SPECIFICATION D.C. NANOVOLTMETER MODEL N1a

RANGE	11 basic ranges ± 10nV f.s.d.to ± ImV f.s.d. X10^3 Attenuator. 3mV to IV. X10^6 Attenuator 3V to IKV.
METER	4" Mirror scale. Centre zero, calibrated 10-0-10 and 3-0-3.
ACCURACY	Direct output ± 0.2% Isolated output ± 0.5% Meter 2%
ZERO DRIFT	Typically 500pV/°C.
LONG TERM DRIFT	No long term drift detectable.
NOISE	Equivalent noise resistance approximately 60 ohms. Peak to peak noise voltage depends on filter setting, e.g. filter time constant 5 seconds gives peak to peak noise voltage approx. 900 pV with s/c input.
SOURCE RESISTANCE	Up to IMohm.
RESOLUTION	Better than 300pV.
INPUT RESISTANCE	Direct input greater than 30Mohms 3 seconds after a step input, increasing with time to over 10^9 ohms. Attenuator. IMohm.
OFFSET CURRENT	Nominally zero at 23 °C. Temperature coefficient typically 2pA/ °C.
RESPONSE TIME	Depends on setting of filter and range. Minimum 250mS. Maximum 40 seconds.
FILTER	Six position low pass filter operated by a switch on the front panel.

OFFSET	10 turn potentiometer calibrated 0-1000 with nine position switch giving maximum offsets of plus and minus 100nV, 1uV,10uV, 100uV and an 'off' position. resolution better than 0.02%.Accuracy better than 1%.
SERIES MODE REJECTION	Greater than 80dB with superimposed line signal less than 0.3mV p/p degenerating to 40dB at 5mV.
COMMON MODE REJECTION	Greater than 180dB at 50Hz (output to input)
OUTPUTS	Direct and isolated outputs giving 0 to $\pm$ Iv for full scale defelection.Amplifier gain equals Iv divided by the range setting in volts.
ISOLATION	Input to case or output typically 10^{11} ohms shunted by IpF unbalanced capacity.
CONNECTORS	Input,low thermal e.m.f.terminals for basic ranges.Screw terminal/4mm socket for attenuator. Outputs 4mm sockets at rear.
POWER SUPPLY	Internal rechargeable battery giving more than 50 hours operation from a full charge. Internal charger fully charges the battery in 16 hours with the instrument switched off or 20 hours when in use.
DIMENSIONS	Width $14\frac{1}{2}$" (365mm) Depth Inc. Handles $11\frac{1}{2}$" (285mm) Height Inc. Feet $6\frac{1}{2}$" (165mm)
WEIGHT	$18\frac{3}{4}$ lbs (8.5 Kg)

INTRODUCTION

The EM D.C. Nanovoltmeter model N1a is an extremely sensitive D.C. measuring instrument, designed for specialist application in the fields of calibration, scientific research and engineering. State of the art technology is used to ensure that extremely low levels may be measured with ease and convenience.

The equipment is all solid state and employs an input modulator, A.C. amplifier, and demodulator in the input amplifying stages. The techniques used allow overall negative feedback around the input amplifier, which gives a high input impedance and closely controlled gain.

The overall gain of the instrument is controlled by negative feedback networks of the input amplifier and also the following amplifier stages.

The offset control is applied at the summing junction of the input amplifier stage, and this allows small voltage changes to be measured in comparatively large levels.

The outputs of the amplifier appear at the rear panel. The direct output is used where isolation is not wanted and the full linearity of the instrument is required. There is also an isolated output.

OPERATION

SWITCHING ON. The settling time of the instrument will depend on the filter time constant selected. To save time, it may be advantageous to select filter position 1 until the amplifier has settled and then to adjust as required.
This will save delay caused by the time constant of the filter and the wide dynamic range of the input amplifier.
No 'warming up' time is necessary.

RANGE. There are 11 basic ranges, and potentials from 1mV down to a few hundred pico volts may be measured. The response time of the instrument varies with the filter setting and increases on the lowest ranges as well. The basic ranges are used in conjunction with the direct (Hi X1, Lo) input terminals.

SCALE. When voltages higher than 1mV need to be measured, the scale switch should be set to $X10^3$ for up to 1v and $X10^6$ for higher than 1v. The attenuated input terminal (Hi Att) and the common or Lo terminal must be used.

FILTER. The instrument is fitted with a variable low pass filter having six positions, position six having the narrowest bandwidth. The time constant is increased in a 1-2-5 sequence, and the actual time is constant on all but the lowest 3 ranges, where the bandwidth is reduced, filter time constants are given in the accompanying tables.

OFFSET. The offset voltage control is provided to allow small changes in comparatively large voltages to be measured. It is also useful to neutralize thermal e.m.fs. from the circuit under test. The offset switch has 9 positions. The central position disconnects the offset circuit. The four right hand positions indicate the maximum positive offset which may be applied by adjusting the ten turn calibrated potentiometer. The four left hand positions apply a negative offset voltage.

ZERO. This control is used to bring the input amplifier to zero, and should only be used with the input terminals short circuited by a clean, pure copper strap, which is used as an input reference. The zero control should not need adjustment in normal use.

CURRENT ZERO. A fine current offset control is adjustable through a hole in the switch box lid. This gives approximately 3pA per turn of the trimmer.

BATTERY CHECK. The on/off switch contains a check for each of the two internal batteries. If the voltage of either battery falls below 8v, the mains supply should be connected.

CHARGER. The batteries will be charged automatically when the A.C.mains supply is connected. Whether or not the instrument is switched on, and the charger indicator will be illuminated. When the charger is not in use, it is preferable to disconnect the mains lead from the instrument, thereby allowing the complete advantage of battery operation. The battery will be completely charged in 16 hours, with the instrument switched off, or 20 hours if it is switched on, and will give about 50 hours of operation from a full charge.

INPUT TERMINALS. The direct input terminals have been designed for low thermal e.m.fs. characteristics, and ease of operation. The voltage applied to the direct input (Hi X 1) should not be allowed to exceed 1mV in order to avoid unwanted thermo-electric effects. Connections should be made using clean, pure copper wire. If potentials greater than 1mV are to be measured, then the attenuator input terminal (Hi Att) should be used in conjunction with the appropriate setting of the "scale" switch. The terminal marked "case" is a direct connection to the chassis of the instrument, and is earthed when the mains is connected.

OUTPUT. The outputs are taken from the red and black sockets at the rear of the instrument. One output is isolated from the input, both outputs have a level of plus and minus 1v for full scale deflection, and are capable of driving 1mA. The amplifier gain is 1 volt divided by the range setting in volts. The green socket at the rear is connected to the case and is earthed when the mains is connected.

MEASURING NANOVOLTS.

When making measurements at very low levels, care must be exercised to minimise the effects of unwanted signals. These

can arise principally from the following causes:

1. Noise
2. Thermal e.m.f.
3. Electric & magnetic fields
4. Ground loops
5. Interference.

I. NOISE. This is generated in all conductors, by thermal agitation of electrons. In a perfect conductor the noise voltage developed across the conductor is given by:

$$en = \sqrt{4KTRdF}.$$

From this equation, it appears that the noise may be minimised by reducing source impedance, cooling, and limiting bandwidth. In many cases, only the latter is practical, and this has the disadvantage of increasing the time necessary to resolve very low levels.

2. THERMAL e.m.f. A potential arises at the junction of dissimilar conductors and even at the contact between two pieces of material which are nominally similar. All junctions should be kept at the same temperature, and as close together as possible.

3. ELECTRIC & MAGNETIC FIELDS. The effects of these sources of unwanted signal can be minimised by keeping the area enclosed, by the circuit under test, to a minimum. Measurement leads should be twisted pairs, and the whole circuit should be screened, if necessary, using high permeability substances such as mumetal.

4. GROUND LOOPS. This source of unwanted signal is familiar even with normal signal levels. At ultra low levels, even more care is necessary, and all common connections should be made to a single point. The EM d.c. detector is battery operated and so may be connected without contributing to the problem.

5. INTERFERENCE. One of the chief causes of difficulty in measuring ultra low potentials is interference from noisy mains supplies. Signals which may be too small to view with an oscilloscope are frequently present in circuits under test, especially when there are many pieces of equipment connected, which are powered from the mains supply. These signals may be many hundreds of times the full scale of the voltmeter, and small, slow changes in amplitude may appear as input noise. External filtering, screening, or isolation of power supplies may be necessary.

The detector incorporates a low pass filter, which may be switched in to minimise the effects of noise from the circuit under test, if measurement time permits.

Another useful feature is the offset control. This may be used to back off a potential from the circuit under test, and so small changes may be measured more easily. The zero control should not be used for this purpose. This control is for maintaining the amplifier's internal zero, which should only be checked using a clean pure copper strap across the input terminals, as a zero reference.

CIRCUIT DESCRIPTION

The low thermal e.m.f. terminals are connected to the input unit via matched copper conductors, and a thermal equaliser.

The input unit operates as a modulator, whose output is an A.C.signal, proportional to the d.c. input. The A.C. is taken to the input of an A.C.amplifier, on p.c.b.1d, whose output is coupled by means of a transformer, to the demodulator. The demodulator consists of T2 to T5, and is an active bridge driven in synchronism with the modulator.
The amplified and restored d.c. signal is taken to the input of IC2, and a d.c.potential from RT2 is brought to the summing junction of IC2.

The signal at the output of IC2 is further amplified by IC3. The feedback networks of IC1, IC2, and IC3, control the gain and phase shift of the input amplifier. The output of the input amplifier is connected via Pin 4 to the feedback network which controls the gain of the input amplifier.

The output of the input amplifier stage is taken via R22 to IC5. This is a stable d.c.amplifier whose gain is controlled by the switched feedback network operated via the 'Range'switch. This feedback network also contains a series of capacitors, switched by the 'Filter' switch. The output of IC5 goes to a further amplifier stage using IC6. Ic6 has a fixed resistor R31, in its feedback, and this is shunted by a series of capacitors which are switched by the 'Filter'switch. RT4 is the overall gain adjustment. The output of IC6 is taken to the direct output of the instrument and also to the meter and the input of the isolator.

The modulator and demodulator drive functions are provided by the circuit including IC7, IC8, IC9, T8, and T9.
IC7 is a stable square wave generator, which drives a shaping network using T8, T9, and IC8. The signals at pins 9 and 10 are used to operate the modulator circuit. The demodulator drive is taken from the outputs of IC9.

IC10 is a quad amplifier and is connected as four voltage regulators to provide the stable supplies needed for the d.c. amplifier circuits. D4 is a band gap device and is used as the basic reference voltage.

The amplifier output is at pin 8 of p.c.b.1d, and this is connected via IC1 on p.c.b.2c, and the on/off switch to the meter. The meter is short circuited when the instrument is switched off.

The isolator, output stage, and battery charger are contained on p.c.b.2c. IC2 is a dual phase switching stage, which is driven from the oscilator on p.c.b.1d. The outputs of IC2 are connected to a transformer, Tr2. The current in the secondary circuit of Tr2 is rectified and smoothed and provides the power for the output stage. Tr2 also drives the synchronous demodulator, IC6. The signal from the output of the main amplifier is connected to pin 1, the input of p.c.b.2.

The signal at pin 1 is connected via r.f.filters to the direct output of the instrument. This output is used when isolation is not needed, and when maximum linearity is required.

Pin 1 is also connected to an amplifier stage which raises the level to drive the meter, and also to undergo modulation in IC3 and thence to the signal isolating transformer,Tr1. The output of Tr1 is demodulated by IC6, and then passed through an active filter stage, IC7, whose output is taken, via r.f.filters to the isolated output at the rear panel of the instrument.

The output of Tr3 is rectified and taken via D10 and R28 to the instrument batteries. A further output via R27 goes to the front panel charging indicator. The batteries can give high current and so each is fused at 200mA and the mains input is fused at 100mA anti-surge.

A terminal is provided at the front and rear of the instrument which is connected to the case.

ADJUSTMENT PROCEDURE

1. ACCESS. Remove the screw holding the top cover in place, and slide off the top cover. Remove the six screws holding on the switch box lid and lift it off. p.c.b.1 containing the main amplifier and drive circuits may be moved upwards to gain access to the components, if necessary. Do not under any circumstances, interfere with the input unit,which is mounted in foam plastic at the right hand side of the switch box. If this unit is suspected of being faulty, then the instrument must be returned to the manufacturer for servicing.

2. POWER SUPPLY. Check the voltage at pin 11 of p.c.b.1, referred to 13, using a digital voltmeter with an accuracy of 0.1%. The reading should be + 6.2v adjusted by RT10. Check the voltage at pin 12, and adjust RT11 if necessary until the reading is - 6.2.v.

3. INPUT MODULATOR. The input modulator drive circuit is very stable and should not need adjustment during the life of the instrument. The following procedure should be undertaken only if absolutely necessary. Disconnect the wire from 4 on p.c.b.1. Connect a link across C4. Connect a function generator to the input terminals, via an attenuator, to give a level of about 10 microvolts. The frequency range should be 0.1Hz to 10KHz with a sine wave signal. Connect an oscilloscope to TP1, and trigger it externally from TP3. Set the time base to ImS/cm and sensitivity to 2v/cm. With the generator set to about 20Hz adjust RT9 for maximum constant amplitude, without any steps in the response. Sweep the frequency down to 0.1Hz and check that maximum amplitude is maintained without discontinuities. It should be noted that the signal will increase at very low frequency because of the characteristic of the amplifier. Reconnect the wire to pin 4 of p.c.b.1. Remove the link across C4.

4. ZERO. Connect a clean pure copper strap between the input terminals, and set the front panel zero control to the middle of its travel. With the instrument switched off, check the mechanical zero on the meter. Switch on and set the range to 1mV. Adjust RT3 for less than 0.1mV at the rear panel direct output. Adjust RT2 on p.c.b.2 for zero on the meter, and adjust RT4 for zero at the isolated output. Connect the oscilloscope to TP1. Adjust RT7 and RT8 for minimum spike amplitude. Replace the input strap by a 100K ohms resistor. Switch to the 10uV range and adjust RT2 for zero. Some noise from the 100K resistor will be observed. Replace the input strap and switch to the most sensitive range. Wait until any thermal e.m.fs have equalised and then adjust the front panel zero control for zero on the meter. Repeat these tests if necessary.

5. SENSITIVITY. Connect a d.v.m. to the direct output terminals at the rear of the instrument, set to the 1v range. switch the nanovoltmeter to the 1mV range. Apply an input of exactly 1mV and adjust RT4 on p.c.b.1c for 1.000 volts out. Adjust RT1 on p.c.b.2 for f.s.d. on the meter. Connect the input strap and switch to the 100uV range. Switch the 'offset' switch to minus 100uV. Turn the offset control to maximum and adjust RT10 on p.c.b.1 to read minus 1.000v on the d.v.m. Switch to offset positive and check that the d.v.m. reads plus 1.000v. A small adjustment of RT11 will correct any discrepancy. With a calibrated source connected to the input check the other ranges. Switch to the 1mV range and connect the d.v.m. to the isolated output.
Check that the isolator gain is within $\pm$ 0.5%.
Remove the test equipment and replace the covers on the instrument.

Parts list

Mainframe

R1	Resistor	300R	0.1%	50ppm	
R2	Resistor	1KO	0.1%	50ppm	
R3	Resistor	3KO	0.1%	50ppm	
R4	Resistor	10K	0.1%	50ppm	
R5	Resistor	30K	0.1%	50ppm	
R6	Resistor	100K	0.1%	50ppm	
R7	Resistor	300K	0.1%	50ppm	
R8	Resistor	1MO	0.1%	50ppm	
R9	Resistor	3MO	0.1%	50ppm	
R10	Resistor	10M	0.1%	50ppm	
R11	Resistor	30M	0.5%	100ppm	
R12	Resistor	1MO	0.25%	100ppm	Thick Film
R13	Resistor	1KO	0.25%	100ppm	
R14	Resistor	1RO	0.25%	100ppm	
R15	Resistor	62K	0.25%	100ppm	
R16	Resistor	620K	0.25%	100ppm	
R17	Resistor	6.2M	0.25%	100ppm	
R18	Resistor	62M	1%	100ppm	
R19	Resistor	33M	5%		Thick Film
R20	Resistor	1MO	1%		Metal Film
R21	Resistor	1MO	1%		Metal Film
R22	Resistor	1MO	1%		Metal Film
R23	Resistor	1MO	1%		Metal Film
R24	Resistor	1MO	1%		Metal Film
R25	Resistor	1MO	1%		Metal Film
R26	Resistor	1MO	1%		Metal Film
R27	Resistor	1MO	1%		Metal Film
R28	Resistor	1MO	1%		Metal Film
R29	Resistor	1MO	1%		Metal Film
R30	Resistor	20K	1%		Metal Film
R31	Resistor	20K	1%		Metal Film
RT1	Potentiometer	100K			Ten Turn
RT2	Potentiometer	5K			Ten Turn
RT3	Potentiometer	100K			
C1	Capacitor	.047uF	10%	63v	
C2	Capacitor	0.1uF	10%	63v	
C3	Capacitor	0.22uF	10%	63v	
C4	Capacitor	0.47uF	10%	63v	
C5	Capacitor	1.0uF	10%	63v	
C6	Capacitor	.047uF	10%	63v	
C7	Capacitor	0.1uF	10%	63v	
C8	Capacitor	0.22uF	10%	63v	
C9	Capacitor	0.47uF	10%	63v	
C10	Capacitor	1.0uF	10%	63v	
F1	Fuse	100mA			
F2	Fuse	100mA			
F3	Fuse	100mA	Anti surge		

P.c.b.1d.

R1	Resistor	3K9	1%	Metal Film
R2	Resistor	3K9	1%	Metal Film
R3	Resistor	5K6	1%	Metal Film
R4	Resistor	2M2	5%	Metal Film
R5	Resistor	820R	1%	Metal Film
R6	Resistor	22K	1%	Metal Film
R7	Resistor	2K2	1%	Metal Film
R8	Resistor	10K	1%	Metal Film
R9	Resistor	10M	5%	Metal Film
R10	Resistor	100R	1%	Metal Film
R11	Resistor	1M	1%	Metal Film
R12	Resistor	1K	1%	Metal Film
R13	Resistor	100K	1%	Metal Film
R14	Resistor	10K	1%	Metal Film
R15	Resistor	10M	1%	Metal Film
R16	Resistor	220K	1%	Metal Film
R17	Resistor	1K	1%	Metal Film
R18	Resistor	47R	1%	Metal Film
R19	Resistor	47R	1%	Metal Film
R20	Resistor	10K	1%	Metal Film
R21	Resistor	3K0	1%	Metal Film
R22	Resistor	3K0	1%	Metal Film
R23	Not required			
R24	Resistor	3K0	1%	Metal Film
R25	Resistor	10K	1%	Metal Film
R26	Resistor	1K	1%	Metal Film
R27	Not required			
R28	Resistor	2M7	5%	Metal Film
R29	Resistor	3M0	1%	Metal Film
R30	Not required			
R31	Resistor	10M	1%	Metal Film
R32	Resistor	1K5	1%	Metal Film
R33	Not required			
R34	Not required			
R35	Not required			
R36	Not required			
R37	Not required			
R38	Not required			
R39	Not required			
R40	Not required			
R41	Resistor	10K	1%	Metal Film
R42	Resistor	10K	1%	Metal Film
R43	Resistor	560K	1%	Metal Film
R44	Resistor	330K	1%	Metal Film
R45	Resistor	1K0	1%	Metal Film
R46	Resistor	1M	1%	Metal Film
R47	Resistor	4K7	1%	Metal Film
R48	Resistor	4K7	1%	Metal Film
R49	Resistor	3K0	1%	Metal Film
R50	Resistor	3K0	1%	Metal Film
R51	Resistor	100K	1%	Metal Film
R52	Resistor	100K	1%	Metal Film
R53	Resistor	100K	1%	Metal Film
R54	Resistor	220K	1%	Metal Film
R55	Resistor	100K	1%	Metal Film
R56	Resistor	100K	1%	Metal Film
R57	Resistor	10M	5%	Metal Film
R58	Resistor	10M	5%	Metal Film

R59	Resistor	10M	5%	Metal Film	
R60	Resistor	10M	5%	Metal Film	
R61	Resistor	100K	1%	Metal Film	
R62	Resistor	47K	1%	Metal Film	
R63	Resistor	220R	1%	Metal Film	
R64	Resistor	220R	1%	Metal Film	
R65	Resistor	10K	1%	Metal Film	
R66	Resistor	10K	1%	Metal Film	
R67	Resistor	10K	1%	Metal Film	
R68	Resistor	100K	1%	Metal Film	
R69	Resistor	100K	1%	Metal Film	
R70	Resistor	39K	1%	Metal Film	
R71	Resistor	1KO	1%	Metal Film	
R72	Resistor	120K	1%	Metal Film	
R73	Resistor	30K	1%	Metal Film	
R74	Resistor	100K	1%	Metal Film	
R75	Resistor	100K	1%	Metal Film	
R76	Resistor	120K	1%	Metal Film	
R77	Resistor	30K	1%	Metal Film	
R78	Resistor	100K	1%	Metal Film	
R79	Resistor	100K	1%	Metal Film	
R80	Resistor	100K	1%	Metal Film	
R81	Not required				
R82	Not required				
R83	Not required				
R84	S.O.T.				
R85	S.O.T.				
R86	S.O.T.				
C1	Capacitor	3.3pF	10%	Ceramic	
C2	Capacitor	100nF	20%	Ceramic	30V
C3	Capacitor	100nF	20%	Ceramic	30V
C4	Capacitor	470nF	10%	Polycarbonate	100V
C5	Capacitor	100nF	10%	Polyester	100V
C6	Capacitor	100nF	10%	Polyester	100V
C7	Capacitor	10nF	10%	Polyester	100V
C8	Capacitor	100pF	10%	Ceramic	100V
C9	Capacitor	2u2	10%	Polyester	100V
C10	Capacitor	47nF	10%	Polycarbonate	100V
C11	Capacitor	100nF	10%	Polyester	100V
C12	Capacitor	100nF	10%	Polyester	100V
C13	Capacitor	22nF	10%	Polyester	100V
C14	Not required				
C15	Not required				
C16	Not required				
C17	Capacitor	100nF	20%	Ceramic	30V
C18	Capacitor	100nF	20%	Ceramic	30V
C19	Capacitor	100nF	20%	Ceramic	30V
C20	Capacitor	2n2F	1%	Polystyrene	
C21	Capacitor	2n2F	1%	Polystyrene	
C22	Capacitor	100nF	10%	Polyester	100V
C23	Capacitor	100nF	10%	Polyester	100V
C24	Capacitor	100nF	10%	Polyester	100V
C25	Capacitor	100nF	10%	Polyester	100V
C26	Capacitor	220nF	20%	Ceramic	100V
C27	Capacitor	220nF	20%	Ceramic	100V
C28	Capacitor	47uF	20%	Electrolytic	10V
C29	Capacitor	220nF	20%	Ceramic	30V
C30	Capacitor	220nF	20%	Ceramic	30V
C31	Capacitor	47uF	20%	Tantalum	10V
C32	Capacitor	47uF	20%	Tantalum	10V

C33	Capacitor	47uF	20%	Tantalum	10V
C34	Capacitor	47uF	20%	Tantalum	10V
D1	Diode	1N4148			
D2	Diode	1N4148			
D3	Diode	1N4148			
D4	Diode	04BJ			
D5	Not required				
D6	Not required				
D7	Not required				
D8	Not required				
T1	Transistor	2N6484			
T2	Transistor	J304			
T3	Transistor	J304			
T4	Transistor	J304			
T5	Transistor	J304			
T6	Transistor	2N2484			
T7	Transistor	BCY71			
T8	Transistor	BCY71			
T9	Transistor	2N2484			
T10	Transistor	BF244B			
T11	Transistor	BF244B			
T12	Transistor	J175			
T13	Transistor	J175			
IC1	Integrated Circuit	NE5534N			
IC2	Integrated Circuit	ICL7650CPD			
IC3	Integrated Circuit	TL071CP			
IC4	Integrated Circuit	ICL7650CPD			
IC5	Not required				
IC6	Integrated Circuit	TL071CP			
IC7	Integrated Circuit	CA3130E			
IC8	Integrated Circuit	TL062CP			
IC9	Integrated Circuit	TL062CP			
IC10	Integrated Circuit	TL064CP			
RT1	Potentiometer	100K			
RT2	Potentiometer	100K			
RT3	Potentiometer	100K			
RT4	Potentiometer	100K			
RT5	Not required				
RT6	Not required				
RT7	Potentiometer	5K			
RT8	Potentiometer	5K			
RT9	Potentiometer	100K			
RT10	Potentiometer	2K			
RT11	Potentiometer	1K			

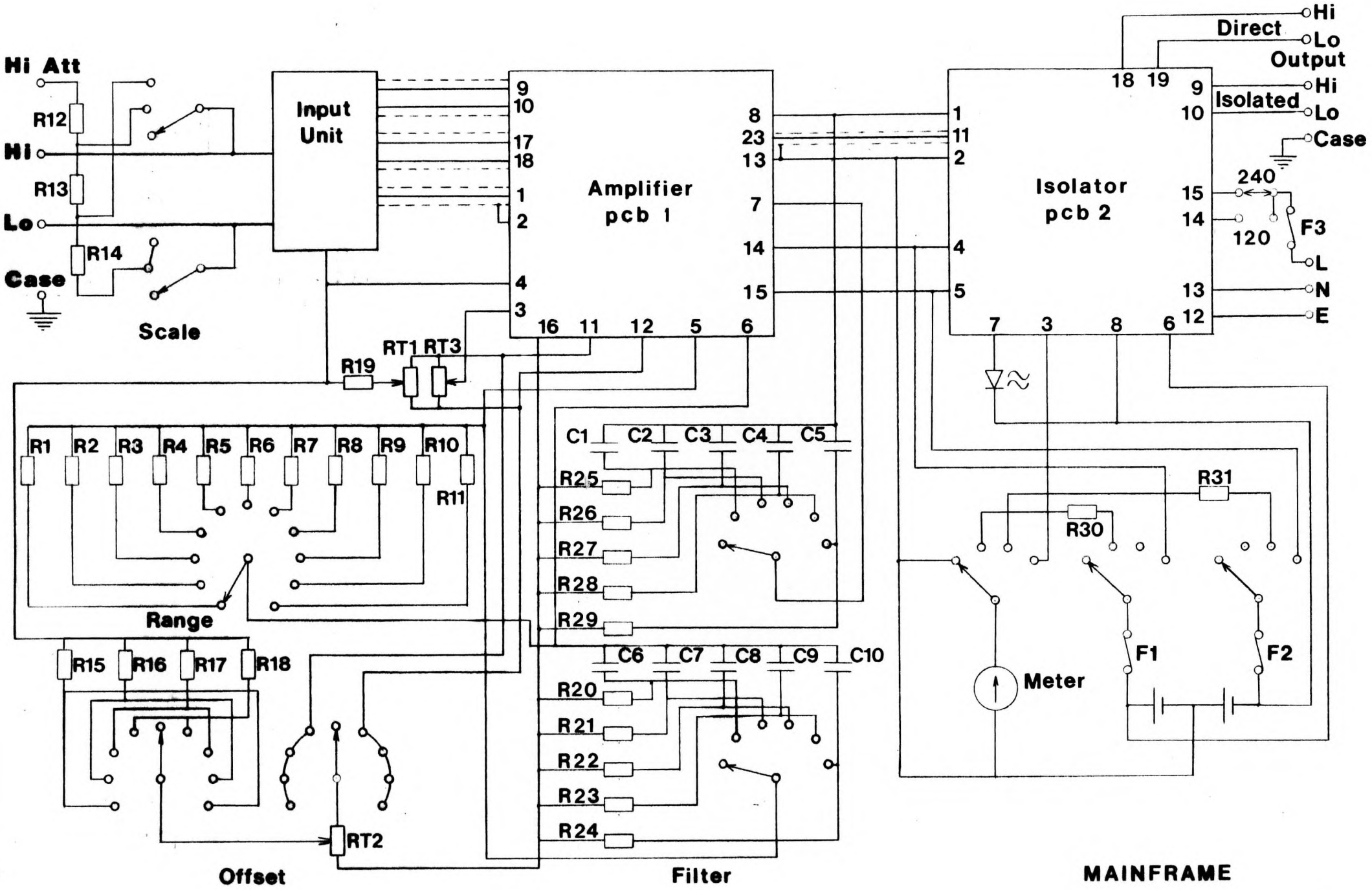
Isolator

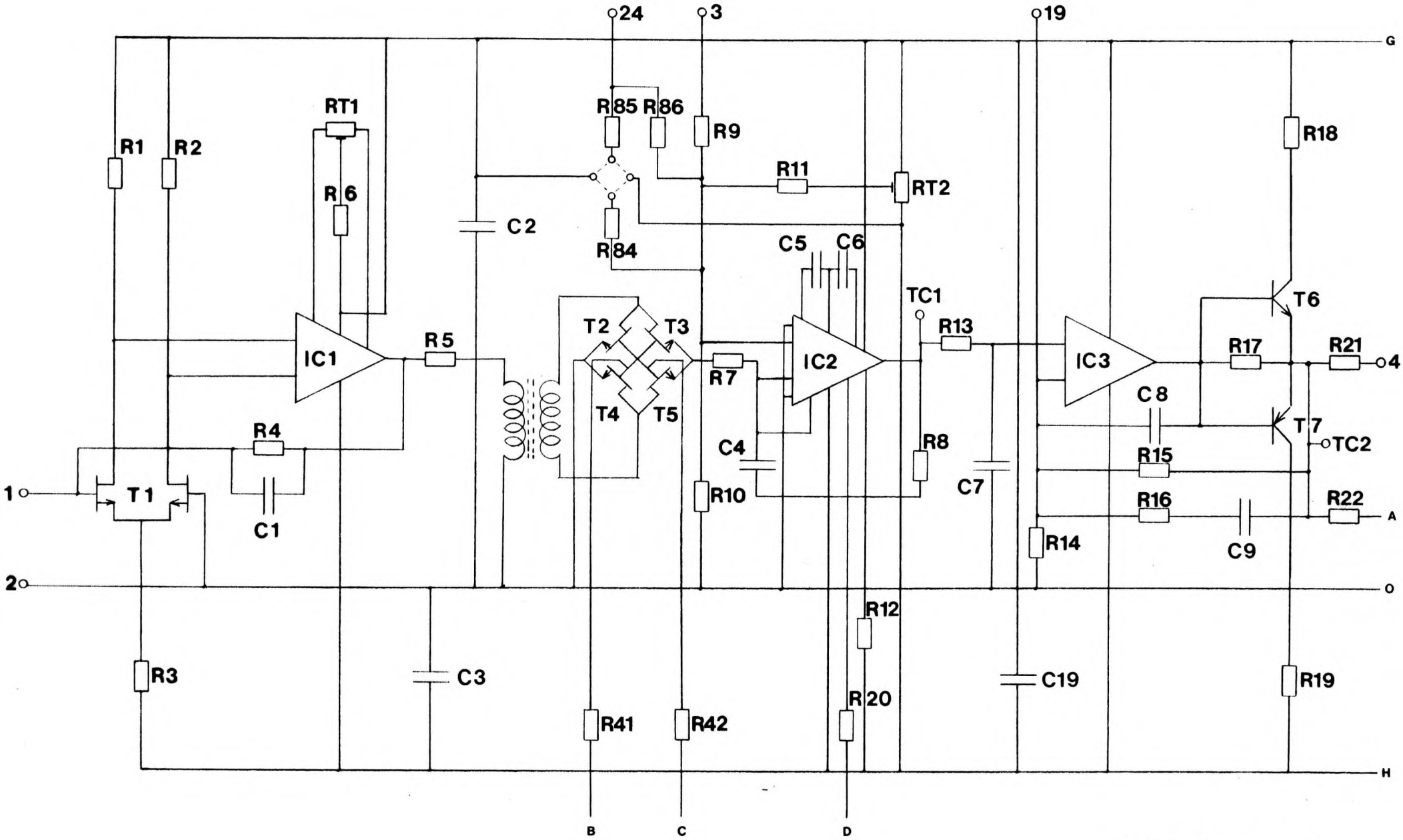
R1	Resistor	100R	1%	50ppm	Metal Film
R2	Resistor	5K6	1%	50ppm	Metal Film
R3	Resistor	10K	1%	50ppm	Metal Film
R4	Resistor	20K	1%	50ppm	Metal Film
R5	Resistor	1K5	1%	50ppm	Metal Film
R6	Not required				
R7	Resistor	1K	1%	50ppm	Metal Film
R8	Not required				
R9	Resistor	1M	1%	50ppm	Metal Film
R10	Resistor	1M	1%	50ppm	Metal Film
R11	Resistor	39K	1%	50ppm	Metal Film
R12	Resistor	22K	1%	50ppm	Metal Film
R13	Resistor	100K	1%	50ppm	Metal Film
R14	Resistor	100K	1%	50ppm	Metal Film
R15	Resistor	100K	1%	50ppm	Metal Film
R16	Not required				
R17	Not required				
R18	Not required				
R19	Not required				
R20	Resistor	1M	1%	50ppm	Metal Film
R21	Resistor	1M	1%	50ppm	Metal Film
R22	Resistor	150K	1%	50ppm	Metal Film
R23	Resistor	470K	1%	50ppm	Metal Film
R24	Resistor	470K	1%	50ppm	Metal Film
R25	Resistor	47K	1%	50ppm	Metal Film
R26	Resistor	1K5	1%	50ppm	Metal Film
R27	Resistor	4K7	1%	50ppm	Metal Film
R28	Resistor	120R	5%	2.5w	
R29	Not required				

RT1	Potentiometer	1K
RT2	Potentiometer	100K
RT3	Potentiometer	5K
RT4	Potentiometer	100K

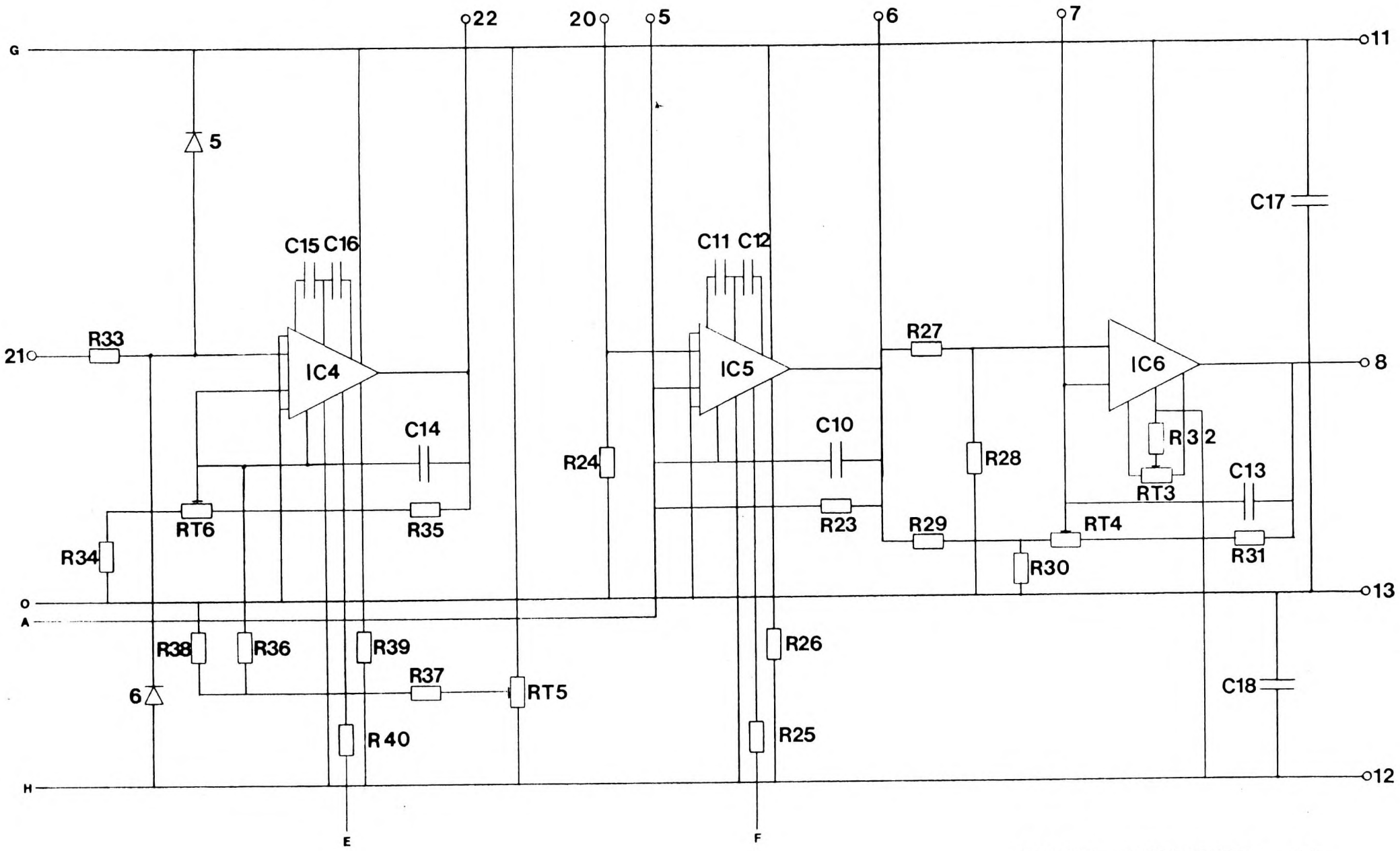
C1	Not required				
C2	Capacitor	100nF		Ceramic	
C3	Capacitor	100nF		Ceramic	
C4	Not required				
C5	Not required				
C6	Capacitor	47uF		Tantalum	16V
C7	Capacitor	47uF		Tantalum	16V
C8	Capacitor	330uF		Electrolytic	10V
C9	Capacitor	330uF		Electrolytic	10V
C10	Capacitor	470nF	10%	Polyester	63V
C11	Capacitor	220nF		Polyester	63V
C12	Capacitor	22nF		Polyester	63V
C13	Capacitor	1000uF		Electrolytic	40V

D1	Diode	04BJ
D2	Diode	1N4148
D3	Diode	1N4148
D4	Diode	1N4148
D5	Diode	1N4148
D6	Diode	1N4148
D7	Diode	1N4148
D8	Diode	1N4148
D9	Diode	1N4148
D10	Diode	1N4004
D11	Diode	W04
IC1	Integrated Circuit	TL061CP
IC2	Integrated Circuit	TL062CP
IC3	Integrated Circuit	HEF4066P
IC4	Integrated Circuit	TL062CP
IC5	Not required	
IC6	Integrated Circuit	HEF4066P
IC7	Integrated Circuit	TL061CP
L1	Inductor	1mH r.f.
L2	Inductor	1mH r.f.
L3	Inductor	1mH r.f.
Tr1	Transformer Signal	
Tr2	Transformer Power	
Tr3	Transformer Mains	

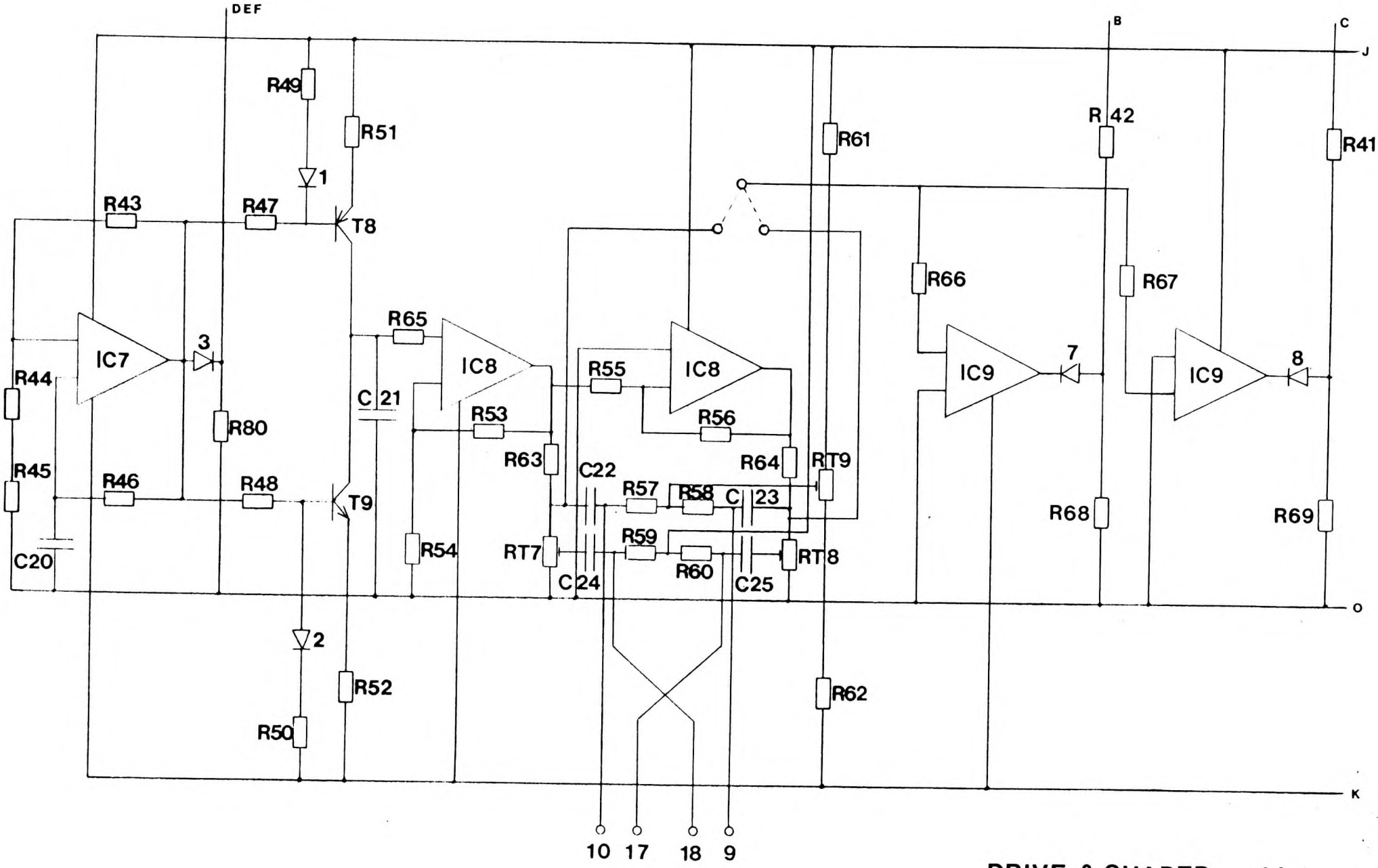

Hi Att
R12
Hi
R13
Lo
R14
Case
Scale
Input Unit
9
10
17
18
1
2
4
3
Amplifier pcb 1
8
23
13
7
14
15
16 11 12 5 6
RT1 RT3
R19
R1 R2 R3 R4 R5 R6 R7 R8 R9 R10
R11
Range
R15 R16 R17 R18
RT2
Offset
C1 C2 C3 C4 C5
R25
R26
R27
R28
R29
C6 C7 C8 C9 C10
R20
R21
R22
R23
R24
Filter
Hi
Direct
Lo
Output
18 19
9
Isolated
Hi
10
Lo
Case
1
11
2
Isolator pcb 2
240
15
14
120
F3
L
4
5
13
N
12
E
7 3 8 6
R31
R30
Meter
F1
F2
MAINFRAME



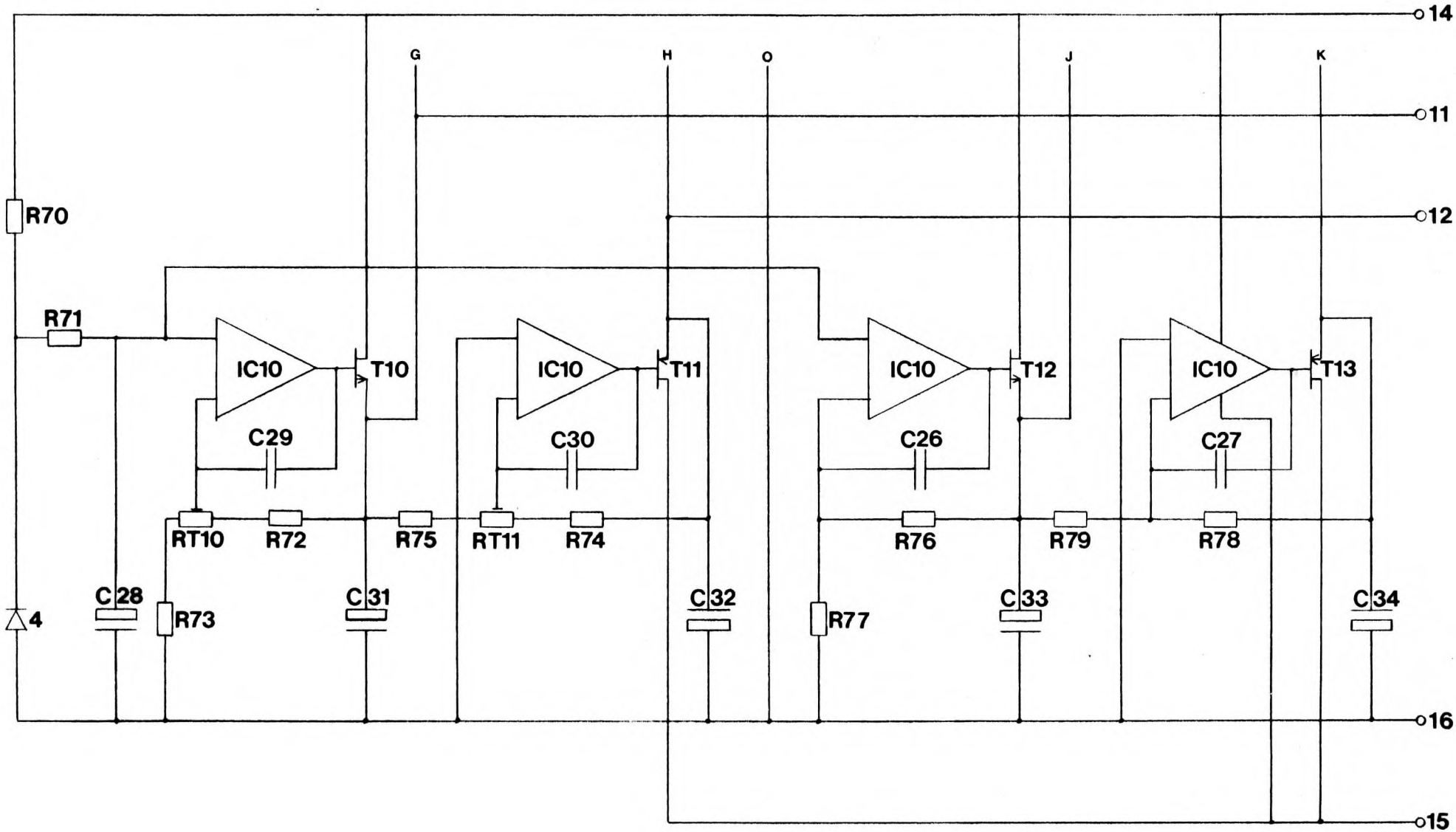
AMPLIFIER 1d



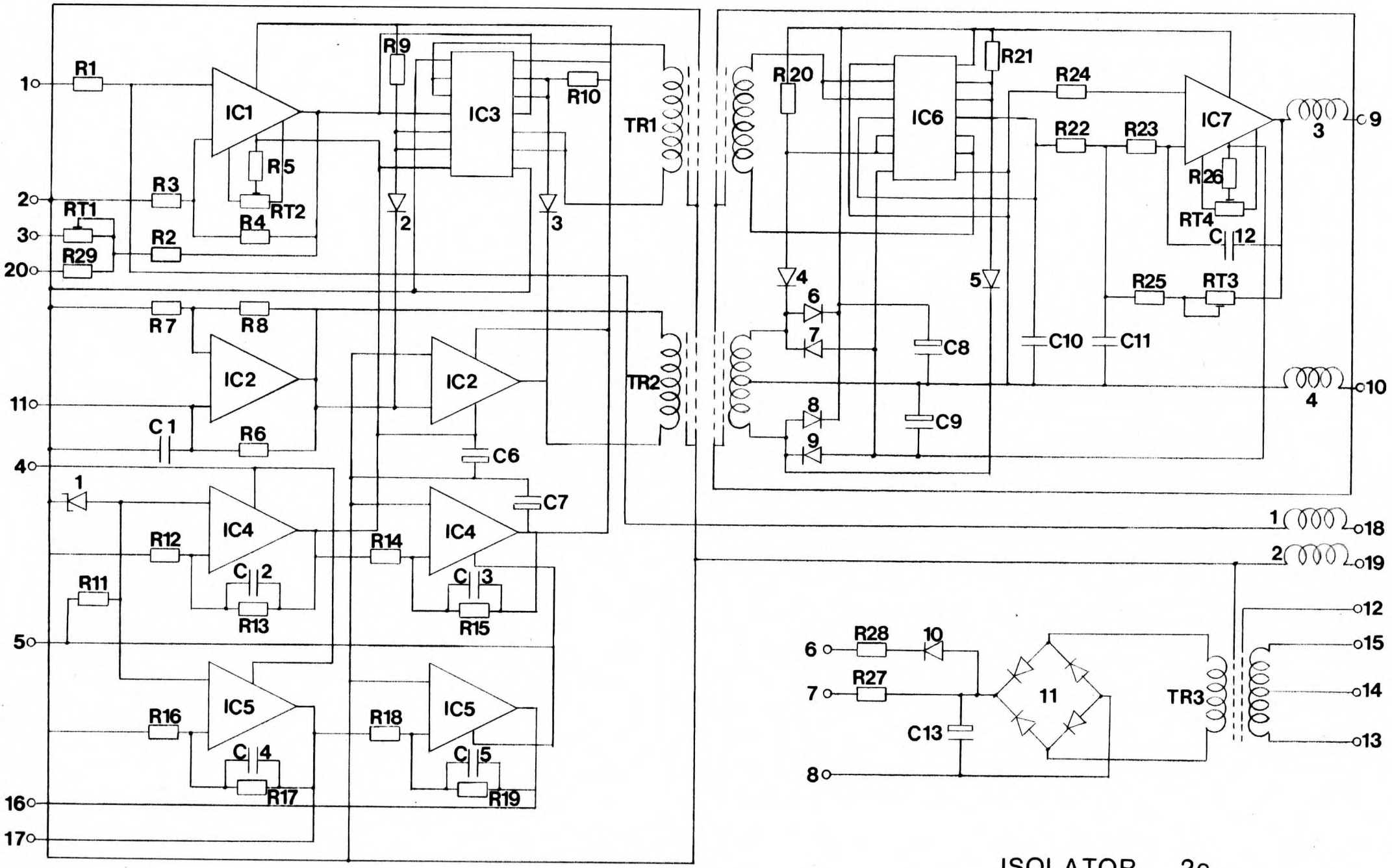
POST AMPLIFIER 1d



DRIVE & SHAPER 1d



REGULATOR 1d


R1
R9
R10
IC1
IC3
TR1
R5
R3
RT2
R4
RT1
R2
R29
2
3
R7
R8
IC2
IC2
TR2
C1
R6
C6
C7
1
IC4
IC4
R12
R14
C2
C3
R11
R13
R15
IC5
IC5
R16
R18
C4
C5
R17
R19
R20
R21
IC6
R24
IC7
R22
R23
R26
RT4
C12
4
5
6
7
8
9
C8
C9
C10
C11
R25
RT3
3
4
1
2
R28
10
R27
C13
11
TR3
1
2
12
15
14
13
18
19
1
2
3
4
5
6
7
8
9
10
11
16
17
20

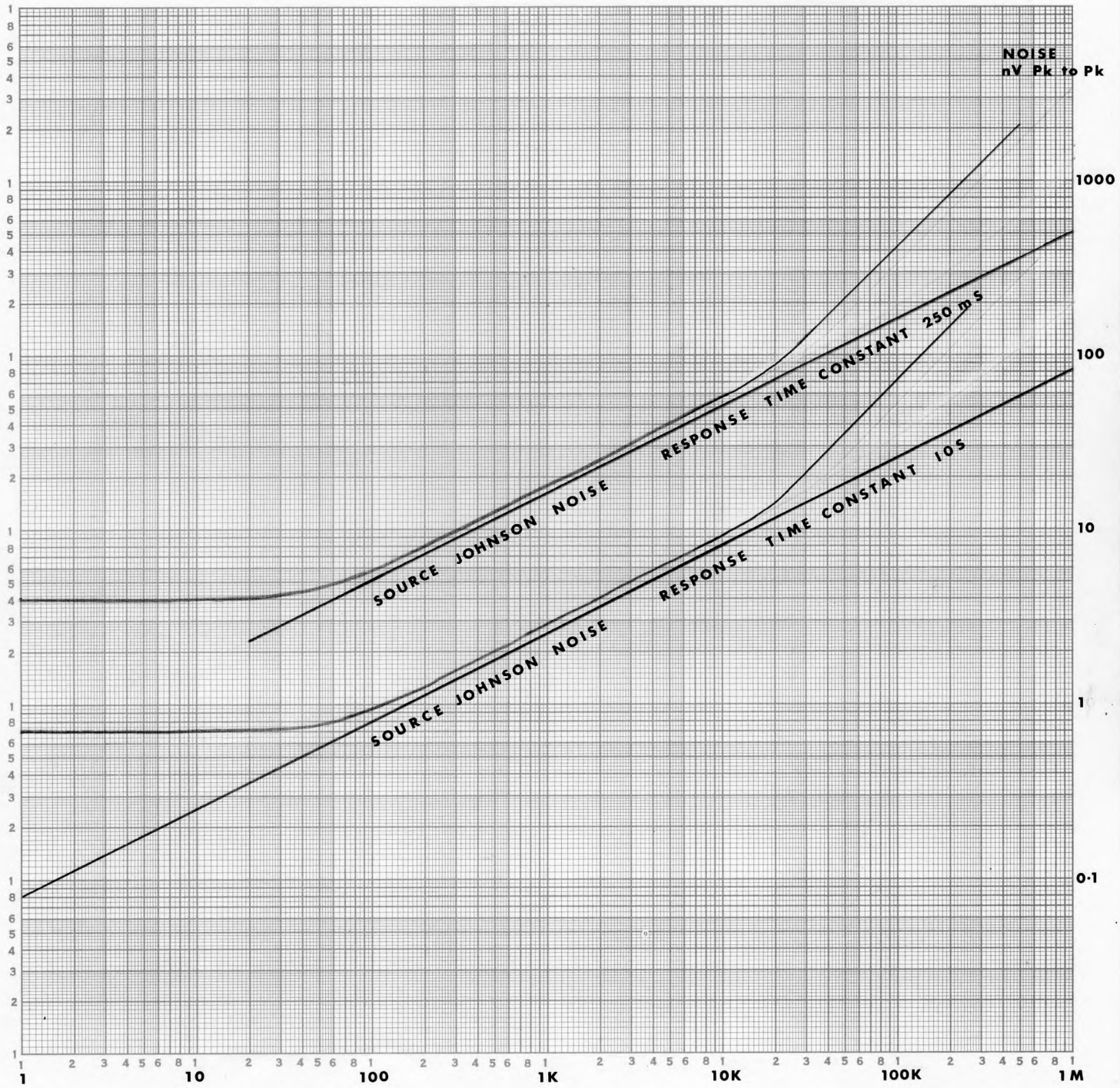
ISOLATOR 2c

NIa Response Time Constant (Seconds)

Range	Filter Position					
	1	2	3	4	5	6
ImV	0.25	0.7	I.3	2.5	5.0	IO
.3mV	0.25	0.7	I.3	2.5	5.0	IO
.ImV	0.25	0.7	I.3	2.5	5.0	IO
30uV	0.25	0.7	I.3	2.5	5.0	IO
IOuV	0.25	0.7	I.3	2.5	5.0	IO
3uV	0.25	0.7	I.3	2.5	5.0	IO
IuV	0.25	0.7	I.3	2.5	5.0	II
.3uV	0.3	0.9	I.5	2.7	6.0	I2
.IuV	0.4	I.I	I.8	3.2	7.0	I3
30nV	0.7	2.I	3.I	6.0	II	23
IOnV	I.5	3.I	5.5	II	21	40

EM D.C. NANOVOLTMETER MODEL NIa

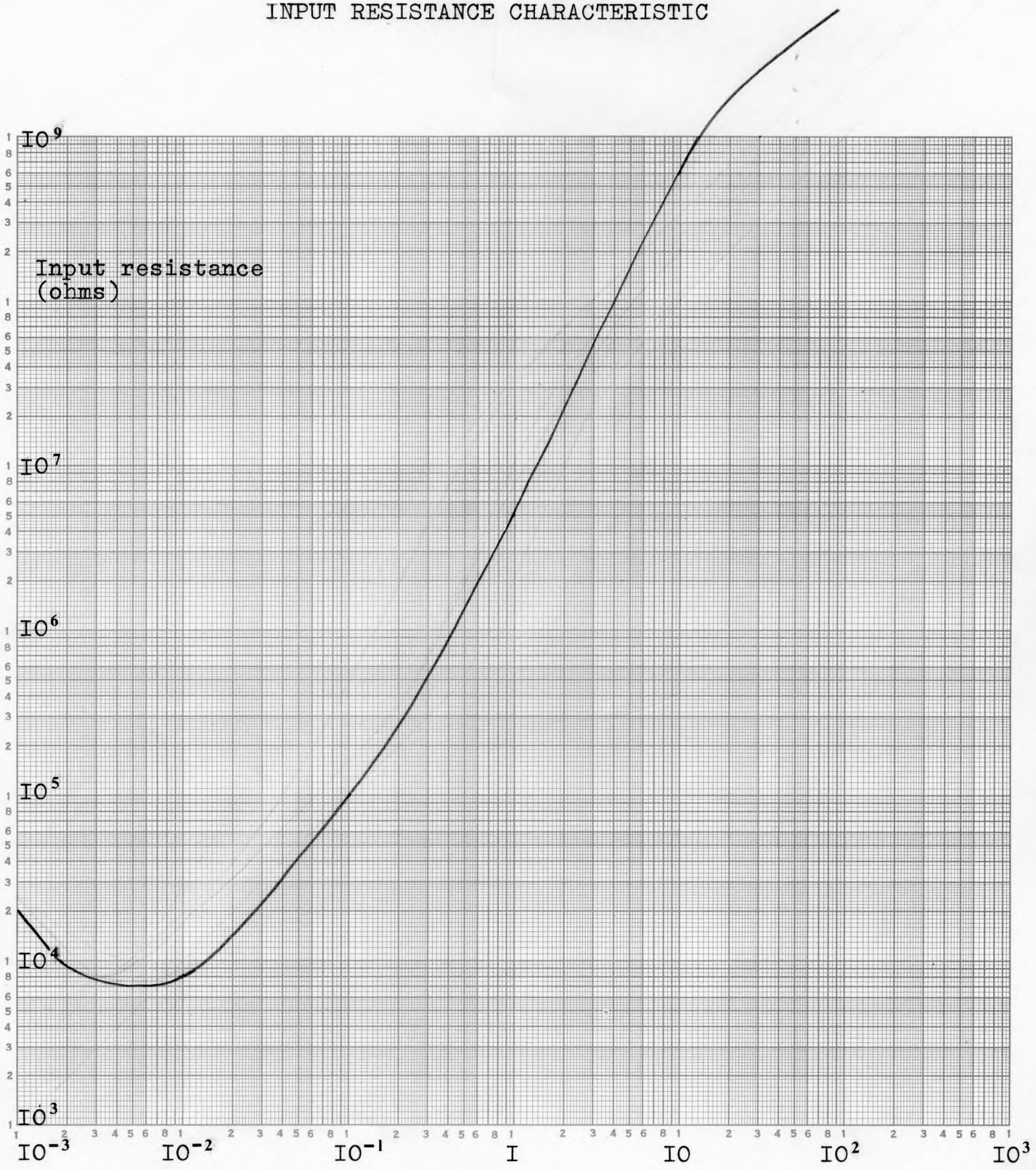
NOISE CHARACTERISTIC



SOURCE RESISTANCE (OHMS)

EM D.C. NANOVOLTMETER MODEL NIa

INPUT RESISTANCE CHARACTERISTIC



Time in seconds following an input step function