TECH. MEMO
FS(F) 550

TECH. MEMO
FS(F) 550

ROYAL AEROSPACE ESTABLISHMENT

THE DESIGN, CONSTRUCTION, PERFORMANCE AND CALIBRATION OF PULSE GENERATORS TO FULFIL THE REQUIREMENTS OF SPECIFICATIONS DEFENCE STANDARD 59-41, FS(F) 510 AND FS(F) 457

by

R. A. Hobbs

September 1988

Procurement Executive Ministry of Defence
Farnborough, Hants

RAE TECHNICAL MEMORANDUM FS(F) 550

Received for printing: 22 September 1988

THE DESIGN, CONSTRUCTION, PERFORMANCE AND CALIBRATION OF PULSE GENERATORS TO FULFIL THE REQUIREMENTS OF SPECIFICATIONS DEFENCE STANDARD 59-41, FS(F)510 AND FS(F)457

by

R.A. Hobbs

SUMMARY

This Memorandum describes the construction, performance and calibration of pulse generators to fulfil the electromagnetic transient test requirements of the Defence Standard 59-41 (June 1986), RAE Technical Memorandum FS(F)510 and FS(F)457(Issue 2). Three pulse generators are described, Type 1A which produces damped sinusoidal waveforms in the frequency range 2 to 30MHz, Type 2 which is a fixed frequency 100kHz generator, and Type 3 which produces two waveforms for ground voltage lightning effects simulation. The generators have been designed to enable electronic systems to be assessed for immunity to the effects of EMC, LEMP and NEMP. The NEMP capabilities of the Type 1A generator meet the Airside requirements of the Defence Standard.

A-1

CONTENTS

1. INTRODUCTION

The testing of avionic equipments for susceptibility to the effects of transients has been revised in Defence Standard 59-41 (ref 1), FS(F)510 (ref 2) and FS(F)457 Issue 2 (ref 3). The methods used enable transient tests to be applied as part of normal laboratory qualification electromagnetic compatibility (EMC) tests and can easily be applied to all power supply and signal cable bundles. For EMC transients such as those caused by the switching of electrical loads, the generators Types 1 and 2 are used. The test methods are fully described in the Defence Standard and FS(F) 510. For nuclear electromagnetic pulse (NEMP), the indirect high frequency lightning effects (LEMP) and the 'spike' voltages induced in the ground returns during lightning strikes (GVS) generator types 1 and 3 are used. The test methods are described in FS(F)457 Issue 2.

The specifications mentioned describe the test methods for the transient threats as perceived at the time of writing. It should be noted that for any new project the validity of the frequency ranges and amplitudes should be considered by the Project Officer or his specialist advisors. The design of the generators will be subject to continuous review in order that realistic threat level testing may be maintained.

Each generator is described separately. Types 1 and 2 were developed under MOD(PE) contract by ERA Technology. These are described in ERA Reports 4000/17/13/01 (ref 4) and 4000/17/13/02 (ref 5) respectively. The Type 1 generator has since been modified to increase the available output levels and this version is described in this Memorandum as the Type 1A to avoid confusion. The Type 3 generator was developed at the Royal Aircraft Establishment, Farnborough. Various designs have given for producing transients of these types but were considered to have many shortcomings. The generator described in this Memorandum overcomes some of these problems. A phasing unit which allows the 100kHz transient to be phased with respect to a 50 to 400Hz ac power supply frequency is also described. This unit allows the position of the transient to be adjusted to any point on the supply waveform.

2. TRANSIENT GENERATOR TYPE 1A

2.1 Performance requirements

The generator is required to produce waveforms of a damped sinusoidal nature for bulk current injection. The frequency range required is 2 to 30 MHz with a peak current level of 20 amps in a cable bundle of zero ohms impedance. When the generator is injecting into a load of very high impedance an output of 2000 volts must be available. This is measured by means of a short loop of wire pased through the injection probe. When loaded with intermediate impedances, a volt-amp product of 10 kilo-volt amps must be obtained. The damping of the waveform is specified to be such that the amplitude of the eighth half cycle shall be between 25 and 75 per cent of the amplitude of the second half cycle when the injection probe is loaded by 100 ohms (Figure 1).

Since the impedance of the cable bundle can vary over a very large range and the rf efficiency of the injection probe is good, it is to be expected that there will be degradations of waveform at the impedance limits together with some influence on tuning where the looms under test have high Q resonances.

The choice of component type and layout are extremely critical in this generator as a result of the techniques available for producing such pulses. It is not recommended for construction by anyone who has not a good knowledge of high voltage, high current radio frequency techniques and the means of making measurements of such parameters. The choice of capacitor type is a good example of the problems that are to be faced. During the development it was obsvered that pulse discharge capacitors of different dielectric type could vary the Q of the output waveform from 20 per cent for the eighth half cycle to 54 per cent.

2.2 General circuit description

The circuit diagram is given in Figure 2. A variable output high voltage supply is used to charge one of seven capacitors, depending on frequency range selected, via a high value resistor. A contactor discharges the capacitor into a variable inductor which is used for fine tuning of the frequency. This produces an oscillatory discharge of the energy stored in the capacitor. A transformer couples a portion of these oscillatory currents into the output cable to the current injection probe. A means of measuring the charge voltage is provided to enable test conditions to be repeated, if required, and the position of the tuning inductor is monitored to enable a frequency calibration to be made. The switching of the contactor may be triggered from either an external switch, front panel switch or repetitively from an internal oscillator as required. Figure 3 shows the internal layout.

2.3 Detailed circuit description

Figure 2 and Figure 4 refer.

2.3.1 Power supplies

The primary power unit is a proprietary unit providing two unregulated 25 volt outputs. These are arranged to give +/- 25 volt inputs to the electronics box in which +/- 15 volt supplies are produced by integrated circuit regulators Reg 1 and Reg 2. The +25 volt supply is used for the high voltage power unit. Relay 1 is latched on when a front panel switch is pressed. This switches the +25 volt supply to the high voltage unit such that the generator is powered up in a safe condition. Within the electronics box IC1 produces a stable +10 volt reference supply. This is used for the EHT control voltage setting potentiometer, VR1, and the potentiometer, VR3, which enables the position of the tuning inductor to be determined. Details of each unit will be found in Appendix 1.

2.3.2 Contactor and high voltage resistors

The discharge switch, Relay 3, together with the charge resistors R1 to R4 and the monitor resistor R5 are enclosed in a sealed glass reinforced plastic box. The box is filled with transformer oil to reduce corona discharge. The contactor as supplied has silver plated contact bars which must be modified in order to maintain a satisfactory surface finish. Flats are filed on the contact bars and short lengths of 2mm square platinum bar are soldered on. This is shown in Figure 5. The contactor coil is rated at 240 volts ac but operates adequately at 50 volts dc with diode D1 providing suppression across the coil. The resistors are fixed in the bottom of the box with silicone adhesive and a sheet of 1mm polythene covers them to ensure adequate insulation of the wires within the box. Appendix B gives further constructional information.

2.3.3 High voltage switch and capacitors

Figure 6 shows the high voltage switch and capacitor arrangement. Capacitors C8 to C15 are selected as required to provide coarse frequency selection. The type of capacitor used is important since the dielectric loss of the capacitors under pulse discharge conditions must be as low as possible. The complete assembly is sprayed with several coats of an anti-corona lacquer since at the maximum charge voltage of 20 kv corona discharge can become significant if no steps are taken to control the problem. It is also important that the whole of the rf circuit is manufactured with minimum stray inductance and capacitance to enable the upper frequency of 30 MHz to be reached. The common end of the capacitors is formed by an aluminium plate which is supported by a piece of insulating material. This arrangement must be followed in order that only one rf connection to the main case is made via the output lead. Failure to observe this will result in high frequency oscillations on the output waveform. The type of capacitor used has a very high insulation resistance and can retain a charge for long periods. It is therefore important that they are all fully discharged prior to any internal adjustments or repairs being made to the generator. Appendix C gives further information on the switch and capacitors.

2.3.4 Tuning inductor

Fine tuning on each frequency range is provided by a 'roller coaster' inductor. Figure 7 shows the completed inductor and constructional details are in Appendix D. A reduction gear drive is provided since the rider contact produces considerable friction with the wire as the coil rotates. The internal position of the inductor is important since the capacitive coupling to any adjacent metal must be kept to a minimum. The position of the inductor is monitored by a digital voltmeter, DVM2, measuring the voltage on the wiper of a 10 turn potentiometer which is linked to the gear drive. This enables accurate repositioning of the inductor for frequency calibration purposes.

2.3.5 Output transformer and cable

This item has to be constructed with care as it forms a critical part of the performance determining elements in the generator. It couples the resonant energy in the discharge circuit out to the injection probe. As can be seen in Figure 8 the primary is a single turn of insulated copper strip bound tightly to a ferrite core of the same type as is used in the injection probe. The secondary winding is wound half on each side of the primary turn and gives a step up ratio of 5:1 from the primary. Due note must be taken of the start and finish directions of each winding and the connections made to them. If not correctly installed the damping and available output levels will be adversely affected.

A short circuit turn is placed around the ferrite core at one side of the secondary winding. Care must be taken with the position of this and its size in order that the output damping is correct. Its purpose is to control the reflected impedance of the probe and secondary winding into the primary circuit, such that the losses associated with these do not predominate over the tuning inductor. The orientation of the transformer within the generator is orthogonal to that of the roller coaster to minimise the coupling between them. Appendix E gives constructional details of the transformer. The cable to the front panel connector and from the generator to the injection probe is RG 63B/U, 125 ohm impedance. The connectors used are 50 ohm 'C' type, though not correct for this cable they are easily assembled and otherwise satisfactory. This cable is used for its low capacitance characteristics. It preferable not to use more than a 1 metre length between the generator and injection probe.

2.3.6 Control electronics

Figure 4 shows the circuit diagram. A metal box houses the reference power supply and the triggering system for the generator. All wires passing into the box are filtered to protect the internal integrated circuits. The repetition rate of the internal trigger system is controlled by integrated circuits IC2 and IC3. The front panel control, VR5, sets an input current via R11 into IC2 which is arranged as an integrator. At the minimum setting of VR5, the diode D3 and the bias produced by R12/R13 ensure that there is no input current and thus turn off the internal oscillator. Assuming that a control setting is made for internal triggering the charge across the integrator capacitor, C20, increases until the the Schmitt trigger formed by IC3, R15, R16 trips. This gives a fast discharge of the integrator until the Schmitt trigger relaxes. As the output of IC3 falls the monostable, IC4, is triggered and relay Rly2 is switched thus connecting 50 volts to the main discharge contactor.

External manual triggering is accomplished by the grounding of the base of TR2 with a push button switch via a front panel socket. Internal triggering on a single shot basis is available via the push button PB2.

2.4 Calibration

The waveform of the generator is checked by using the calibration jig connected as shown in Figure 9. This should be terminated at one end with a 50 ohm load and at the other end with a 20dB attenuator. These should have a pulse rating of 4kW for a low duty cycle. In practice most 50W coaxial loads will be adequate. The output of the attenuator is taken to the input of a suitable digitiser or storage oscilloscope and terminated with a 50 ohm load.

The waveform shown in Figure 1 should be obtained for all EHT settings above about 1000 volts. Below this level the waveform may become ragged due to the discharge arc intermittently quenching as the contactor closes. The first half cycle will sometimes be of reduced amplitude compared with that of the second. This is normal and is a function of the limitations in the frequency response of the output transformer and injection probe. The preferred injection probe is the ERA36 or 36A. In order to obtain best damping response and open circuit EHT capability it is necessary to shunt the winding of the probe with a high voltage, high Q capacitor of between 100 and 150 pico-Farads. This must be as close to the coil as possible. The prototype was developed with such a capacitor soldered across the winding though later an arrangement using in-line connectors was tried with equal success. A calibration of capacitor range and tuning inductor position is made by averaging the zero crossing times of the output waveform over several cycles. Figure 10 shows a typical calibration of frequency and damping. This is useful for setting the output frequency as required in Def Stan 59-41, FS(F)510 and FS(F)457 Issue 2. It must be remembered that since the probe couples efficiently to the cable bundle under test it is possible for the output frequency to be 'pulled' by the resonances of the cable bundle.

2.5 Safety

It must be remembered that this generator contains a power unit that produces voltages up to 20 kilo volts. This will prove fatal if touched during testing of the generator. Those who build, test and use the generator must be made to understand the implications of interfering with it. Care should also be taken not to touch the output connector if no probe is attached since high voltages will be present if the generator is accidentally pulsed.

A key switch, in the mains input, should be installed to restrict the use of the generator to those authorised.

The prototype generators were all constructed with a double box technique such that good rf screening was obtained from the inner box and a reasonable appearance given by the outer box.

3 TRANSIENT GENERATOR TYPE 2

3.1 Performance requirements

The Type 2 generator is required to produce, by means of bulk current injection, a fixed frequency transient oscillatory waveform. The injection probe specified for use in this test method is the purpose designed ERA Type 50. The frequency is 100kHz with a peak current of 30 A, and 700 V open circuit when injecting into a high impedance. The waveform, as shown in Figure 11, is verified by loading the injection probe with a short loop of wire terminated in a 5 ohm load. The amplitude of the third half cycle shall be at least 25 per cent but less than 50 per cent of the amplitude of the first half cycle.

3.2 General circuit description

A capacitor is charged from a variable high voltage supply via a resistor. As required the capacitor is discharged into the injection probe by means of a semiconductor switch. The inductance of the injection probe resonates with the capacitor to give the required waveform. Reverse conduction is maintained by diodes across the switch. A capacitor-resistor network is used in order to limit the rate of rise of voltage at the output.

3.3 Detailed circuit description

The complete circuit diagram is given in Figure 12. Power is derived from 50 Hz mains via a variable transformer T1 and high voltage transformer T2. Capacitor C1 is charged via resistor R1 to the required voltage level. Switching is accomplished using the pair of series connected thyristors Th1 and Th2. Current flow on reverse half cycles is maintained by silicon diodes D1 and D2. Voltage equalisation networks R2 R4 C2 and R3 R5 C3 ensure equal division of reverse voltages across the thyristors. Resistor R6 and capacitor C4 serve to moderate the high initial rate of rise of current in the injection probe.

Trigger pulses for the thyristors are applied via the pulse isolation transformer T3. The primary winding of T3 is energised by discharging capacitor C5, charged to 24 volts, via mercury wetted relay Rly1. The actuating coil of the relay is energised via the front panel push button.

Pulse transformer T4 allows the generator to be triggered from an external source such as the phasing unit to be described later in this Memorandum.

3.4 Construction of the 100kHz generator

Construction of this generator is straight forward and should present no problems. The unit is mains powered and should incorporate a key switch in the primary of the high voltage transformer. This is a safety feature since if the generator is powered without a probe connected to the output it is possible for dangerous voltages to be present at the output connector. Further details of construction and components will be found in Appendix F.

3.5 Calibration of the generator

As described in 3.1 above the waveform is verified when injecting into a 5 ohm load. Since the injection probe forms part of the frequency determining network, it is important that the correct probe be used.

When injecting into low impedances it is possible to obtain an induced current of at least 1500 amps. If ordinary current monitoring probes are used at this level and are of a type that incorporate resistive loading of the probe winding, this being very common, there is a great risk of damaging the probes. The available energy in the output of this generator is quite high and as such should be applied to equipment testing with caution.

4 PHASING UNIT FOR 100kHz GENERATOR

4.1 Performance requirements

Defence Standard 59-41 and FS(F)510 require that the 100kHz transient be positioned on supply lines relative to the phase of the supply for ac systems. The Phasing Unit allows synchronisation to an ac waveform at any frequency between 25 and 500 Hz. The exact moment of injection of the transient can be selected by the use of this unit together with any normal twin channel oscilloscope.

The unit will accept an ac input up to 350 volts rms and the output will directly drive the 100kHz generator as described above.

4.2 Circuit description

The circuit diagram is given in Figures 13 and 14. The ac waveform to be used as the reference is input to the unit and IC3 acts as a comparator to 'square up' the waveform. The output of this IC, Compl, is in phase with the incoming ac. The diodes on the input serve to limit the voltage at the input to a safe level. The choice of IC type is not critical except that a fast slew rate is required.

Capacitor C1 is charged from a constant current source. The switch, Sw1, is used to allow an increased charge rate for operation at equipment supply frequencies of greater than 200 Hz. On the positive going zero crossing, phase angle 0 degrees, Compl triggers IC4 to provide a 10 μs sample pulse to IC1, a sample and hold amplifier. A short delay, provided by the 100kohm and 100 pF between IC4 and IC5 allows the sample and hold amplifier to lock out before the pulse from IC5 to the VMOS transistor resets the voltage across C1 to zero. This process takes a total of 25 us from phase 0. A linear voltage ramp on C1 now starts and is finished at the next positive zero crossing of the input waveform, phase 360 degrees.

The output voltage of the sample and hold amplifier represents the maximum voltage of this ramp and is applied to a potentiometer. The demanded phase position for transient injection is set by this potentiometer and is compared with the ramp voltage by IC2. When the ramp voltage has reached equality with the demand IC2 output, Comp2, triggers IC6 to give a 'fire if armed' pulse. The output of IC6 is buffered to give a pulse output for an oscilloscope to allow accurate positioning of the pulse with respect to the ac waveform.

When the position is correct the push button switch - 'ARM' is used to set IC7. The next phased pulse from IC6 will reset IC7 and as the Q output goes low IC8 is triggered. The output from IC8 is buffered to give a positive going trigger pulse of approximately +5 volts for the triggering of an oscilloscope. It is also buffered by the transistors arranged as a Darlington pair. The 1.5 uF capacitor is rapidly discharged giving a positive pulse of 14 volts at up to 1 amp into a short circuit. This is the trigger pulse for the 100 kHz generator. If an oscilloscope is triggered by the 5 volt pulse it will be easy to observe the injected transient thus avoiding triggering difficulty from the ac supply waveform.

4.3 Operation of the phasing unit

Trigger 1 output has a pulse that is approximately 15 µs wide and +5 volts in amplitude. This is available continuously and is monitored together with the reference waveform on a dual beam oscilloscope to set the required phase position for the pulse injection. Variation of the phase is obtained by the 'PHASE' control on the front panel. When this has been set according to the requirements of the test specification and the operator is ready to apply the 100 kHz pulses then the 'ARM' push button should be pressed. This will set the phaser to trigger the pulse generator at the next point in the supply waveform that corresponds to the previously set phase.

A pulse of 15 us and +5 volts appears on the 'TRIGGER' output several microseconds before the pulse generator is fired. Thus this output may be used to trigger the oscilloscope that is being used to monitor the amplitude of the transient. The phaser will only accept another 'ARM' pulse after a period of 2 - 3 seconds. This will ensure that the 100 kHz pulse generator is fully charged and gives the correct output for each pulse.

5 TYPE 3 GENERATOR, GROUND VOLTAGE LIGHTNING EFFECTS

5.1 Performance requirements

The test method is described in FS(F)457 Issue 2. The pulse generator is inserted in the equipment bond to ground such that the case of the equipment plus any wiring which is bonded to ground in the vicinity of the equipment grounds via the pulse generator. The most severe test level required is for an open circuit voltage of 1600 volts or a maximum current of 320 amps. This level applies to both pulse types that the generator produces. The first pulse is similar to a double exponential pulse. It has a rise time that must be 50 ns or less and a fall time of 2 μs, 10 per cent to 90 per cent. Figure 15 shows the pulse. The longer pulse has a rise time of 1 us and a fall time of 150 μs. This is shown in Figure 16.

5.2 Circuit description

Figure 17 shows the circuit diagram. Capacitors C1 and C2 are charged via resistors R1 and R2 respectively from a variable high voltage supply. In the prototype generator a commercial supply was utilised. The supply must be capable of being reversed such that both positive and negative going output pulses are obtainable. For the short pulse C2 is discharged by switch Sw2 into the output circuit. Resistors R3/R4 limit the maximum current and the combination of R5 R6 R7 R8 and L2 control the discharge characteristics. The long pulse is obtained by discharging C1 via Sw1 into the inductor L1. This inductor sets the rise time of the pulse to 1 us. The internal inductance of the capacitor C1 and the inductance of the wiring may require a different value to that quoted in order to achieve the correct discharge characteristic. The output circuit configuration defines the fall time as for the short pulse.

The principle purpose of the inductor L2 is to control the low frequency impedance of the generator that is seen by the unit under test. Resistors R5 to R7 were added to prevent an otherwise excessive value of storage capacitor being required. The inductor serves to present a larger impedance for the transients. Resistor R8 limits this impedance at high frequencies such that the impedance to ground seen by any rfi filters in the equipment under test does not become excessive.

To monitor the output current resistors R9 to and R12 are in series with the output and in conjunction with R13 and R14 serve to give an output of 1 volt per 100 amps when the monitor output is loaded by 50 ohms.

The discharge switches in the prototype generator were mercury tilt switches. These perform well with fast turn on times. The objection to the use of such devices is that they may be difficult to obtain and can produce a health hazard if the glass envelope is broken, allowing spillage of the mercury. The Ross switch as used in the Type 1A generator has been used successfully and may be substituted. The use of the Ross switches will require a suitable power unit for the coil voltage rating chosen. This is left to the builder to select.

5.3 Construction of ground voltage generator

The capacitors used for this generator must be capable of withstanding high discharge currents. The inductors are air cored devices and must be mounted orthogonally to avoid interaction. It is also advisable to make the circuit connections out of copper strip or braid to present low inductance and resistance. The EHT supply should be capable of providing +/- 5000 volts. As with the other types of generator described in this Memorandum potentially lethal voltages can be present and great care must be taken during use and servicing.

5.4 Operation of ground voltage generator

The output waveforms of the generator should be checked when it is loaded by an impedance of 1 ohm. The waveforms previously described should be obtained without any difficulty. In use the load should always be connected directly to the generator terminals and not by means of coaxial cables etc.

6 FUTURE DEVELOPMENTS

The pulse generators described in this Memorandum will meet the specifications quoted at the time of writing. These specifications are subject to review with developments either in aircraft construction techniques and the resultant change in rfi threat or any future weapon technology.

At the time of writing a damped sinusoid generator is nearing completion which will cover the frequency range 30 to 50 MHz. There will be further issues or this Memorandum as required.

7 ACKNOWLEDGEMENT

The author would like to thank those people who contributed to the development of these generators.

8 REFERENCES

No.	Author	Title etc.
1	MOD Directorate of Standardisation	Defence Standard 59-41, 13 June 1986
2	Dr N J Carter	R A E Technical Memorandum FS(F)510. Recommended Test Specification for the Electromagnetic Compatibility of Aircraft Equipment.
3	R A Hobbs	R A E Technical Memorandum FS(F)457 Issue 2. Equipment Test Methods for Externally Produced Electromagnetic Transients.
4	B W Smithers R Orchard	ERA Report No 4000/17/13/01 The Design, Construction, Performance and Calibration of ERA Transient Generator Type 1.
5	B W Smithers R Orchard	ERA Report No 4000/17/13/02 The Design, Construction, Performance and Calibration of ERA Transient Generator Type 2.

INDEX TO FIGURES

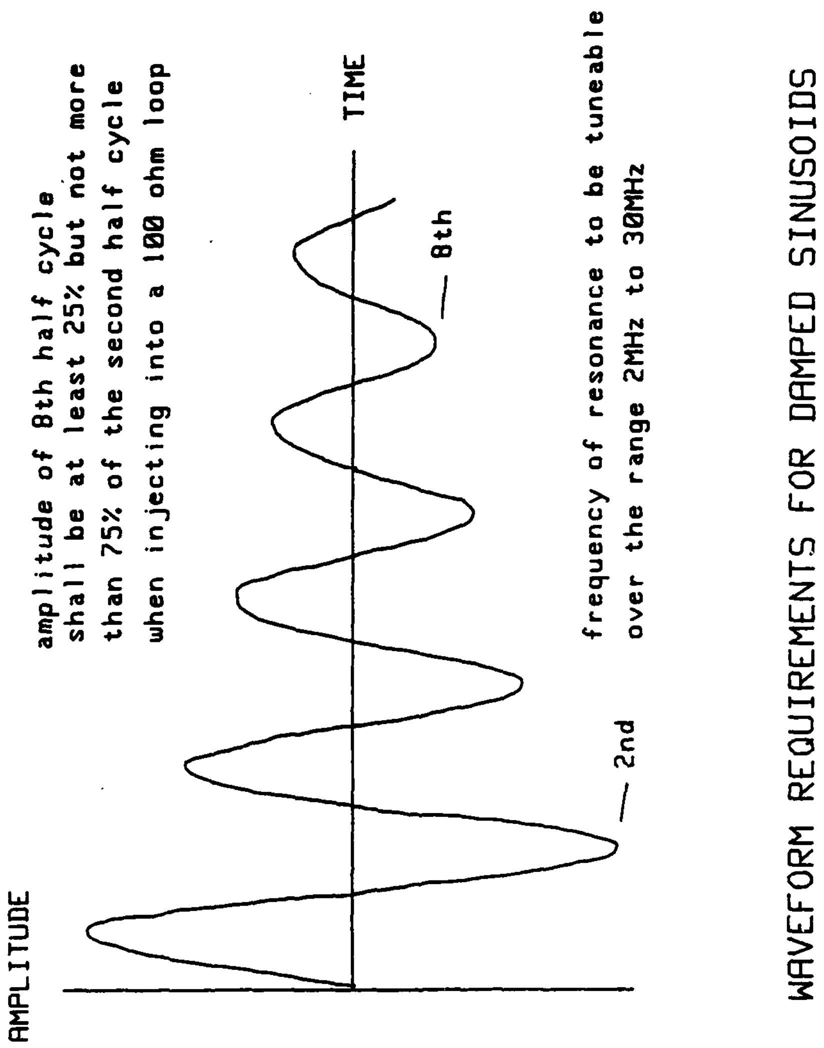


Fig 1 Damped sinusoid

Fig 2

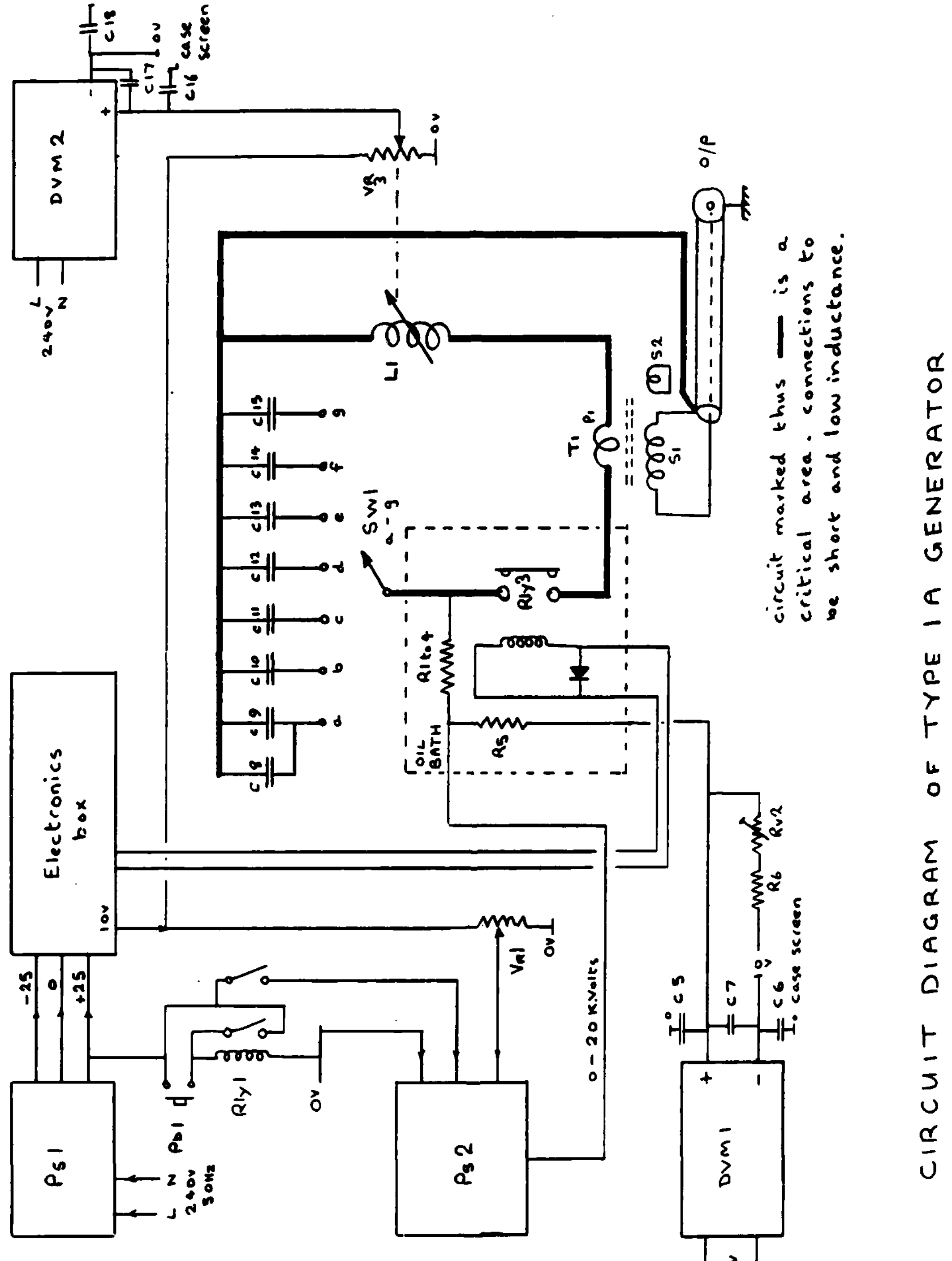


Fig 2 Type 1A circuit

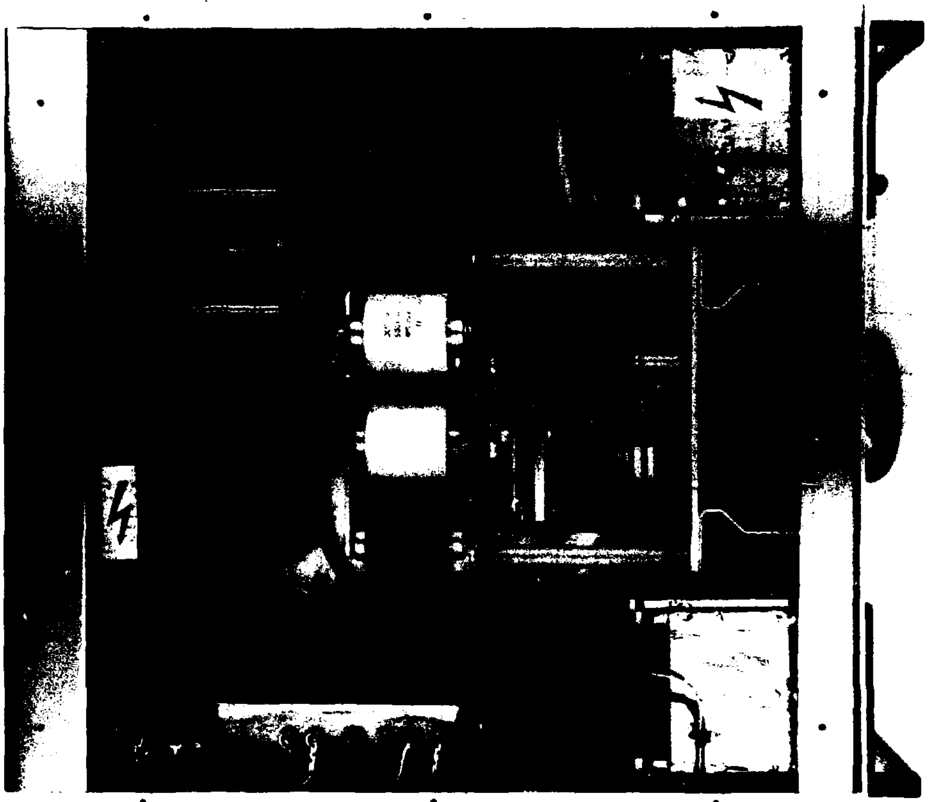


Fig 3

Fig 4

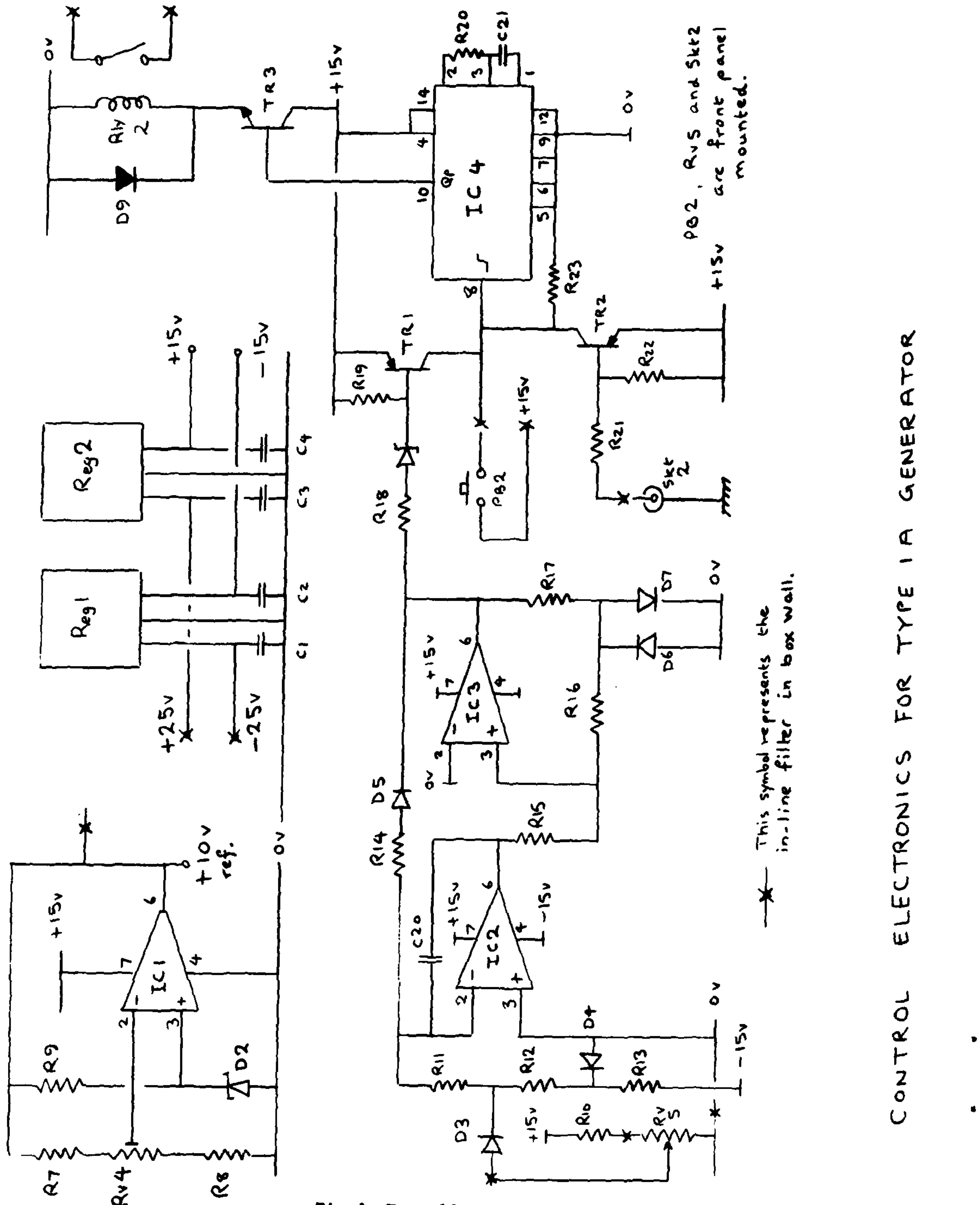


Fig 4 Type 1A control electronics

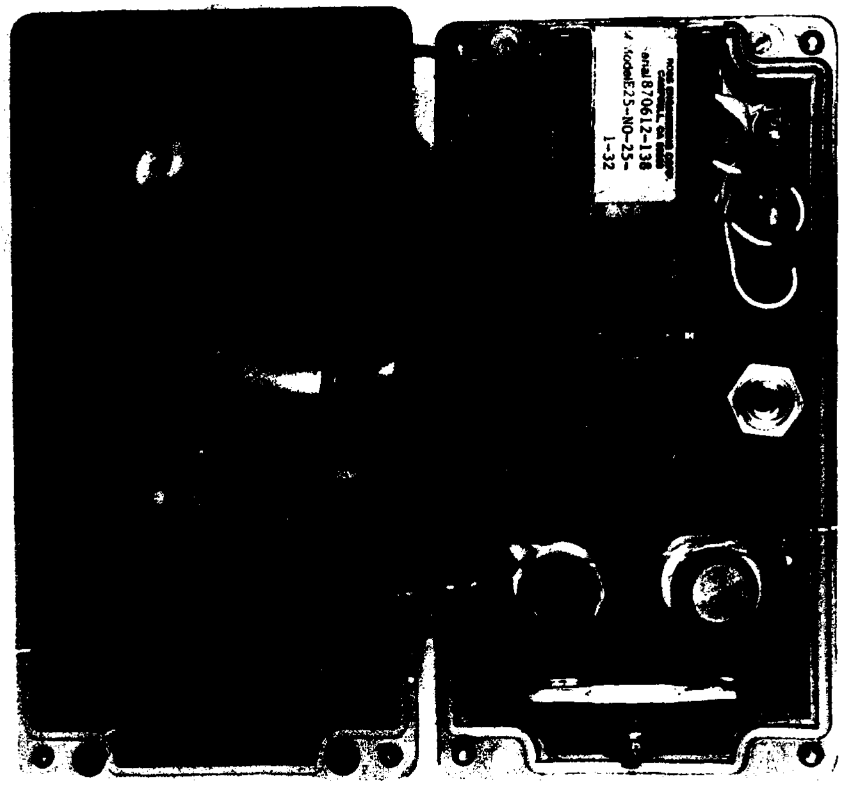


Fig 5

Fig 6A

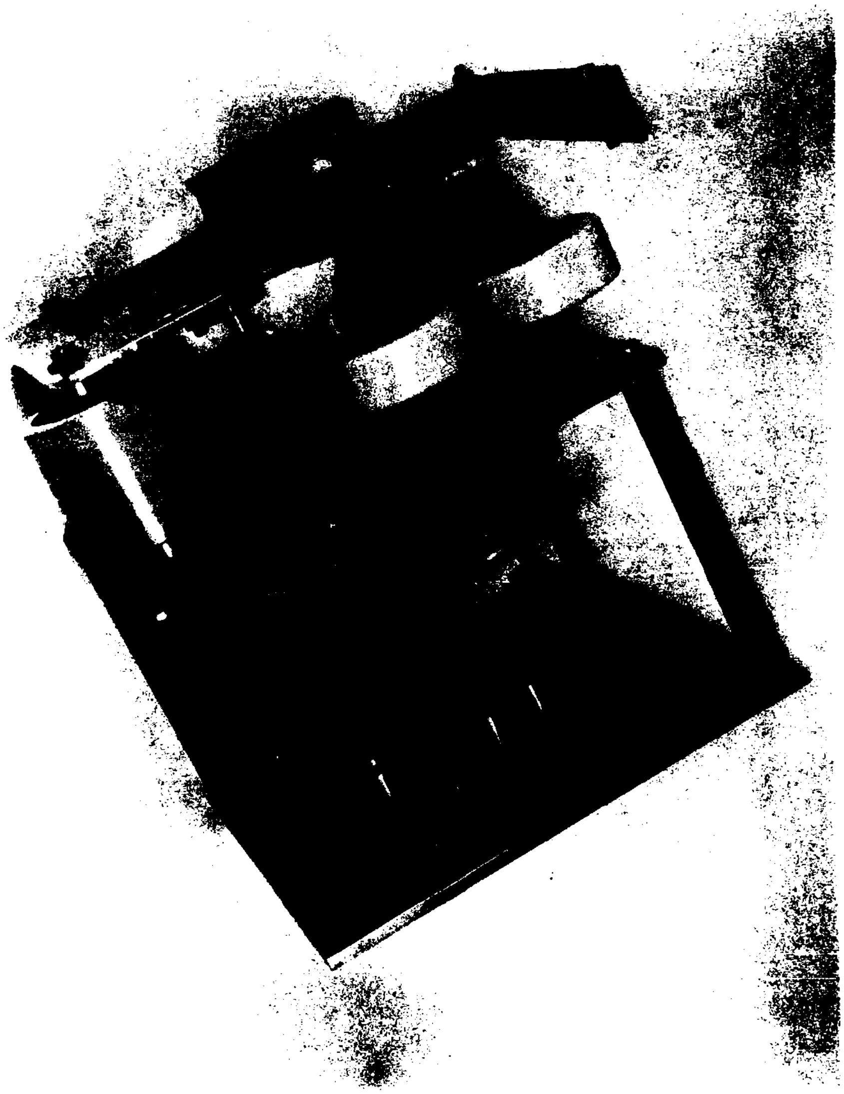
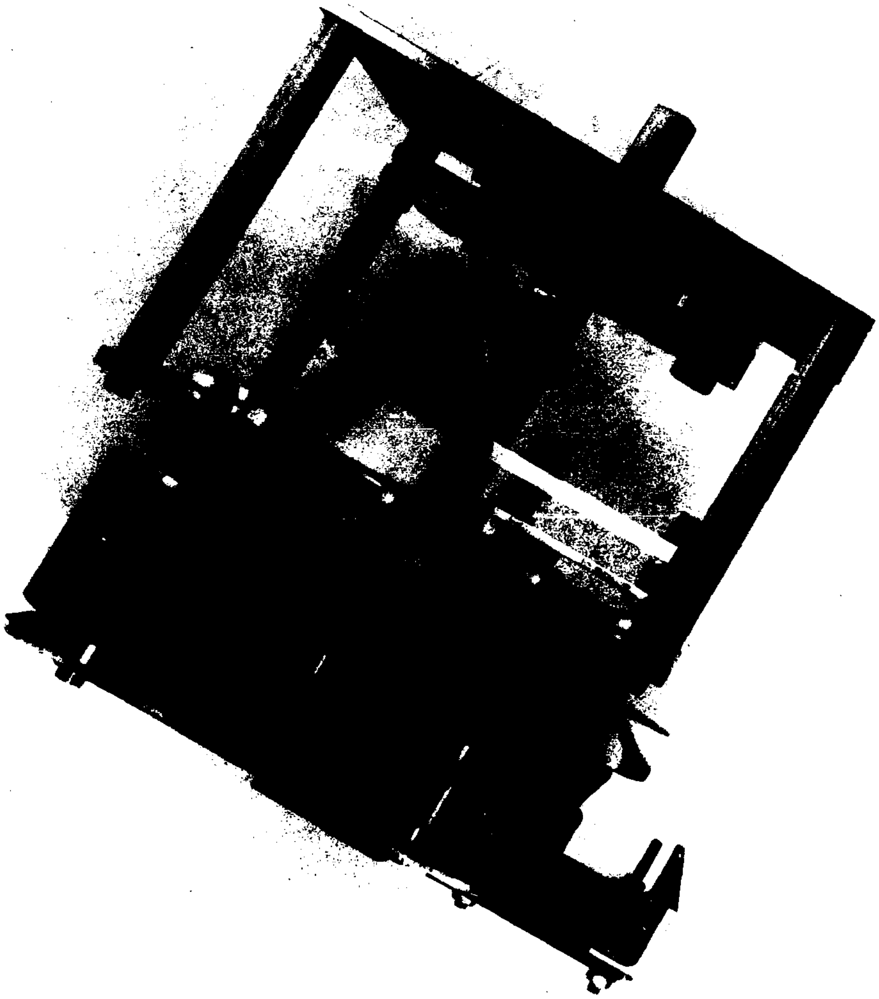


Fig 6A

Fig 6B



TM FS(F) 550 - C20690

Fig 6B

Fig 7

TM FS(F) 550 - C20691

Fig 7

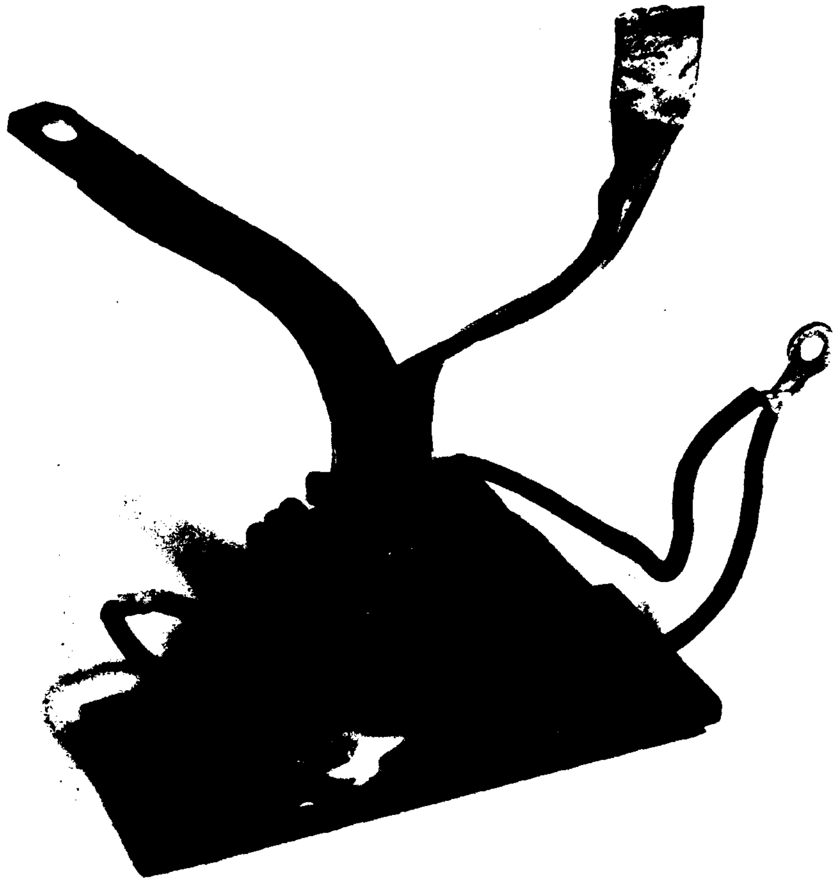


Fig 8

Fig 9

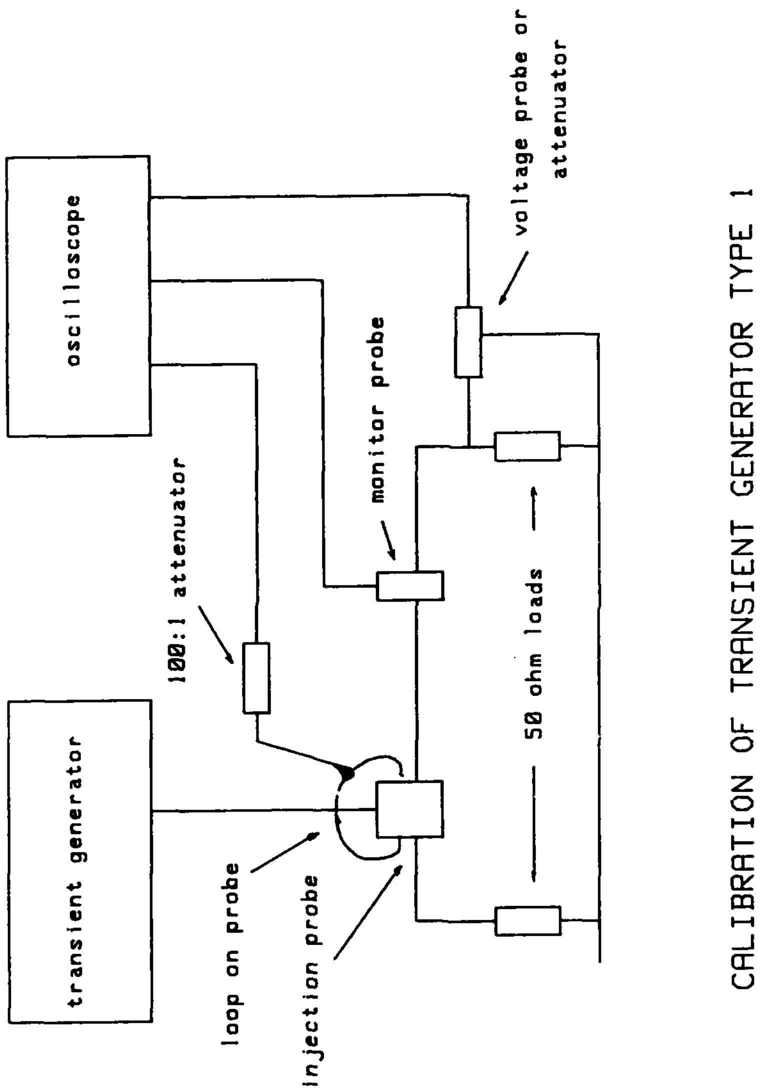


Fig 9 Type 1A calibration

Fig 10

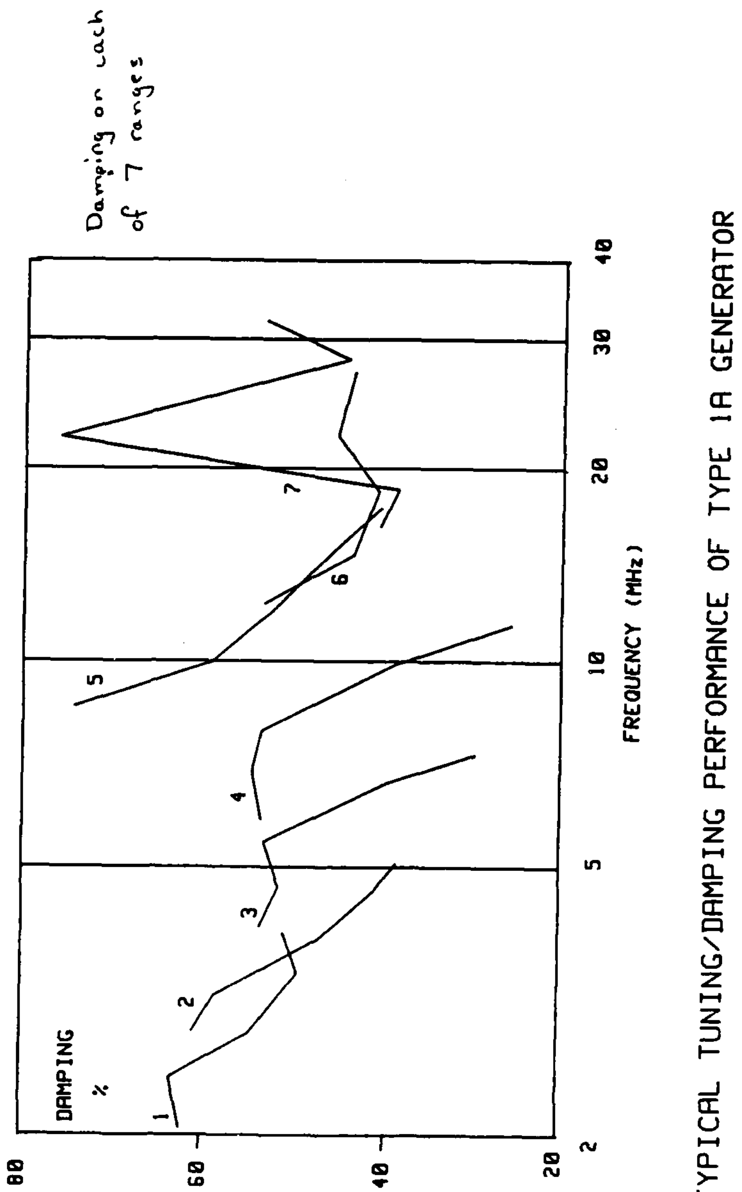
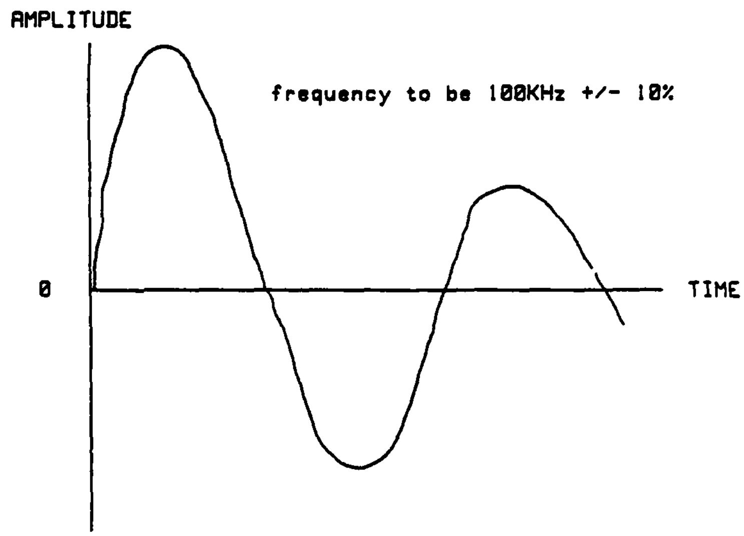


Fig 10 Type 1A performance

Fig 11



amplitude of third half cycle
shall be at least 25% but less
than 50% amplitude of first half cycle

WAVEFORM REQUIREMENTS FOR TYPE 2 GENERATOR

Fig 11 Type 2 waveform

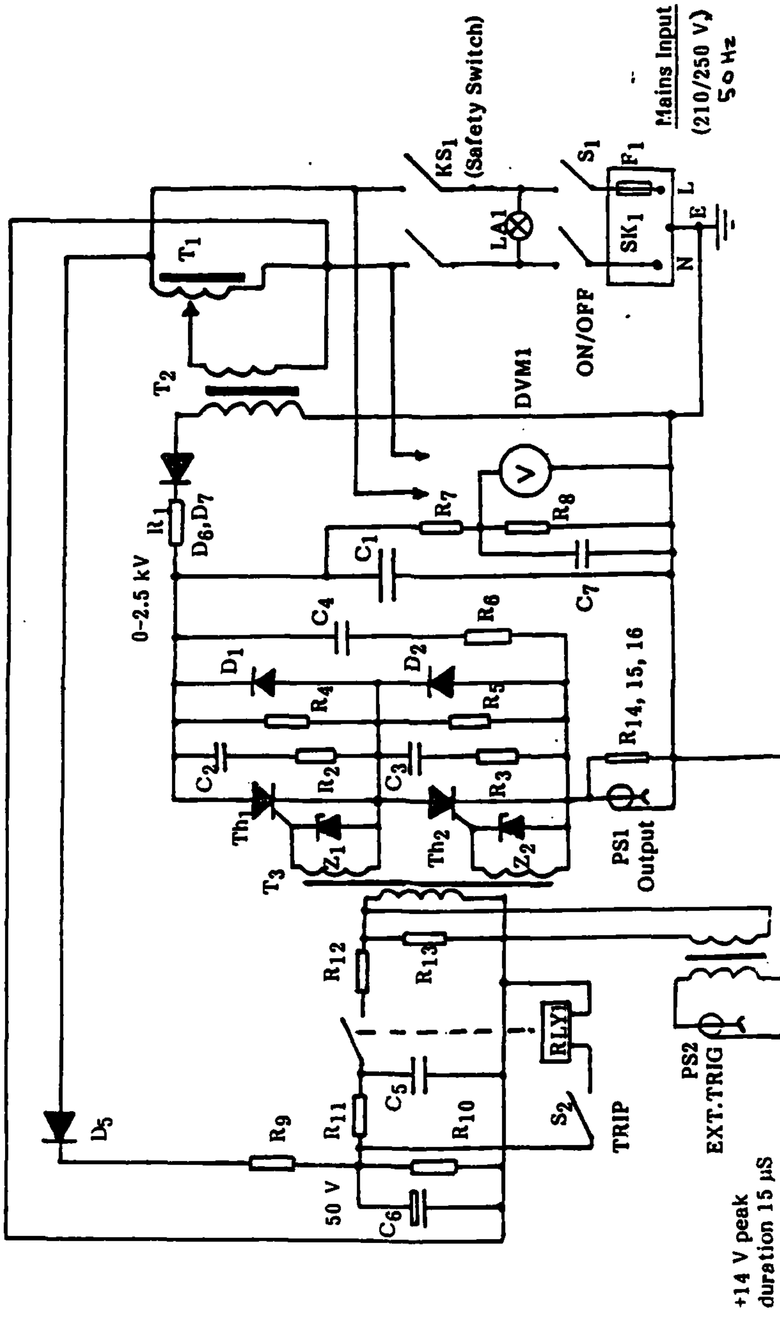


Fig 12 Type 2 circuit

Fig 13

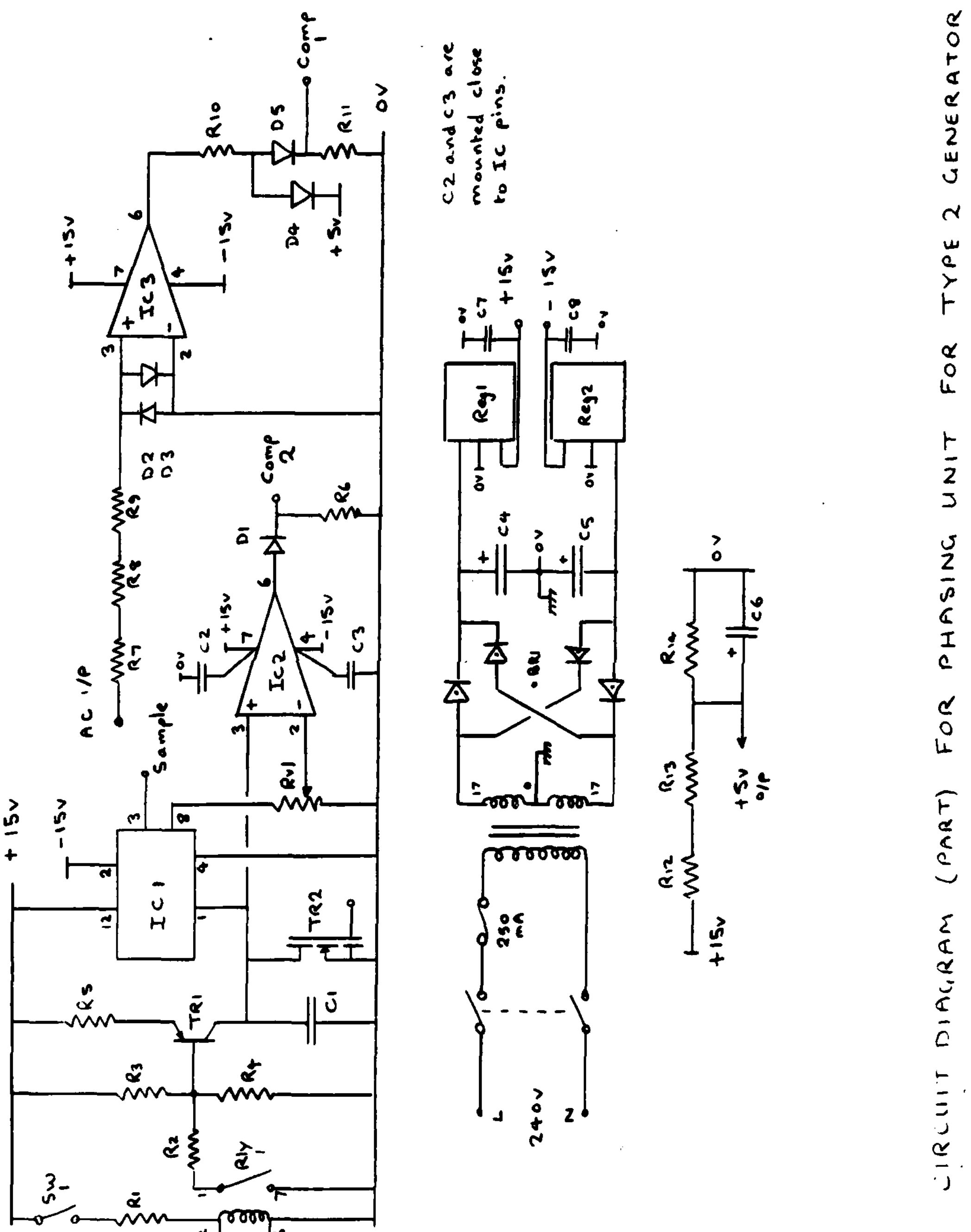


Fig 13 Phasing unit

Fig 14

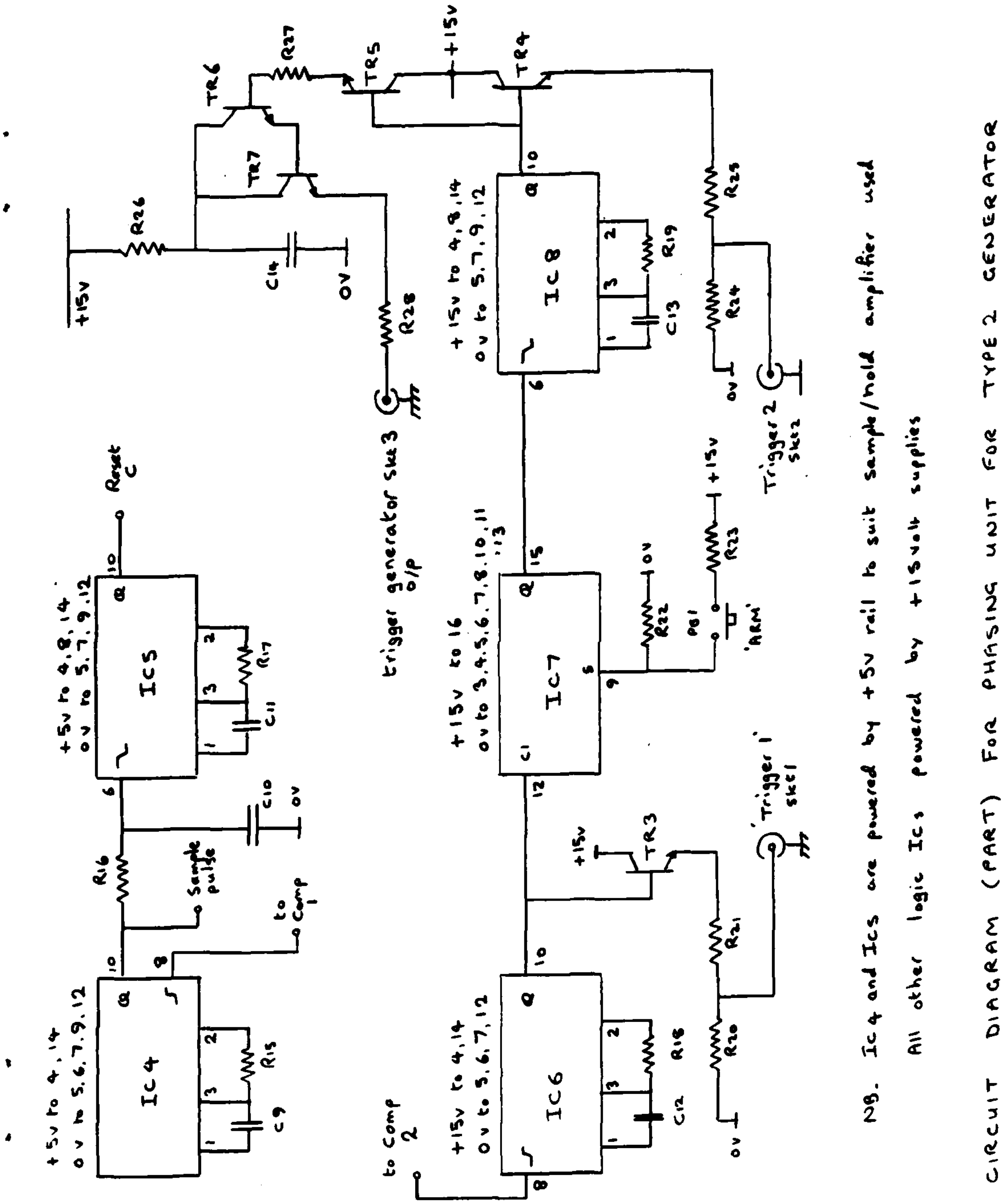


Fig 14 Phasing unit

Fig 15

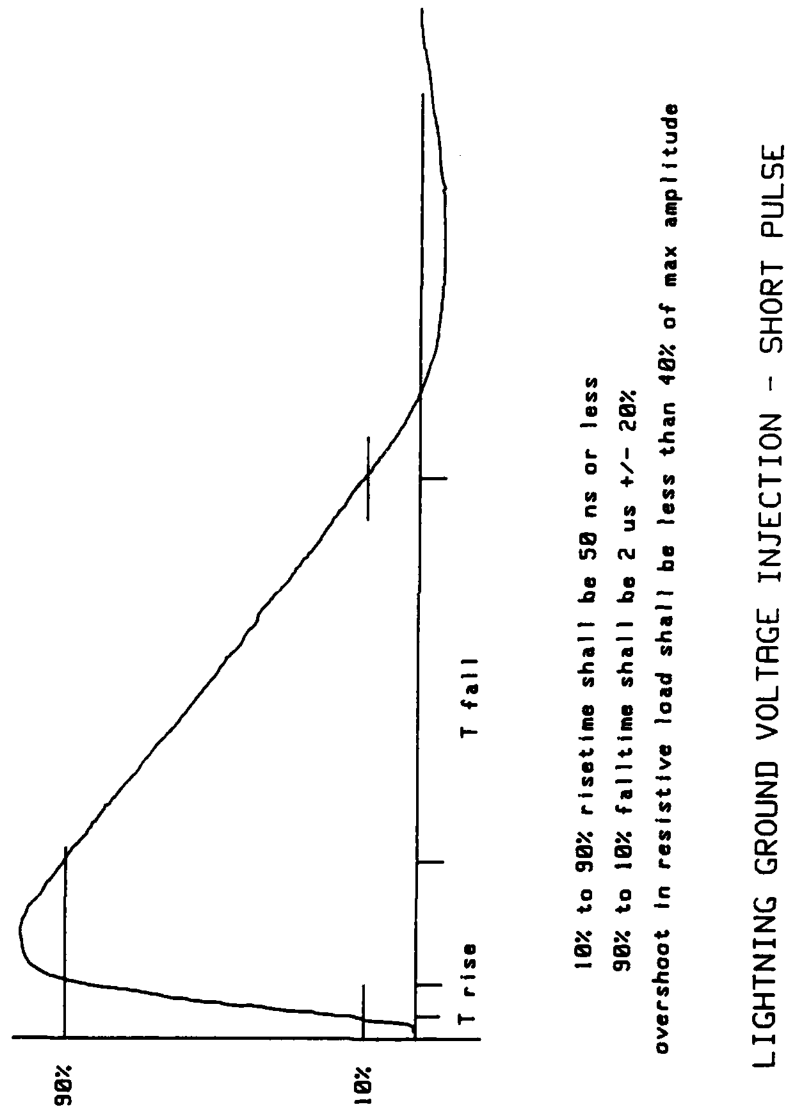


Fig 15 Type 3 generator output 1

Fig 16

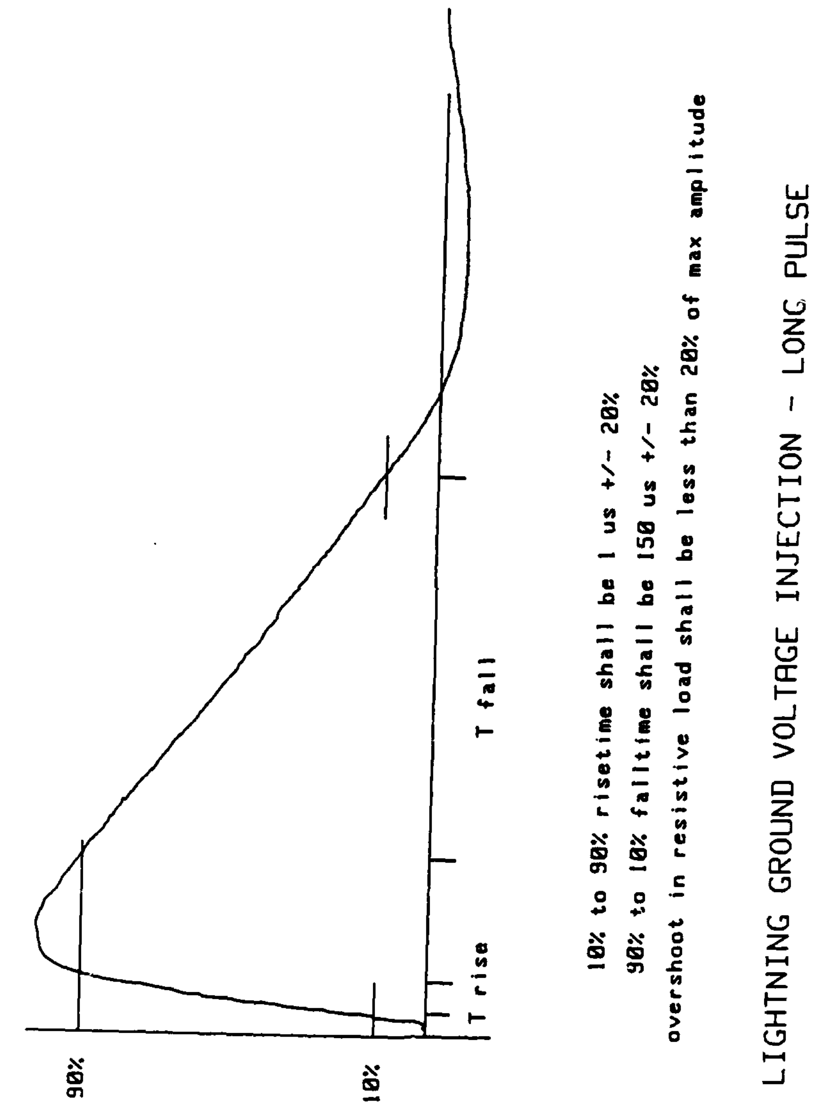


Fig 16 Type 3 generator output 2

Fig 17

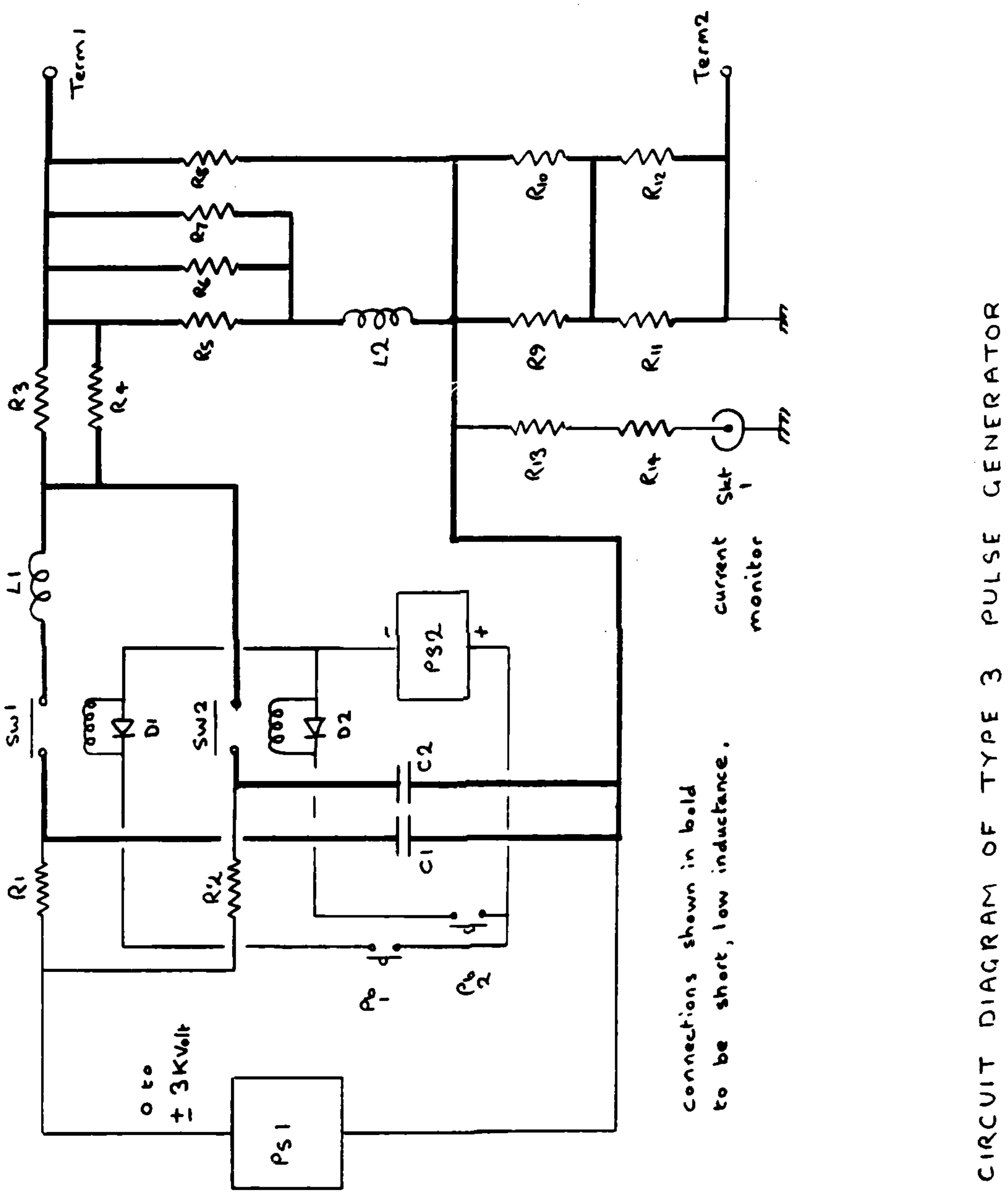


Fig 17 Type 3 generator circuit

INDEX TO APPENDICES

APPENDIX A

TYPE 1A GENERATOR POWER SUPPLIES

A 1 Power supply PS1

This unit is an unregulated twin supply supplied by R S Components, part number 591-843.

Input to the supply is 240 volt 50 Hz

Outputs are two 25 volt at 2 amp, 30 volt no load.

Protection of the unit against overload is by means of fuses.

The supply incorporates a toroidal transformer, full wave rectifier and 6800 uF smoothing capacitors.

A 2 Power supply Ps2

This is manufactured by Wallis Electronics, reference number M303/56P + Option X.

The input supply to the unit is 24 volts dc.
A 0 to 10 volt control input sets the output voltage as required.
The unit is supplied complete and ready to use.

A monitor output is incorporated though this is not used. Instead a 300 meg-ohm resistor is used to monitor the output via a digital voltmeter.

A 3 15 volt supplies in electronics box

These are derived from the +/- 25 volt supply and use standard integrated circuit regulator devices. Capacitors are installed on the input and output to provide stability.

A 4 10 volt reference supply

Diode D2 is a precision reference diode. The input to IC1 is maintained at 6.2 volts with a feedback arrangement to the inverting input. Since the reference diode supply is derived from the stabilised 10 volt output the whole circuit provides excellent long term drift characteristics. The supply could be replaced by a commercial 10 volt reference though in the prototype generator the effects of the filter resistance were allowed for in setting the output voltage.

APPENDIX B

DISCHARGE CONTACTOR AND HIGH VOLTAGE RESISTORS

The contactor is manufactured by Hartley Measurements, part number E25-NO-25. The contacts are modified to incorporate platinum bars available from Johnson Matthey Metals Ltd. Grade 4 strip 3mm by 1.5mm is used. Figure B1 shows the contactor. The return spring is modified to exert less force and the contactor is remounted in the lid of the sealed box in which it is housed.

The box is filled with transformer oil and thus all the connections made into the box should be sealed with silicone mastic or similar materials. The transformer oil is used to prevent corona discharge and more importantly to give better pulse to pulse uniformity.

The resistors for the charge circuit and the monitor voltmeter are rectangular ceramic-substrate devices. In the prototype generator these were fixed to the bottom of the box with silicone adhesive. A layer of 1mm thick polythene was shaped to cover the resistors and provide isolation in the event of the connection wires passing too close when the box is closed. The resistors for the charge circuit are formed in a series-parallel configuration as the proof voltage rating would otherwise be insufficient. Housing the resistors in the oil bath prevents corona discharge problems. The table given as Figure B2 shows the performance of the resistors.

Fig B1

SPECIFICATIONS										
	PEAK TEST RATING		CURRENT				OPERATE TIME	RELEASE TIME		
CONTACT	HV CONTACT	INSULATION	CONT	10 CYCLE	CAPACITOR DISCHARGE		ms	ms		
SPND	25 kV	25 kV	125A	1000A	2500A		20/40	30		

DIMENSIONS (INCHES)										
A	B	C	D	E	F	G	H	J	K	L
5.48	7.06	2.75	2.25	2.19	1.187	.25	.25		1.5	.56

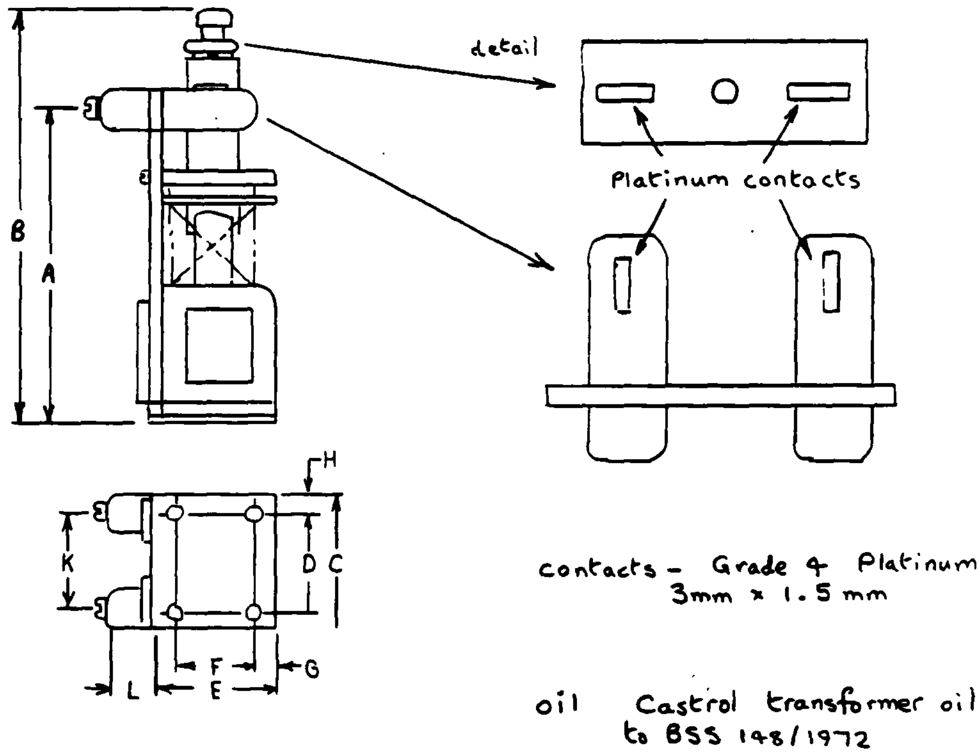
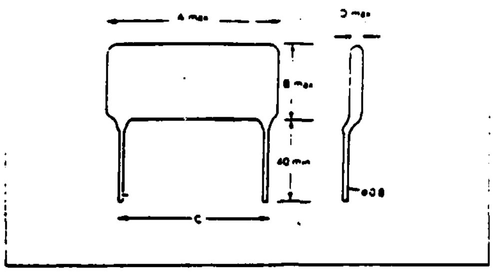


Fig B1

■ DIMENSIONS

Fig B2



Resistance (MΩ)	Resistance Tolerance (%)	Max. Voltage Rating (KV)	Max. Power Rating (W)	Dimensions (unit : mm)			
				A	B	C	D
300	±10	33	3·7	61	38	52	4.5

■ Electrical and Environmental Characteristics

Item	Test Conditions	Performance
Temperature characteristics	Resistance shall be measured at the temperature range of −25°C to 130°C with the base of resistance at 25°C	ΔR ≦ ± 3%
Voltage characteristics	Resistance shall be measured at impressing the rated voltage with the base of impressing 1/10 rated voltage.	ΔR ≦ ± 4%
Pulse characteristics	Resistors shall be charged 10,000 pulses of the rated voltage as the following test circuit. (1000 pF, Specimen, 6 seconds/cycles)	ΔR ≦ ± 2%
Thermal shock	Resistors shall be subjected to 10 cycles of thermal shock as the following. (+130°C 1hr, −30°C 1hr, 1 cycle/2hrs)	ΔR ≦ ± 2% No evidence of mechanical damage.
*Load Life (At elevated ambient temp.)	Resistors shall be subjected to the rated DC voltage for 1000 hours at ambient temp 70°C as the following. (ON 1.5hr, OFF 0.5hr)	ΔR ≦ ± 5%
*Load Life (Humidity)	Resistors shall be subjected to the rated DC voltage for 1000 hours at ambient temp 40°C and relative humidity 90 ~ 95% as the following. (ON 1.5hr, OFF 0.5hr)	ΔR ≦ ± 5%
*Humidity	Resistors shall be exposed to a relative humidity of 90 to 95% and temp. 40°C for 1000 hrs	ΔR ≦ ± 3%

ΔR denotes variation of resistance value.

■ Mechanical Characteristics

Item	Test Conditions	Performance
Lead pull strength	The load of 3kg shall be applied to the terminal in its draw-out direction in 1 minute	No slack and break of lead
Lead terminal bending strength	Resistors shall be held so that draw-out axis of the lead is kept vertical and load in 1kg shall be applied to the terminal. The body of resistor shall be bent 90° and returned to its original position. Then the body shall be bent 90° to opposite direction and returned to its original position	No damage of lead
Vibration	Frequency vibration 10 ~ 55 c/s (in 1 minute) Amplitude 1.5mm Period Each 2 hours in the 3 perpendicular directions	No visible damage

* Items of asterisk shall be applied to the resistor that is encapsulated in epoxy resin with provided case.

■ Electric Power Reduction Curve

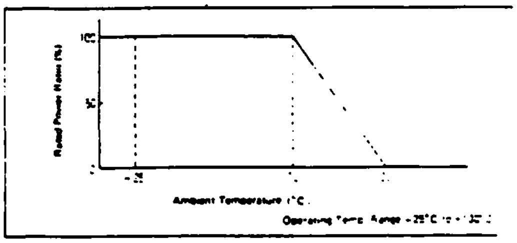


Fig B2

APPENDIX C

TUNING CAPACITORS AND RANGE SWITCH

The tuning capacitors, as stated in the main text, form a critical part of the generator and any deviation from the types listed here may lead to inadequate performance from the generator. The parameters of each are listed in Table C1. The layout of the capacitors around the switch is shown in Figure C2. The connections to the range switch are made from copper strip 15mm wide and 1mm thick, or 20swg copper sheet for the range 1 position where two capacitors are used in parallel. The 'earthy' ends of the capacitors are linked by a metal plate, 3mm thick, which provides mechanical support to the capacitor/switch assembly. Though this plate is at ground potential it is isolated except via the output coaxial cable sheath. This precludes circulating current flow at high frequencies.

The switch is manufactured by Ross and is available from Hartly Measurements, part number R30-IP7T-30. It was necessary to solder the contacts to the switch bar to prevent arcing at high output levels.

Capacitors C8, C9 and C10

2500 pF	20 kV dc.	Murata Mfg Co Ltd part number DHS52 N4700 252M20 2.04 in dia, 0.95 in long.

Capacitor C11

1000 pF	20 kV dc.	Unilator. Part number 891 1.57 in dia, 1.3 in long.

Capacitor C12

500 pF	20 kV dc.	Unilator. Part number 890 1.18 in dia, 1.3 in long.

Capacitor C13

250 pF	20 kV dc.	Murata. Part number DCC509 N750 251K

Capacitor C14

100 pF	20 kV dc.	Murata. Part number DCC509 N7P0 101K

Capacitor C15

50 pF	20 kV dc.	Murata. Part number DCC509 N7P0 500K

Capacitors C13, C14 and C15 are each as below:

Size	1.97 in dia, 3.0 in long
Tolerance	+/- 10 per cent
Temp. coeff.	-750 +/- 120ppm/degree C
Fixing	10-32 NF-2 THD both ends
Insulation resistance	10000 M ohm minimum
Test voltage	30 kV

Table C1

Fig C2

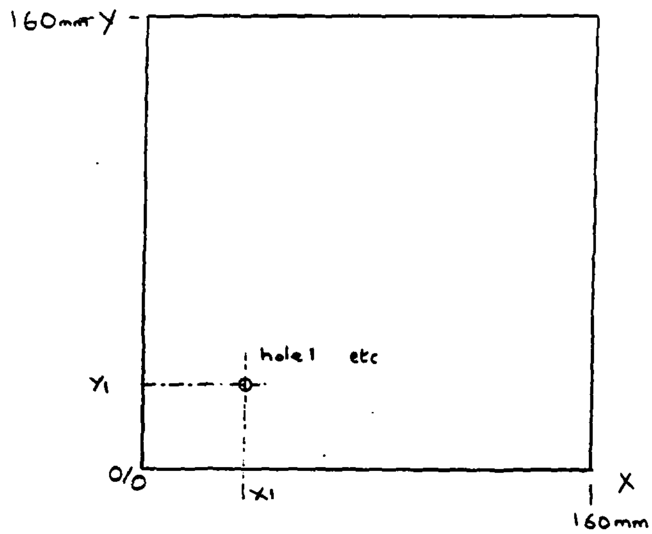


Plate is 3mm alluminium
Dimensions are from corner 0/0 as X/Y coordinates
Hole sizes in millimeters

Hole	Size	X	Y
1	5.0	10	27.5
2	4.1	50	10
3	4.1	80	135
4	4.1	110	10
5	4.1	130	150
6	6.2	145	30
7	6.2	145	100
8	5.0	25	90
9	5.0	25	150

Capacitor mounting plate - hole sizes/positions

Figure C2

APPENDIX D

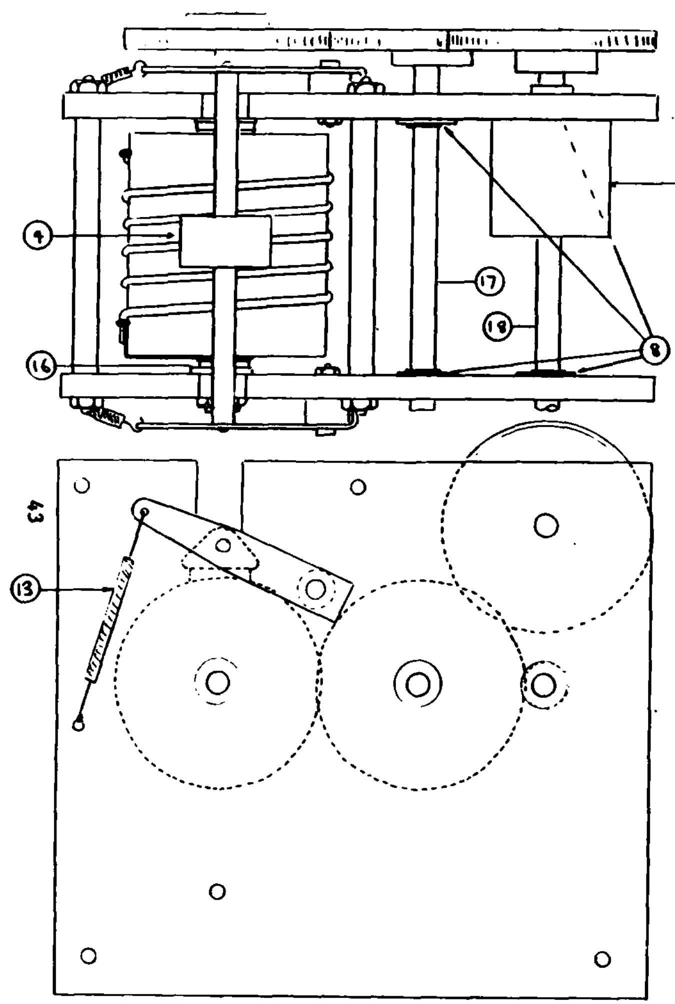
TUNING INDUCTOR

The photograph of the inductor, Figure 7, should be studied carefully together with Figures D1 to D3. Whilst some variation in detail construction is possible the coil dimensions and terminations must be as detailed. As stated earlier the inductor must be mounted clear of any metal structure and adequate insulation provided on the tuning shaft to isolate up to 20 kilo-volts.

Fig D1

ITEM	DESCRIPTION	No	ITEM	DESCRIPTION	No
1	SIDE PANELS	2	10	NUTS 4 (4 mm)	6
2	SPACING BARS	3	11	GEARS (2 INCH 40DP)	3
3	COASTER GUIDE BAR	1	12	POTENTIOMETER (10K/10T)	1
4	COASTER	1	13	SRING	2
5	COIL ASSEMBLY	1	14	HINGE BOLT/NUT	2
6	SPRING	1	15	GEAR (0.5 INCH 40DP)	1
7	BEARING (MAIN)	2	16	WASHER (0.25 INCH)	2
8	BEARING & CLIP	4 on	17	SHAFT	1
9	SPACER	2	18	SHAFT	1

Connection to coil at points marked A and B.
Solder to coaster guide bar side frame at B
connect by 24 swg copper strip at A. See photographs
for detail.



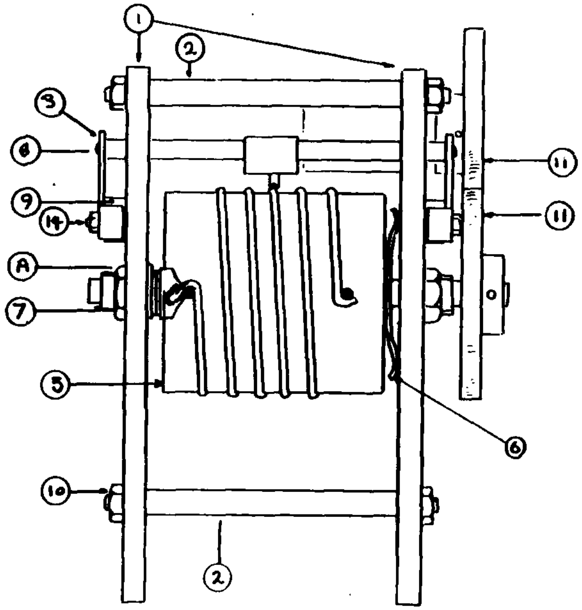


Fig D1 Tuning indicator - General assembly

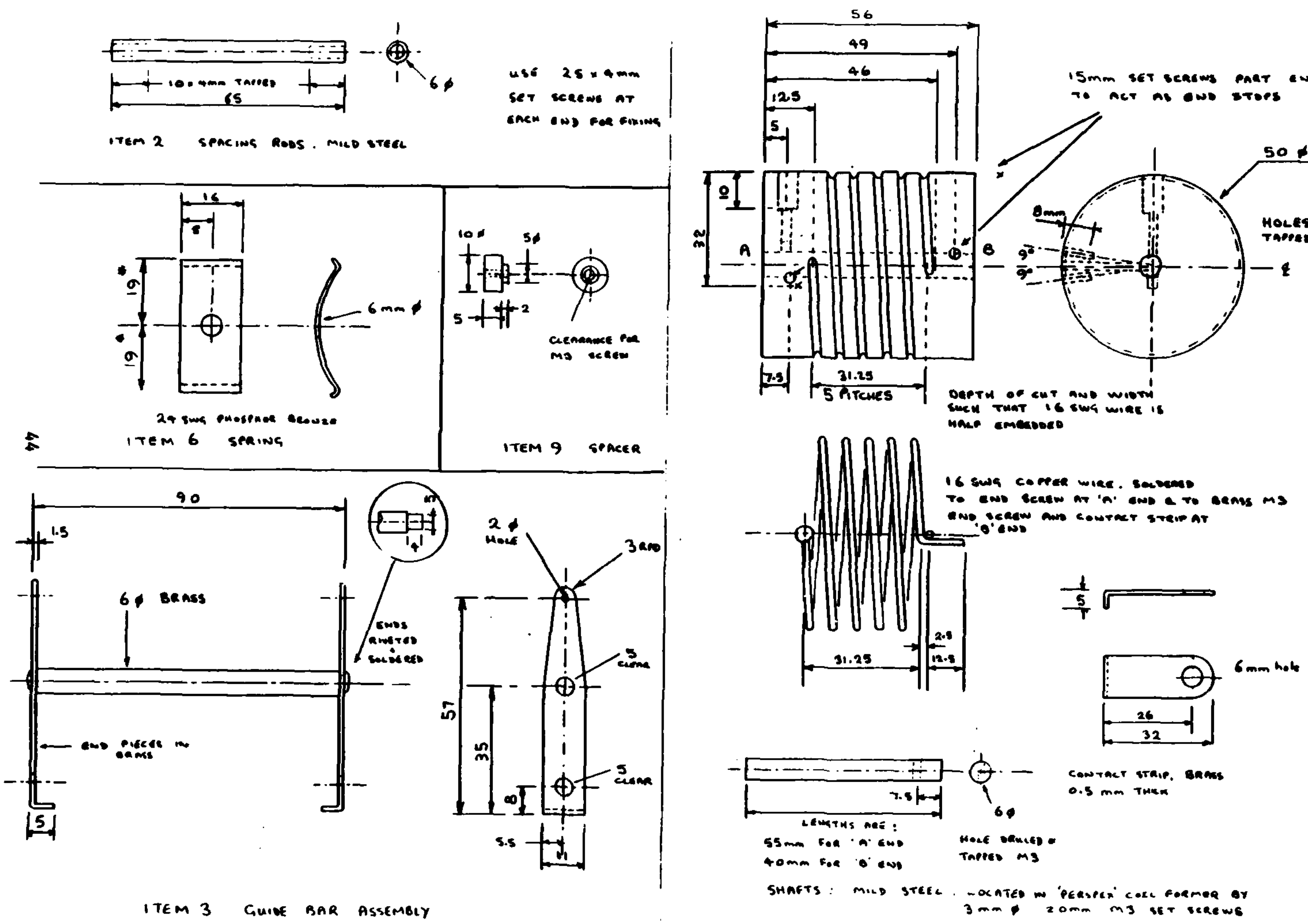


Fig D2

Fig D2 Inductor details

Fig D3

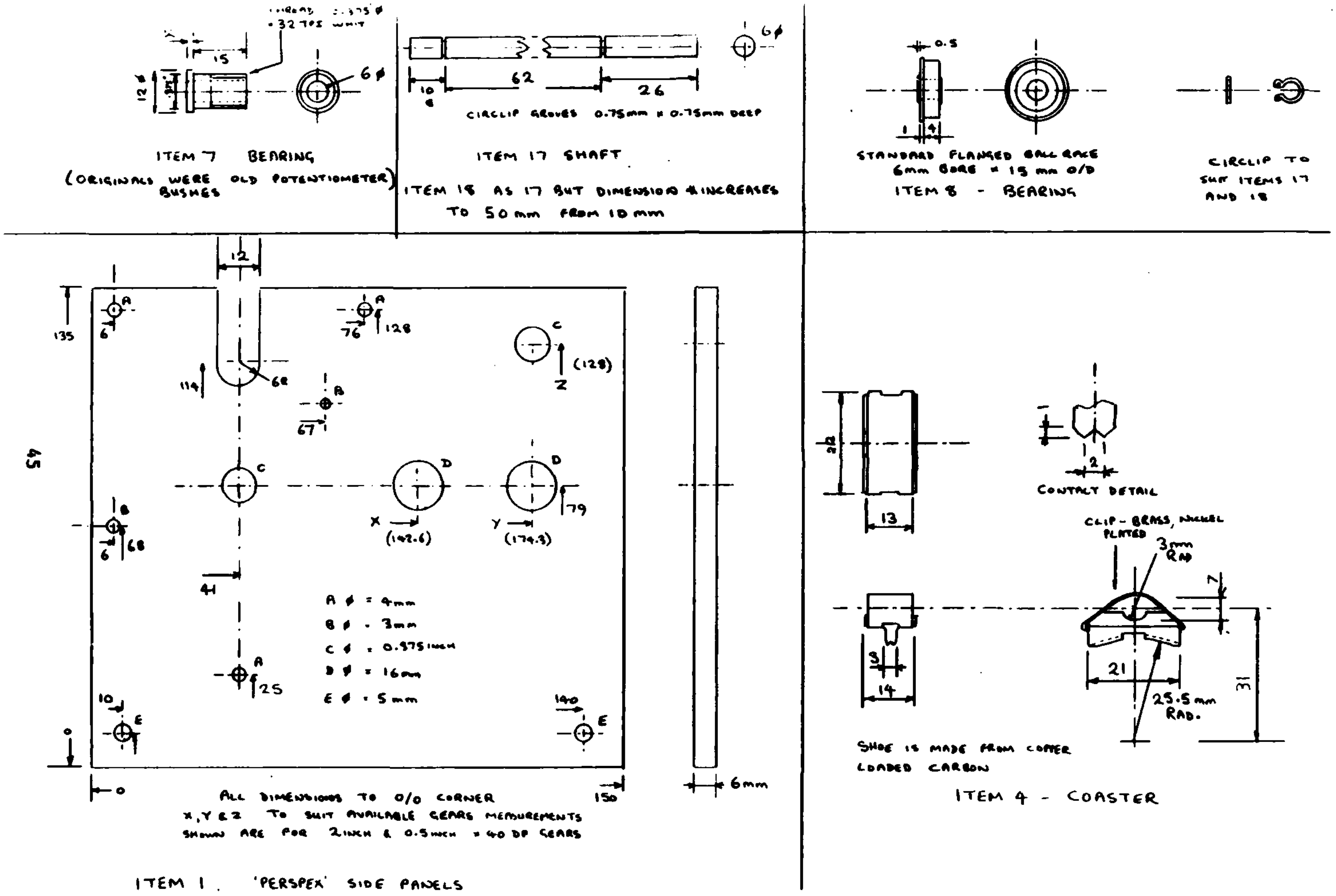


Fig D3 Inductor details

APPENDIX E

OUTPUT TRANSFORMER

The transformer must be constructed exactly as described in this Memorandum. The photograph, Figure 8, and the diagrams in this appendix should be studied carefully. The use of copper strip for the primary is essential. Braid has been shown to be inadequate for the purpose. The windings should be very tight on the core and the secondary should 'wrap around' the primary as shown. The start and finish of these two windings must be observed closely and connected as shown in order to achieve the required damping and output capability. The primary 'C' end connects to the roller coaster and 'D' to the high voltage contactor. The 'A' end of the secondary is the generator output and the 'B' end the earthy end of the winding. The short circuit turn is also important. During development of the generator experiments were made with and without this turn and of variations in its size. The windings can be secured with cable tie-wraps and lacing cord.

The copper strip for the primary winding of the original was earthing strip as used in mineral insulated mains power distribution systems. The secondary winding was 1.5mm diameter wire as used for power ring main systems.

The ferrite core material is the same as that used for the construction of current injection probes type ERA36A and ERA37A. Other materials might be available in the future but must be carefully tested to ensure that they give adequate performance.

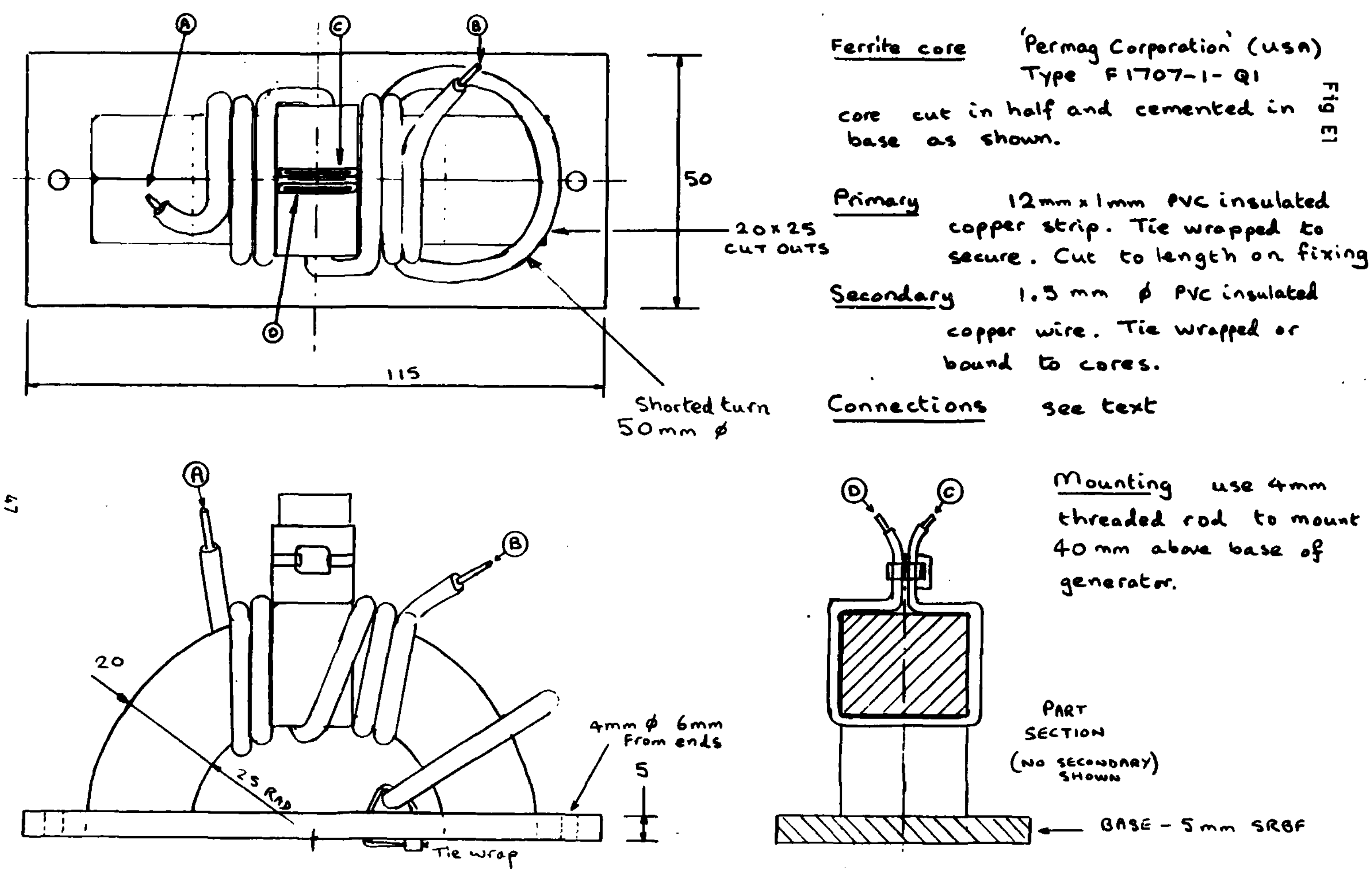


Fig E1 Output transformer details

APPENDIX F

CONTROL ELECTRONICS

The circuit diagram given as Figure 4 is repeated here for convenience as Figure F1. The construction of the original was on Vero board and should present no problems. The board is enclosed in an aluminium box for screening purposes and all connections into the box are made via rfi in-line filters.

The 10 volt reference supply is adjusted such that exactly 10 volts is obtained across the potentiometer attached to the tuning indicator. This should be measured at the potentiometer since the resistance of the rfi filters is significant compared with the resistance of the potentiometer.

The resistor/diode arrangement at the input to IC2 is such that when the internal trigger rate control is fully anti clockwise the input to IC2 is held slightly negative thus inhibiting the internal trigger operation.

Figure F2 gives the component values though mostly these are not critical.

Fig F1

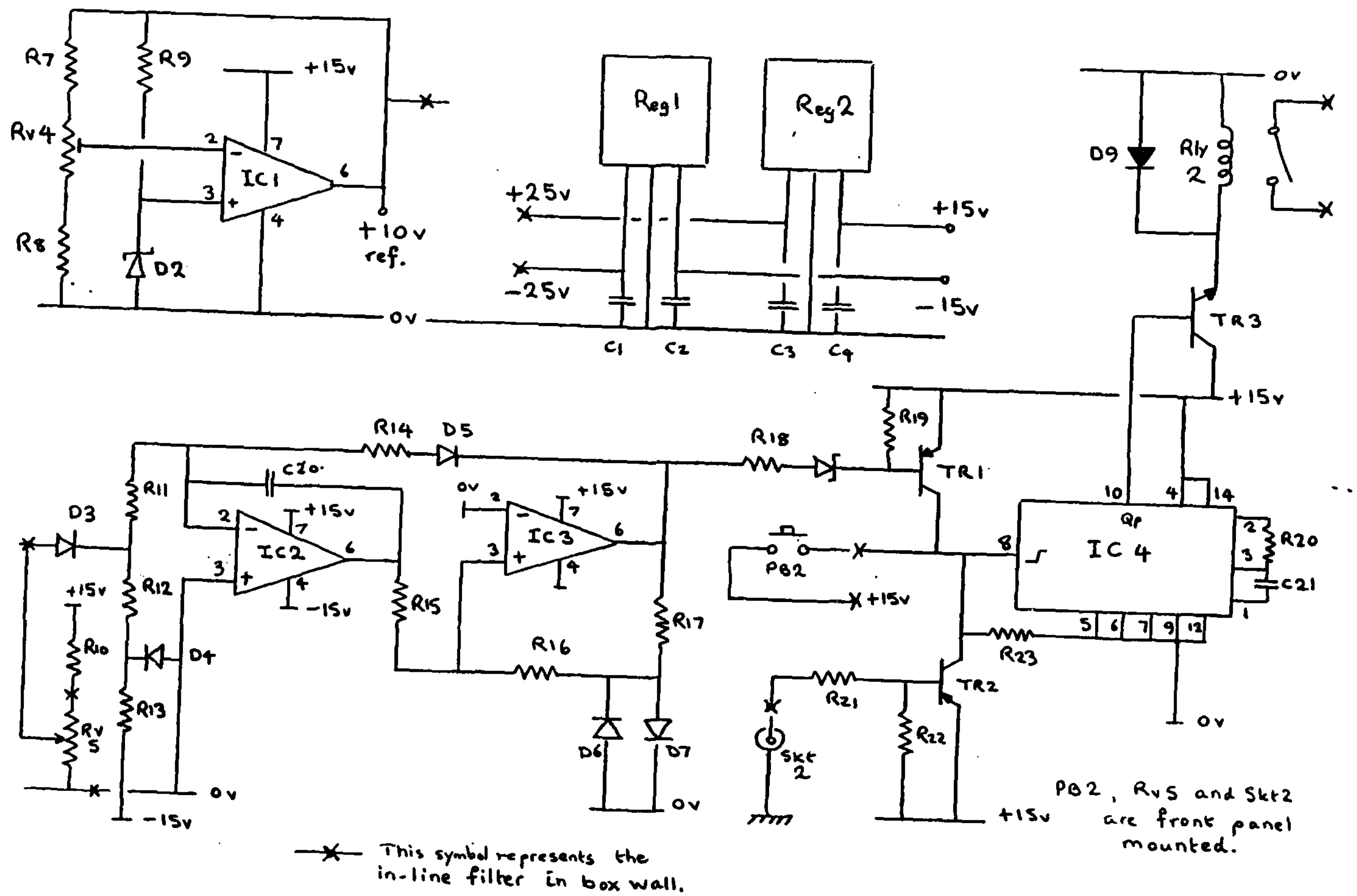


Fig F1 Control electronics for Type 1A generator

Fig F2

COMPONENT LIST FOR CONTROL ELECTRONICS

Ref number		Component	
R7	7K5	2%	0.25W
R8	12K0	2%	0.25W
R9	3K9	2%	0.25W
R10	4K7	2%	0.25W
R11 & R12	1M0	2%	0.25W
R13	15K0	2%	0.25W
R14	4K7	2%	0.25W
R15	100K0	2%	0.25W
R16	13K0	2%	0.25W
R17	4K7	2%	0.25W
R18	10K0	2%	0.25W
R19	10K0	2%	0.25W
R20	1M0	2%	0.25W
R21 & R22	10K0	2%	0.25W
R23	1K0	2%	0.25W
Rv4 & Rv5	10K0	10 Turn wire wound potentiometer	
C1 to C4	100nF	30 Volt Ceramic	
C20	470nF	30 Volt Polyester	
C21	200nF	30 Volt Ceramic	
D2	6V2	1N821 Precision reference diode	
D3 to D7 & D9	1N916	Silicon signal diode	
D8	5V6	BZY88C 5V6, 5.6 V Zenner diode	
IC1 to IC3	LM741C	Operational amplifier	
IC4	HEF4047	Buffered CMOS Monostable	
Reg1	LM7915	-15 Volt 1 Amp regulator	
Reg2	LM7815	+15 Volt 1 Amp regulator	
Rly2			
Tr1 & Tr2	ZTX504	PNP Small signal transistor	
Tr3	ZTX304	NPN Small signal transistor	
Skt2	BNC Socket, Bulkhead mounting		
Pb2	Single pole push to make switch		
FILTERS	Erie Type 9061-103-0000		

FIGURE F2

APPENDIX G

TYPE 2 GENERATOR COMPONENTS

Figure 12 of the main Memorandum is reproduced as Figure G1 for convenience. The component list in Figure G2 and the further details shown in Figures G2 to G8 are taken from the ERA Technology Report, Ref 5. Though this generator is not as critical as the Type 1, care must still be taken with the layout and construction since high voltages and currents are present.

The generator cannot be tested or used without the correct injection probe since the inductance of the primary forms part of the resonant circuit of the generator.

Fig G1

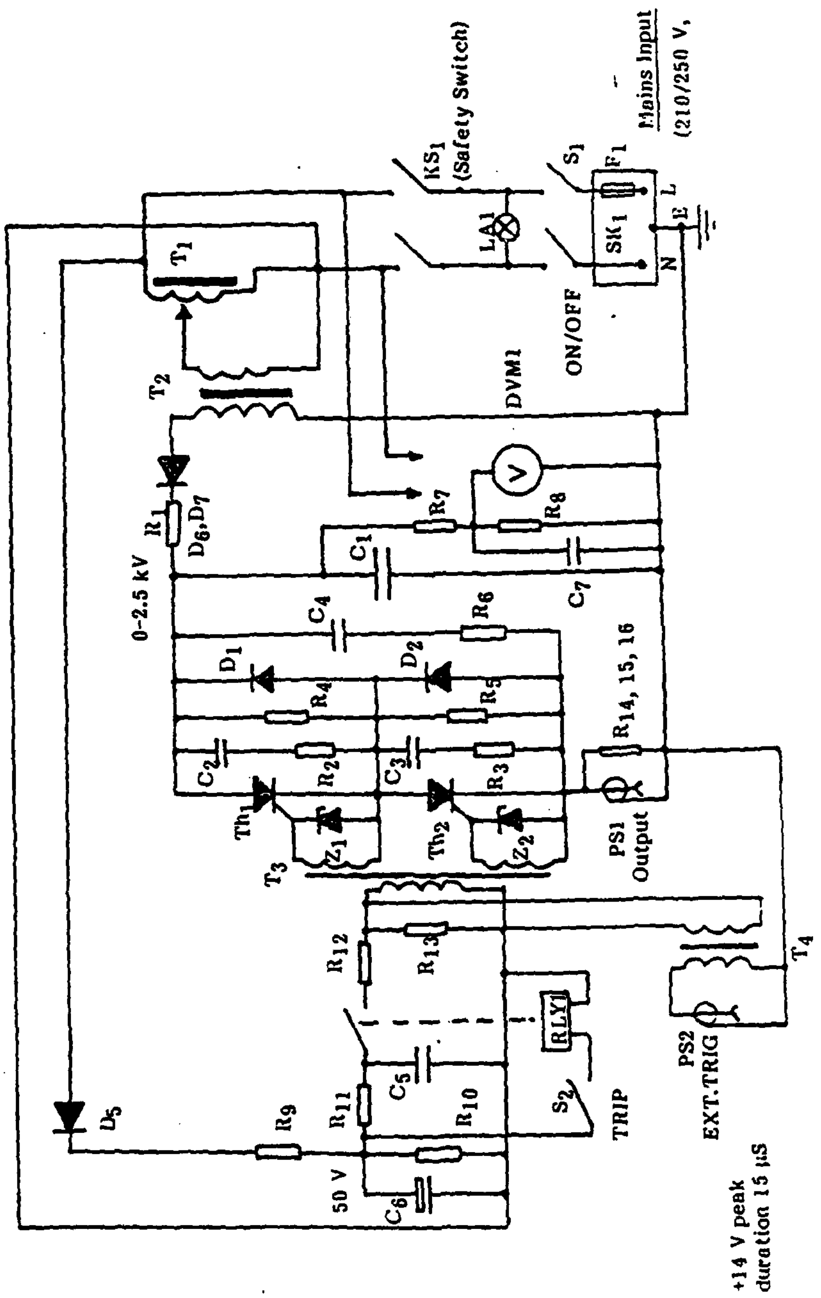

KS1
(Safety Switch)
Mains Input
(210/250 V,
S1
F1
LA1
SK1
L
E
N
ON/OFF
DVM1
T1
T2
V
R7
R8
C1
C7
R1
D6, D7
0-2.5 kV
C4
R6
D1
D2
R4
R5
C2
R2
C3
R3
R14, 15, 16
Th1
Z1
Th2
Z2
T3
PS1
Output
R12
R13
T4
RLY1
PS2
EXT.TRIG
S2
TRIP
D5
R9
R11
C5
R10
50 V
C6
+14 V peak
duration 15 µS

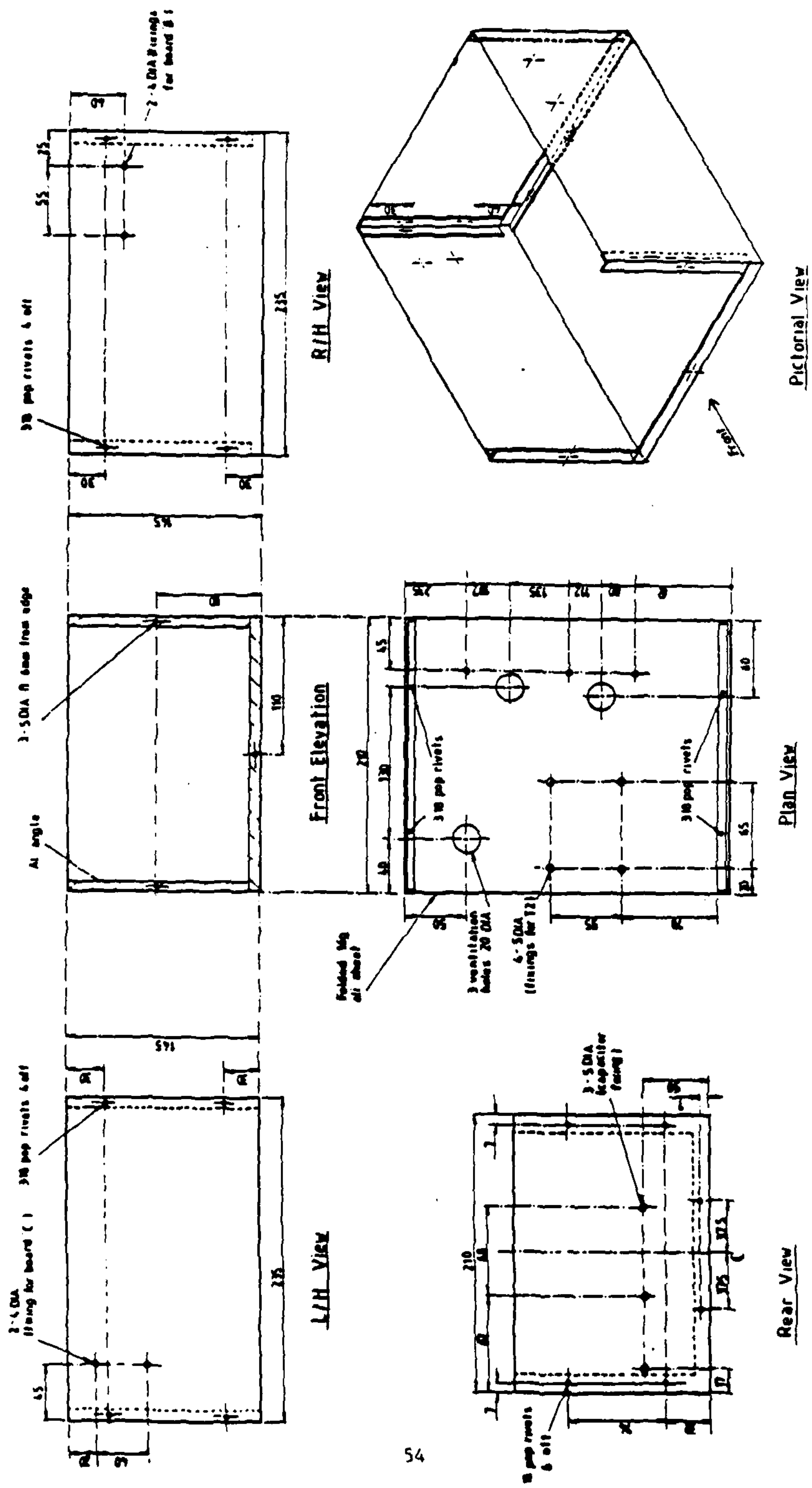
Fig G1

Component	Circuit Ref	Supplier	Part No
Variable Transformer, 0-240 V, 50 Hz, 0.5 A	T1	RS Components Ltd	207-936
H T Transformer, 240/3000 V, 10 mA	T2	Estrasil Ltd	EH/Q45
Trigger Transformer, 1 : 1 + 1	T3	RS Components Ltd	196-375
External Trigger Transformer, 2 : 1 + 1	T4	RS Components Ltd	196-454
Diodes BYX39-1400, 9.5 A, 1400 V_{RRM}	D_1, D_2	STC Electronic Services Ltd	57243R
Diodes LA60, 60 mA, 6000 V_{RRM}	D_6, D_7	STC Electronic Services Ltd	11627C
Diodes IN 5408, 3 A, 1000 V_{RRM}	D_5	RS Components Ltd	261-312
Zener Diodes 7.5 V, 1.3 W	Z_1, Z_2	RS Components Ltd	282-656
Power Thyristors 44RH15, 45A, 1500 V	Th_1, Th_2	STC Electronic Services Ltd	58021X
Mercury Wetted Relay, Contact rating: 500V max Coil: 24 V 2.6 kΩ	RLY1	Verospeed (Div. of BICC-Vero Distribution Ltd)	63-2611OK
Indicator lamp, 250 V neon (red) inc. resistor	LA1	RS Components Ltd	576-608
Digital Panel Meter, See App. B	DVM1	RS Components Ltd	258-669
High voltage resistor, 56 kΩ See App. B	R_1	Rhopoint Ltd	MS310
Carbon Composition Resistors 10 Ω, 1 W, ±10%	R_2, R_3	RS Components Ltd	143-090
High Voltage Resistors, 220 kΩ See App. B	R_4, R_5	Rhopoint Ltd	MS 310
High Voltage Resistors, 300 MΩ See App. B	R_7	Murata-Erie Electronics (UK) Ltd	PA307K00
Wire Wound Resistors, 4.7 Ω, 2.5 W, ±5%	R_6	RS Components Ltd	152-268
Carbon Composition Resistors, 330 Ω, 1 W, ±10%	$R_{14,15,16}$	RS Components Ltd	143-286
Metal Oxide Resistors 0.5 W, ±2% 300 kΩ	R_8	RS Components Ltd	147-086
Carbon Film Resistor 1 W, 68 kΩ, ±5%	R_9	RS Components Ltd	133-970
Metal Oxide Resistor 0.5 W, ±2%, 22 kΩ	R_{10}	RS Components Ltd	146-819
Metal Oxide Resistor 0.5 W, ±2%, 100 kΩ	R_{11}	RS Components Ltd	146-976
Metal Oxide Resistor 0.5 W, ±2%, 10 Ω	R_{12}	RS Components Ltd	146-011
Metal Oxide Resistor 0.5 W, ±2%, 470 Ω	R_{13}	RS Components Ltd	146-415
Capacitor 0.5 μF, See App. B	C1	Cetronic Components Ltd	CP1M
Capacitor 0.1 μF, See App. B	C4	Cetronic Components Ltd	CF1
Capacitors 470 pF, 15 kV ±10%, ceramic	C_2, C_3	Murata-Erie Electronics (UK) Ltd	DHR15B471M
Elect. Capacitor 22 μF, 63 V, ±20%	C_6	RS Components Ltd	105-076
Capacitor 0.022 μF, 400 V ±20% polyester	C_5	RS Components Ltd	112-939
Capacitor 0.01 μF, 1000 V, +80-20% ceramic	C_7	RS Components Ltd	125-941
Group Board SRBP	-	RS Components Ltd	433-725
I.E.C. Filtered Socket and fuse holder 2 A, 240 V	SK1, F_1	RS Components Ltd	238-687
Pulse Out Socket U.H.F.	PS1	RS Components Ltd	455-725
Trig in Socket B.N.C.	PS2	RS Components Ltd	455-674
On/Off Switch 3 A, 250 V	S1	Arrow-Hart (Europe) Ltd	CT 56
Trigger Switch 3 A, 250 V	S2	RS Components Ltd	339-229
Key Switch 2 A, 240 V	KS1	Farnell Electronic Components Ltd	146-811
Case	-	Schroff UK Ltd	10823-016
Front Panel	-	Schroff UK Ltd	30823-269
Handle	-	Schroff UK Ltd	10502-119
Equipment wire, 16/0.2 mm, 1 kV rms, 3 A	-	RS Components Ltd	356-xxx
EHT wire, 16/0.2 mm, 25 kV		RS Components Ltd	357-996

Fig G2

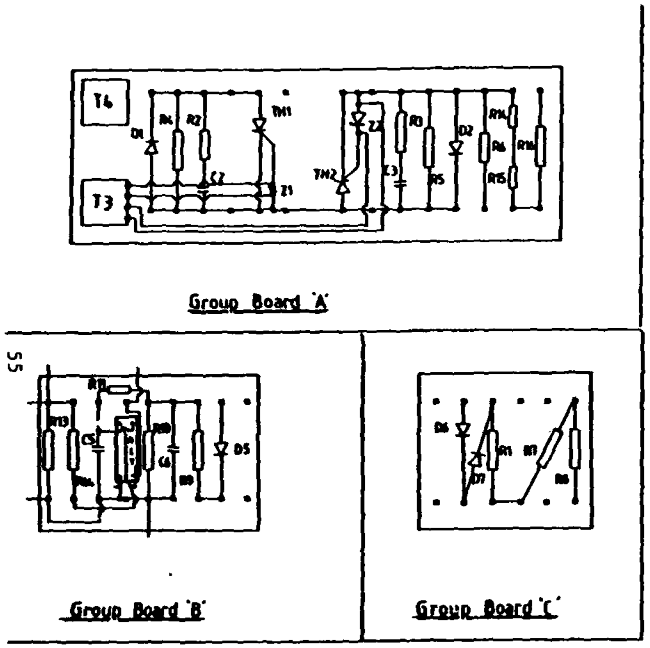
Fig G2

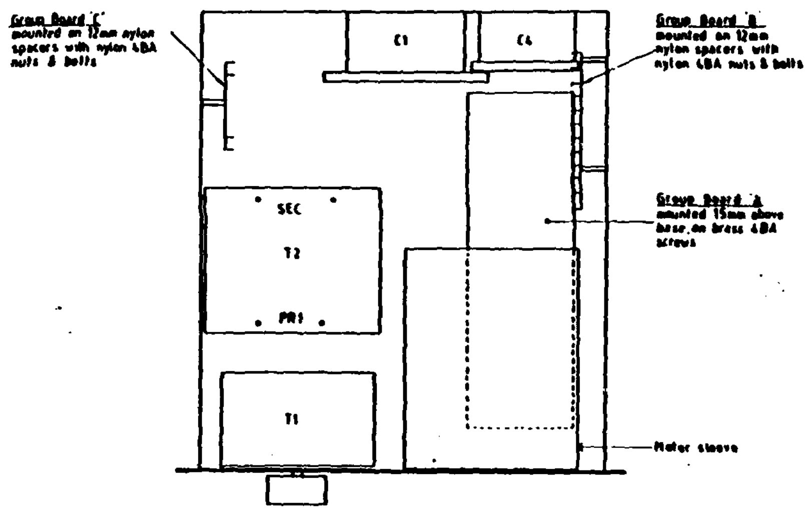
Fig G3



R/H View
Front Elevation
Plan View
L/H View
Rear View
Pictorial View

Fig G3





Internal Layout of Major Components

Fig G4

Fig G4

R1, R4 and R5 56 kΩ and 220 kΩ

Dimensions:-	Length	1.25" ± 0.07
	Diameter	0.35" ± 0.04
	Wire Diameter	0.04" ± .002
	Wire Length	1.5" ± 0.125

Wattage	Max. Voltage	Max Temp	Dielectric Strength	Encapsulation	Leadwire
10	4500	275°C	1000	Silicone Conformal	Gold Plated

Specification:-

Resistance Tolerance: ± 1%.
Insulation Resistance: 100 megohms, minimum.
Overload/Overvoltage: 5 times rated power with applied voltage not to exceed 1.5 times maximum continuous operating voltage for 5 seconds. ΔR, 0.5% max

Thermal Shock: MIL-STD-202, Method 107, Cond. C, ΔR, 0.5% max.

Moisture Resistance: MIL-STD-202, Method 106, ΔR, 0.5% max.

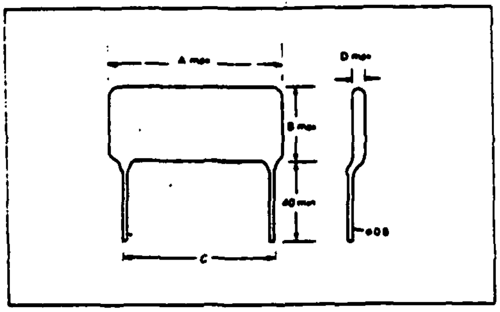
Loadlife: 1000 hours at rated power, ΔR, 0.5% max.

Fig G5

30 MΩ and 300 MΩ

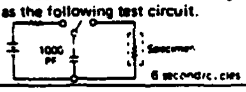
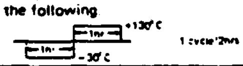
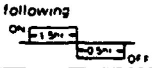
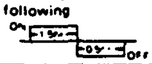
Fig G6

■ DIMENSIONS



Resistance (MΩ)	Resistance Tolerance (%)	Max. Voltage Rating (KV)	Max. Power Rating (W)	Dimensions (unit : mm)			
				A	B	C	D
30 300	±10	13 33	5.0 3.7	61	38	52	4.5

■ Electrical and Environmental Characteristics

Item	Test Conditions	Performance
Temperature characteristics	Resistance shall be measured at the temperature range of −25°C to 130°C with the base of resistance at 25°C	ΔR ≦ ± 3%
Voltage characteristics	Resistance shall be measured at impressing the rated voltage with the base of impressing 1/10 rated voltage	ΔR ≦ ± 4%
Pulse characteristics	Resistors shall be charged 10,000 pulses of the rated voltage as the following test circuit. 	ΔR ≦ ± 2%
Thermal shock	Resistors shall be subjected to 10 cycles of thermal shock as the following 	ΔR ≦ ± 2% No evidence of mechanical damage
*Load Life (At elevated ambient temp.)	Resistors shall be subjected to the rated DC voltage for 1000 hours at ambient temp 70°C as the following 	ΔR ≦ ± 5%
*Load Life (Humidity)	Resistors shall be subjected to the rated DC voltage for 1000 hours at ambient temp 40°C and relative humidity 90 ~ 95% as the following 	ΔR ≦ ± 5%
*Humidity	Resistors shall be exposed to a relative humidity of 90 to 95% and temp 40°C for 1000 hrs	ΔR ≦ ± 3%

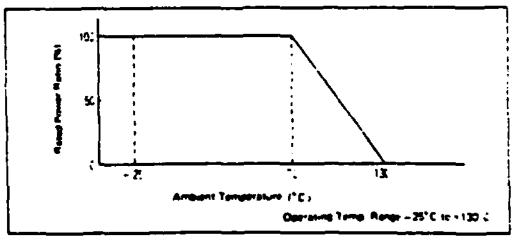
ΔR denotes variation of resistance value.

■ Mechanical Characteristics

Item	Test Conditions	Performance
Lead pull strength	The load of 3kg shall be applied to the terminal in its draw-out direction in 1 minute.	No slack and break of lead
Lead terminal bending strength	Resistors shall be held so that draw-out axis of the lead is kept vertical and load in 1kg shall be applied to the terminal. The body of resistor shall be bent 90° and returned to its original position. Then the body shall be bent 90° to opposite direction and returned to its original position.	No damage of lead
Vibration	Frequency vibration . 10 ~ 55 c/s (in 1 minute) Amplitude 1.5mm Period . Each 2 hours in the 3 perpendicular directions	No visible damage

* Items of asterisk shall be applied to the resistor that is encapsulated in epoxy resin with provided case.

■ Electric Power Reduction Curve



C1:- 0.5 μF

construction
dielectrics

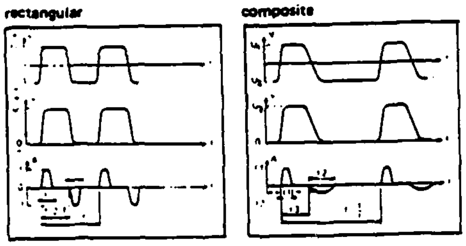
oil impregnated paper
Casings : welded metal
terminals : by solder lugs or screw

technical description	
models	CPIM
Capacitance μF	0·5
tolerance	± 10 %
useful voltage Un - V	1250
useful current . Irms_ A	25 to 50
repetition frequency : fn Hz	55 to 635
maximum temperature °C	80 to 85
d c test voltage between terminals	2.5 Un
d c test voltage between terminals and case, minimum 2,000 Vdc	2.5 Un

Un Vrms	Un Vdc	C μF	I eff A	fn Hz	θ° max	dimensionsfig A	B	H	N°
1250	2500	0,5	25	190	85	60	30	98	8

Voltage wave forms

rectangular composite



symmetrical sinusoid non symmetrical sinusoid

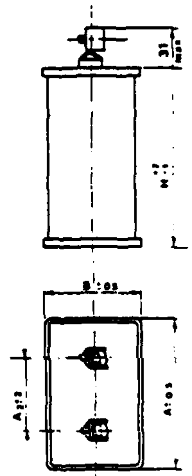
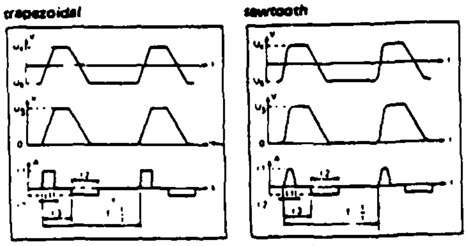


fig 8

current wave forms

$$U\ Vrms = \frac{U_1 + U_2}{2} = U\ Vdc = U_3$$

trapezoidal sawtooth



rectangular composite

Fig G7

Fig G8

C4:- 0.1 µF

Applicable specification NF-UTE C93140 Model CF1
Climatic category −55°C/+85°C/56d,90 % rel.hum. at 40°C (4.5.4)

Construction
Wound paper
Aluminium foil electrodes
Oil impregnation
Welded metal casing
Terminals by lugs on welded bushes, earth lug clamp mounting
Fixing means : on request only

Technical description

tolerance on capacitance at 20°C and 100 Hz (at 1000 Hz for C ≤ 1 µF Un ≤ 2500 V) — ± 10 %

test voltage, between terminals — for Un ≤ 2,000 Vdc — 2.5 Un
between terminals and case — for Un > 2,000 Vdc — 2 Un + 1,000

Reduction of operating voltage with temperature depends on the energy $W = 1/2\,C\,Un^2$
- W < 0,5 — Curve 1
- 0.5 ≤ W < 5 — Curve 2
- 5 ≤ W < 50 — Curve 3

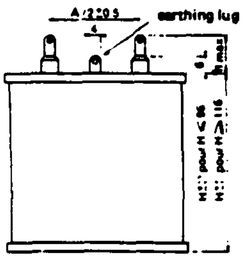
Tangent of the loss angle at 20°C (same frequency as for the capacitance — ≤ 10.10^{-3}

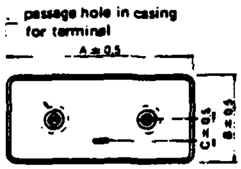
Insulation resistance at 20°C between terminals — ≥ 9000 MΩ/µF
for C < 0.3 µF — ≥ 9000 MΩ
between terminals and case — ≥ 9000 MΩ

Temperature coefficient $\frac{\Delta C}{C}$ per degree C — < $850\ 10^{-6}$

Voltage - capacitances - dimensions (mm)

Un	C	casings			terminals		
Vcc	µF	A	B	H	ϕ	h	C
2500	0,1	45	25	56	16	30	3





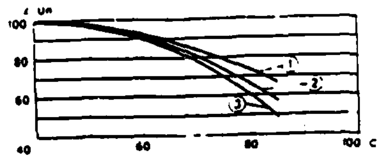


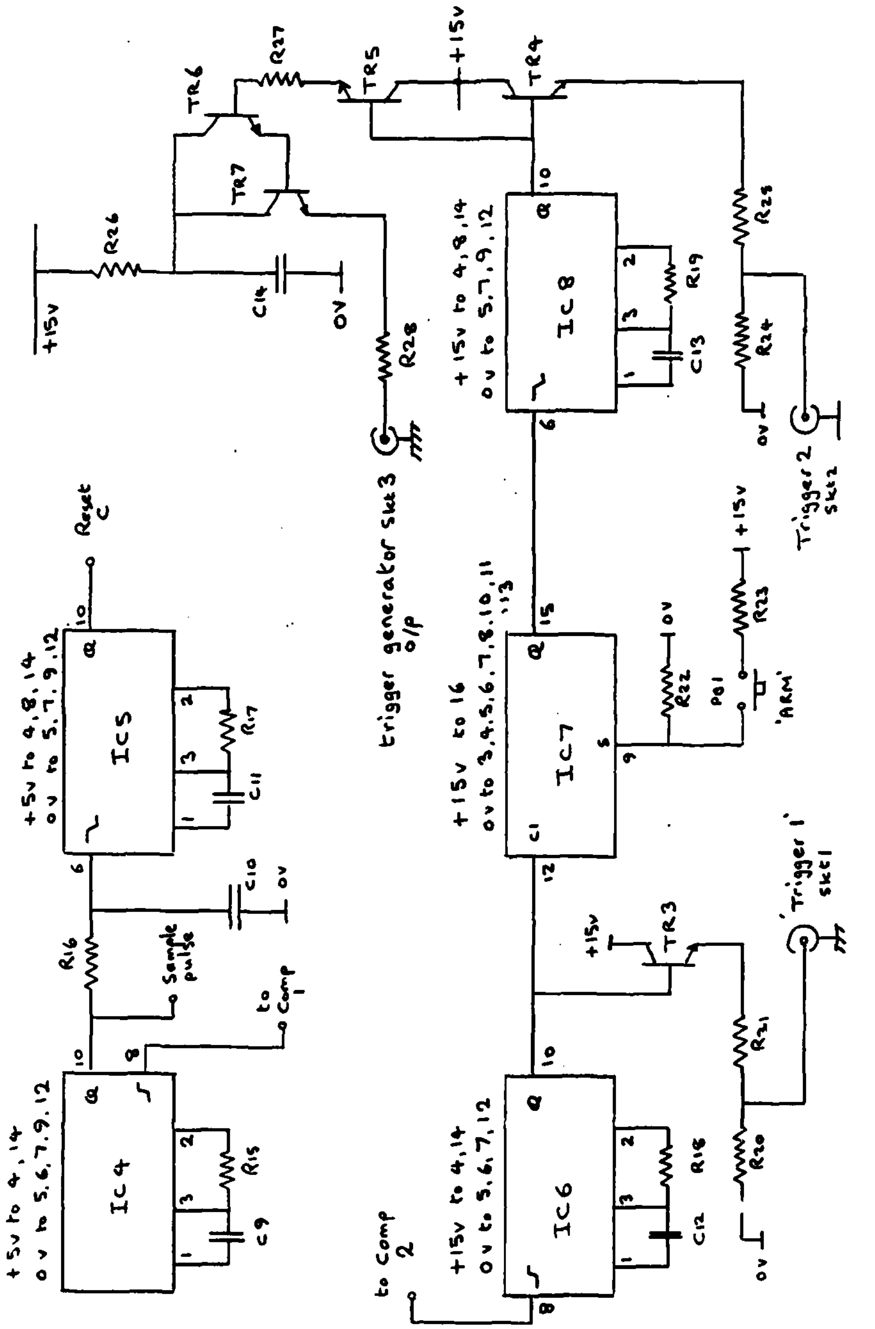
Fig G8

APPENDIX H

PHASING UNIT COMPONENT LIST

The circuit diagram is given again in Figures H1 and H2 with the associated component list in Figure H3.

Fig H1



NB. Ic4 and Ic5 are powered by +5v rail to suit sample/hold amplifier used

All other logic Ics powered by +15volt supplies

CIRCUIT DIAGRAM (PART) FOR PHASING UNIT FOR TYPE 2 GENERATOR

Fig H1

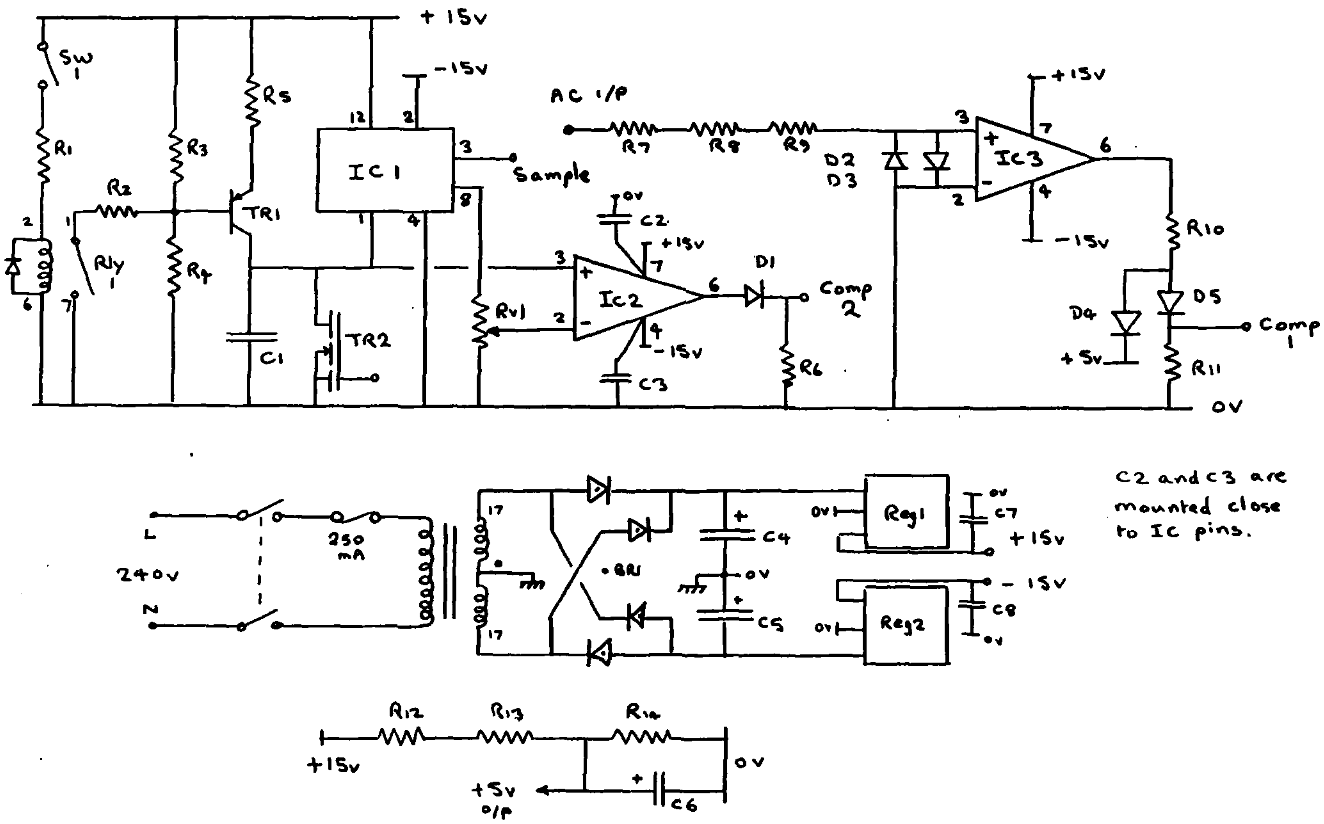


Fig H2 Circuit diagram (part) for phasing unit for Type 2 generator

Fig H3

COMPONENT LIST FOR PHASING UNIT

R1	100R	2%	0.25W
R2	2K2	2%	0.25W
R3 R20 R24	1K2	2%	0.25W
R4	13K0	2%	0.25W
R5 R7 to R9	33K0	2%	0.25W
R6	27K0	2%	0.25W
R10	3K9	2%	0.25W
R11 R21 R25	2K7	2%	0.25W
R12 to R14 R22	100R0	2%	0.25W
R15 R17	22K0	2%	0.25W
R16	100K0	2%	0.25W
R18	56K0	2%	0.25W
R19	120K0	2%	0.25W
R23	1M0	2%	0.25W
R26	4K7	2%	0.25W
R27	5K6	2%	0.25W
R28	15R0	2%	0.25W
RV1	10K0	10 Turn wire wound potentiometer	
C1	100nF	30 Volt Polyester	
C2 C3 C7 C8	100nF	30 Volt Ceramic	
C4 C5	2700µF	30 Volt electrolytic	
C6	22uF	30 Volt electrolytic	
C9 C11 C12 C13	180pF	30 Volt polystyrene	
C10	100pF	30 Volt polystyrene	
C14	2.2µF	30 Volt electrolytic	
Tr1	ZTX 504 Silicon transistor		
Tr2	VN88AF VMOS Field effect transistor		
Tr3 to Tr6	ZTX 304 Silicon transistor		
Tr7	2N2219 Medium power silicon transistor		
T1	20 VA 240 Volt to 17-0-17 Volt transformer		
Reg1	LM7815 +15 Volt regulator		
Reg2	LM7915 -15 Volt regulator		
IC1	SHC85T Burr Brown, or similar Sample/Hold		
IC2	AD528 Analog Devices FET I/P amp		
IC3	741S Operational amplifier		
IC4,5,6 & 8	HEF4047 Monostable		
IC7	HEF4027 Dual JK Flip Flop		
D1 to D5	1N916 Silicon diode		
Br1	1A Bridge rectifier		
Rly1	Astralux 132A-1 Reed relay		
Equipment case	Verospeed Electronics Ltd 91-2674B 304 x 170 x 84 mm		
Mains socket	IEC filtered RS Components 238-687		
Pb1	Push switch momentary contact		
Skt1 to Skt3	BNC panel mounting		

Most of the components are not critical but the sample/hold amplifier should have a short acquisition time and the IC3 should have a reasonably fast slew rate.

FIGURE H3

APPENDIX J

TYPE 3 GENERATOR CONSTRUCTION AND COMPONENTS

Inductor L1 consists of approximately 6 turns wound with 16SWG enamelled copper wire on a former 36mm in diameter and over a length of 25mm.

Inductor L2 is wound with the same wire and on the same diameter former but with 24 turns over 50mm length.

The capacitors in the prototype generator were paper dielectric devices. Suitable capacitors are available from various sources and the choice should reflect the need for low internal inductance, pulse discharge and reverse voltage swing of up to 50 per cent. This last requirement is important for pulse discharge capacitors since life will be adversely affected if an inadequate rating is applied.

Construction of this generator should present no problems if the usual requirements of high voltage and current layout are followed. The inductors should be mounted as far apart as possible and preferably on orthogonal axes.

The inductor L1 value should be trimmed when the generator has been constructed since the circuit stray inductance and the internal inductance of the capacitors may require that less than the value quoted will be required.

The case of the generator should follow good rf screening practice in order that the radiation of spurious signals is kept to a minimum.

Components list for Type 3 Generator

R1	50k	1W wire wound
R2	50k	1W wire wound
R3	1R2	50W metal cased wire wound
R4	1R2	50W metal cased wire wound
R5 to R7	1R8	50W metal cased wire wound
R8	3R6	50W metal cased wire wound
R9 to R12	0R1	25W metal cased wire wound
R13	430R0	0.5W carbon
R14	20R0	0.5W carbon
C1	100μF	3000V non-polarised pulse discharge capacitor
C2	0.5μF	3000V as above

L1 and L2 described in text

Sw1 and Sw2 Ross switches as in Type 1A generator no oil bath required

Ps1 0 to 3000V power unit, eg high voltage step up transformer supplied from variable transformer.

Ps2 Power unit to suit contactor coil as described in Type 1A generator

Skt1 BNC socket - panel mounting

Term1 and Term2 Large screw terminals with 3000V insulation

REPORT DOCUMENTATION PAGE

(Overall security classification of this page)

UNCLASSIFIED

As far as possible this page should contain only unclassified information. If it is necessary to enter classified information, the box above must be marked to indicate the classification, e.g. Restricted, Confidential or Secret.

1. DRIC Reference (to be added by DRIC)	2. Originator's Reference	3. Agency Reference	4. Report Security Classification/Marking
	RAE TM FS(F) 550		UNLIMITED

5. DRIC Code for Originator	6. Originator (Corporate Author) Name and Location
7673000W	Royal Aerospace Establishment, Farnborough, Hants, UK
5a. Sponsoring Agency's Code	6a. Sponsoring Agency (Contract Authority) Name and Location

7. Title The design, construction, performance and calibration of pulse generators to fulfil the requirements of specifications Defence Standard 59-41, FS(F) 510 and FS(F) 457

7a. (For Translations) Title in Foreign Language

7b. (For Conference Papers) Title, Place and Date of Conference

8. Author 1. Surname, Initials	9a. Author 2	9b. Authors 3, 4	10. Date	Pages	Refs.
Hobbs, R.A.			September 1988	115	5

11. Contract Number	12. Period	13. Project	14. Other Reference Nos.

15. Distribution statement

(a) Controlled by –

(b) Special limitations (if any) –

If it is intended that a copy of this document shall be released overseas refer to RAE Leaflet No.3 to Supplement 6 of MOD Manual 4.

16. Descriptors (Keywords) (Descriptors marked * are selected from TEST)

Pulse generators. EMC. EMP. Lightning.

17. Abstract

This Memorandum describes the construction, performance and calibration of pulse generators to fulfil the electromagnetic transient test requirements of the Defence Standard 59-41 (June 1986), RAE Technical Memorandum FS(F) 510 and FS(F) 457 (Issue 2). Three pulse generators are described, Type 1A which produces damped sinusoidal waveforms in the frequency range 2 to 30 MHz, Type 3 which is a fixed frequency 100kHz generator, and Type 3 which produces two waveforms for ground voltage lightning effects simulation. The generators have been designed to enable electronic systems to be assessed for immunity to the effects of EMC, LEMP and NEMP. The NEMP capabilities of the Type 1A generator meet the Airside requirements of the Defence Standard.