Spare outputs to ramp up together to -20kV with the current trip disabled. It will time-out after 60 seconds. The procedure can be aborted with any key.

Notes:

1. The unit can only drive 20kV into open circuit, it cannot drive a 1GΩ probe.
2. The system will only perform the test once, then it needs to be rebooted.
3. The readings of current are a bit unclear due to the zener chains between the various supplies, if a set of zener diodes are forward biased there can be an anomalously high current on that output.
4. The test may be performed with the gate module connected. In this case the output of the gate module should be removed from the streak tube and the end wrapped up in suitable material to prevent significant spraying of charge or any possible breakdown of the end to its environment. Do not touch it.

Figure 24 on page 67 shows a log of the test.

10. SPECIFICATION AS PER STATEMENT OF WORKS

10.1 FOCUS VOLTAGES

Electronic Performance Specifications Table 2: Electrical specifications for the required voltages			
Voltage supply	**Specification**	**Tolerance**	**Notes**
Cathode	-15 kV(nominal) (± 2 kV adjustable)	± 5 V	Programmable from a fixed DC offset value from zero.
Extraction slot #1	-12.5 kV(nominal) (± 3 kV adjustable)	± 5 V	Programmable from a fixed DC offset value from zero.
Extraction slot #2	Slot # 1 ± 300 V	± 5 V	Programmable from a fixed DC offset value from zero or derived from slot 1 after optimization during setup.
Focus	-14.5 kV(nominal) (± 2 kV adjustable)	± 5 V	Programmable from a fixed DC offset value from zero.
Deflection Plates (Sensitivity)	[500 V/cm] +1 kV for the positive plate and -1 kV for the negative plate.	± 100 V	• Linear to 1% across the sweep window for windows between 10 ns and 100 ns. • Best effort outside this range. • Waveform profile shall be programmable across the design window.
Common Mode Voltage (CMV)	Adjustable from 0 to +600 V for the positive plate and 0 to -600 V for the negative plate.	± 10 V	
Spare channels	-15 kV(nominal) (±2 kV adjustable)	± 5 V	Programmable from a fixed DC offset value from zero.
Phosphor	0 V (GND)	N/A	
Gating	Electron flow "**OFF**" gate voltage is that of the slot #1 voltage which is 100 Volts more negative than the cathode voltage. Electron flow "**ON**" is slot #1 voltage set to the DC operational voltage.	± 10 V in operation mode (non-gating)	• Voltage is called out for each streak tube. • Shall be programmed to power OFF when not required. • Pulse width shall be adjustable from greater than 100 ns to DC (No Gating). The gating pulse width can be generated from an external source, programable and generated internally or adjusted from an external accessible "knob"/screw.

10.2 GATING SYSTEM

The table shows the requested specifications from the statement of work with comments to the right.

10.3

Gating Parameter	Value	Notes	What the RSCE can do
Trigger for the gate	Shall be independent of the sweep trigger	The trigger signal shall be provided by an external signal source.	Achieved
Trigger input impedance	50Ω		Achieved
Minimum Gate Width	100ns		100ns
Maximum Gate Width	5μs		5.12μs in 10ns steps
DC mode	YES	This is a programmable value that you can turn off gating all together and run in DC mode.	Achieved
Gate monitor output	Gate monitor output 50 Ohm, TTL represent the pulse width		The control module has a monitor that does this. The monitor on the gate module produces the differential and only into 10MΩ. This is suitable for timing.
Trigger Type	Analog Selection	The user sends in a pulse and the system mirrors this pulse to the gating function.	No slave mode is supported.
Gate delay	System shall allow overall gate delay with respect to the sweep trigger. The gate width shall be centred over the sweep window.	This can be achieved by having an independent gate trigger.	The On time of the gate is referenced to the external trigger + the gate delay. The Off time is normally linked to the on time and the sweep duration.
Rise time (gating on time)	<80ns		Achieved
Fall time (gating off time)	<80ns		Achieved
Connector type	SMA		The Control module gate monitor is on SMA, the gate module monitor is on a Lemo 00 connector but should only be used to drive a 10MΩ scope probe.

10.4 MONITOR REQUIREMENTS

10.4.1 SOW MONITOR REQUIREMENTS

The system shall provide signal monitors for the gate and sweep. The sweep monitor shall represent the sweep profile, and the gate monitor shall represent the width of the gate. The monitors shall be accessible at the HV section of the electronics.

10.4.2 ACTUAL MONITORS

The sweep monitor on the Sweep module is a divided down copy of the signal being sent to the HV module. The HV module has a sweep monitor that is derived from signal picked off from the streak tube, one from each plate. This signal is the positive ramp - the negative ramp, scaled and presented to the user at the HV module on an SMA connector, this will drive 50Ω.

There is also a separate bias monitor that is presented at the HV module. This is a divided down copy of the bias on the positive ramp plate – the bias on the negative ramp plate. Note this is a negative signal when the electron beam is being held off screen prior to sweeping.

10.4.3 SWEEP DELAY REQUIREMENTS

The sweep channels shall be designed such that all sweep windows between 5ns and 100 ns appear to have the same centre crossing in the sweep window to within 500 ps. This feature can be such that the user can program in a sweep window delay once the windows are established such that the final sweep windows all have the same internal delay. (i.e. delay all windows to look like the slowest window).

10.4.4 ACTUAL SWEEP DELAY

The sweep delay has three operating modes. The delay can be applied to the beginning of the ramp, the point at which the ramp brings the electron beam to screen left and the point at which the ramp brings the beam to screen centre. In this last mode, one can zoom in on the centre of a slow sweep.

10.4.5 VOLTAGES

Programming Precision of Bias	All uniquely defined bias voltages shall be programmable to a Voltages precision of 1% or less.	Achieved
Tube DC Biasing Voltages (Cathode, slot, focus and sweep rails including CMV)	Voltages shall be monitored and allow for closed or open loop feedback that is selectable by the user and where closed loop may be completely powered off. Ability to be monitored live during normal operation. In closed loop operation, adjustment to the DC bias voltages shall be based on a user defined programmable value from milliseconds to seconds.	Voltages are stabilised in hardware and can be monitored in real time through the user interface. It is not safe to turn this off, so there is no ability to do so.
	When the sweep window has been triggered, the voltages shall be stable within 2 seconds of the trigger event.	Achieved
	The voltage setting shall have user defined bounds (maximum and minimum bounds) which if exceeded, produces a latched type monitor alarm which may be cleared by the user.	Implemented with 3 modes of response.
Stability of DC Power Supply voltages	Stable to 1% averaged over a 10 second interval when feedback is applied.	Achieved
Power Supply Monitor Points	Each unique power supply shall have a monitor register that is accessible from a software interface.	Implemented
Power Supply Channels	Each uniquely defined bias voltage shall have an individually controlled output.	Implemented, however, there are zener diodes between some channels to prevent damage to a streak tube by incorrect setting or connection failures.
HV and Low Voltage Interface Design	Control voltages and other required low voltage interfaces are separate from the HV section.	The HV module is potted into a screened enclosure.
	Cables connecting the two modules shall be of the appropriate rating and connectors shall be polarized and locking.	This is implemented for connections between the control rack and the HV module.
	Modules shall be able to support the HV section of the power supply up to 33 meters.	The loop resistance of the cable from the Rack to the HV module should be < 2Ω.
	Low voltage side of the connection shall have HV status.	Implemented
	Low voltage side of the connection shall be programmable, with error monitoring and programmable MAX/MIN setting associated with each bias voltage set point.	Implemented
HV Side of DC Supply	Local to the streak tube.	Implemented
	High side of the HV DC supply shall be designed to operate at the nominal maximum voltage required by each tube.	Achieved

	When powered off or the cables are disconnected, the HV returns to a safe value within 1 minute.	This is achieved for the power lead to the HV module.
	HV section layout of the supply shall be designed such that the minimal component spacing can hold off the maximum required voltage plus ATP. HV circuit layouts may include insulating foils and tapes such as Kapton®	

11. PACKING LIST FOR J2008182

The leading numbers correspond to Kentech sub-assembly numbers.

11.4.1 MAIN COMPONENTS

0060-0163 RSCE HV unit

0060-0165 RSCE PC gate module

0060-0160 RSCE rack system

0060-0161 RSCE rack system control unit module (in rack system)

0060-0162 RSCE rack system sweep unit module (in rack system)

External Sweep monitor difference box.

11.4.2 CABLES

0070-0170 RSCE power lead (2m long for testing)

0070-0171 RSCE FO lead Rack to HV unit x 4

(0070-0172 RSCE Sweep lead Rack to HV unit x 2 (Customer to supply)

0070-0173 RSCE Sweep lead HV unit to tube x 2

0070-0175 RSCE Sweep monitor x 2

0070-0176 RSCE HV lead to tube x 3

0070-0177 RSCE HV lead HV unit to PC gate unit x 2

0070-0178 RSCE PC gate unit trigger x 2

0070-0179 RSCE HV lead PC gate unit to tube 1 (attached to Gate module)

A.C Power lead (US style)

11.4.3 MISCELLANEOUS ITEMS

CD with manual and test data