1 GENERAL INFORMATION

1.1 INTRODUCTION

The TF 2600 is a wide-range a.c. voltmeter of high sensitivity and stability; 12 ranges, giving full-scale deflections from 1 mV to 300 V, enable voltages down to the order of 100 μV to be measured.

An amplifier-rectifier type instrument, it maintains good accuracy with moderately distorted waveforms. A cathode follower input stage, with associated attenuators, regulates the signal level to a four-valve amplifier, the output of which energizes a moving coil meter via a full-wave crystal rectifier.

The meter is calibrated in terms of the r.m.s. value of a sinewave, but responds to the average value; it is also calibrated in decibels relative to 1 mW in 600 Ω, giving a range of -72 to +52 dBm.

The output of the amplifier section is made available at a pair of front-panel terminals. This provides a pre-amplifier facility, having a response similar to that of the instrument as a whole, with an output of up to 300 mV on any range.

APPLICATIONS

The extensive measurement range of this instrument makes it suitable for a considerable variety of applications. With the most sensitive range having a full-scale deflection of 1 mV, measurements of small a.c. voltages can be accurately accomplished. The frequency response of audio transducers such as microphones, gramophone pick-up and tape recorder heads can be easily determined using this voltmeter to monitor the output from the transducer direct. A pick-up loop connected to the voltmeter input enables relative field strength measurements to be made. It may also be used as a sensitive balance detector for a.c. bridges. The wide range and high accuracy of the attenuator together with the high input impedance of the voltmeter enable precise measurements of amplifier gain to be made.

1.2 DATA SUMMARY

Voltage Range :	0 to 300 V in 12 ranges, with full-scale deflections of 1, 3, 10, 30, 100, and 300 mV, and 1, 3, 10, 30, 100, and 300 V.
Frequency Range :	10 c/s to 5 Mc/s, with a useful response to 10 Mc/s.
Measurement Accuracy (at normal room temperature):	±1% of full scale, 50 c/s to 500 kc/s, ±2% of full scale, 20 c/s to 1 Mc/s, ±3% of full scale, 20 c/s to 2 Mc/s, ±5% of full scale, 10 c/s to 5 Mc/s. Variation with temperature 0.02% per °C up to a maximum working ambient temperature of 50°C.
Stability :	A variation of ±10% about nominal, with 40 to 400 c/s mains supplies, will cause the meter reading to vary by less than 0.2% for 50 c/s to 500 kc/s inputs. A similar reading variation will be caused by a ±5% change with 1000 c/s mains supplies. Additional error of less than 1% of full scale for measurements at or near mains supply frequency, or its second harmonic due to 'beating' effect.

Calibration :	The meter is calibrated in terms of r.m.s. value of a sinewave, but responds to average value. Also calibrated in decibels relative to 1 mW in 600 Ω, over the range -72 to +52 dBm.
Input Impedance :	10 MΩ, shunted by about 16 pF on 1 to 300 V ranges, and by about 30 pF on 1 to 300 mV ranges.
Amplifier Output :	Output on any range for full-scale deflection on meter, approximately 160 mV; max. output 300 mV. Output impedance 51 Ω.
Power Supply :	200 to 250 V and 100 to 130 V, 40 to 1000 c/s; 75 W. Mains input fused.

Dimensions & Weight:

Height	Width	Depth	Weight
8 in	$11\frac{1}{2}$ in	11 in	15 lb
(20.3 cm)	(29.2 cm)	(28 cm)	(6.8 kg)

NOISE ERROR

When the instrument is energized a meter deflection of a few percent will be observed. This is due to first circuit noise, and should not be backed off with the mechanical meter-zero as to do so would introduce a much greater error. The error only becomes significant when the applied signal is of the same order as the noise; for example, the table shows the error due to 2% circuit noise.

Signal (% of full scale)	100	50	30	10	5
Error (% of full scale)	0.02	0.04	0.067	0.2	0.4

To minimize the problem, work from the lowest possible signal source impedance, especially on the most sensitive ranges, and arrange leads to avoid extraneous interference pick-up.

OPTIONAL ACCESSORIES

Probe Lead, TM 5269: This is a low capacitance coaxial cable assembly 30 inches long, with a test prod and earth clip at one end and a Type 83 plug at the other. The input impedance is 16 pF.

A screened Adaptor, Type GE 51001 (TB 39867), is available that plugs into the input terminals of the Voltmeter and has a Type 83 socket to which the Probe Lead may be connected.

Another similar Adaptor, Type GE 51002 (TB 39868), with a BNC socket is also available.

2 OPERATION

2.1 CONNECTIONS

The mains lead is attached to the rear panel of the instrument. When fitting a suitable mains plug to it note that the earth (or chassis) conductor has a yellow designation sleeve with a green circuit earth symbol, the neutral conductor has a black sleeve with a white 'N' and the line (or phase) conductor has no sleeve.

Before connecting the instrument to the power supply check that the input tapping and the fuse rating are correct for the supply voltage available. If they are, plug into the supply and set the SUPPLY switch to ON; the pilot lamp should now glow. Allow up to 15 minutes warm up for normal measurements. For extreme accuracy when making comparative measurement allow at least 1 hour for the instrument to reach thermal equilibrium.

Connection to the source of voltage to be measured or amplified is made via the INPUT terminals on the front panel of the Voltmeter. In many instances a pair of unscreened leads will be quite adequate for this purpose. However, at high frequencies and at low voltage levels a screened lead will be necessary if mains hum and other spurious pick-up are not to be introduced with the wanted signal. The unscreened ends of the lead should be kept as short as possible, the screen being connected to the earth (or chassis) terminal.

A convenient form of low capacitance screened lead assembly that is available is the Probe Lead, type TM 5269. It is connected to the INPUT terminals via a screened Adaptor as described under Optional Accessories in the Data Summary. The other Adaptor, with a BNC socket, enables direct connection to be made via a coaxial cable to many instruments that use this standard type of connector.

Despite observance of the precautions implied above, hum interference may still be encountered in some situations. Consideration should then be given to the earthing, particularly mains earthing, of both the equipment under test and also the Valve Voltmeter. If each has an individual mains earth, then there is the possibility that circulating currents will flow round the loop which is completed by the signal input connections to the Valve Voltmeter. In these circumstances a great improvement in conditions can generally be obtained by ensuring that there is only one connection to mains earth when the equipment under test and Valve Voltmeter are considered together as a single system.

CAUTION : When measuring an a.c. voltage superimposed on a d.c. supply, the sum of the d.c. and peak a.c. voltages should not exceed 500 V.

2.2 METER READABILITY

The large-scale meter is provided with an anti-parallax mirror to facilitate accurate readings. For further convenience a hinged support is fitted to the under-side of the case, enabling the front of the instrument to be raised so as to present the meter at an improved viewing angle.

Note : It should be remembered that rough handling of the instrument may be detrimental to the high accuracy of the meter.

2.3 VOLTAGE MEASUREMENT

The TF 2600 is suitable for measuring unbalanced a.c. voltages in the frequency range 10 c/s to 10 Mc/s. Measurements may be made from less than 100 µV up to a maximum of 300 V in 12 ranges as follows :-

(1) Set the RANGE switch to the nearest range full-scale above the expected voltage level. If the level is not known, set it to the highest range.

(2) Connect the Voltmeter to the voltage source as described in Section 2.1.

(3) If necessary, alter the setting of the RANGE switch to give a meter deflection in the upper two-thirds of the scale.

(4) Read the voltage from the meter scale, and apply the multiplying factor, appropriate to the setting of the RANGE switch.

Both the meter and the RANGE switch have an auxiliary decibel calibration in red. The decibel values are with respect to 1 mW in 600 Ω, i.e., 0 dBm corresponds to 0.775 V. The value of a voltage being measured is related to this datum by taking the algebraic sum of (i) the meter reading on its red decibel scale and (ii) the decibel marking indicated by the RANGE switch.

The decibel calibrations on the Voltmeter can, of course, be used when the voltage being measured is developed across an impedance other than 600 Ω, although the relationship to 1 mW is no longer valid. Provided the source impedance remains the same the difference in dB between two measurements is obtained by algebraically subtracting the decibel scale readings. They are of particular value when relative levels in successive measurements are the main concern; for instance, when determining amplifier or filter response characteristics. The decibel conversion table, included at the end of this handbook, will also be useful in this respect.

2.4 DISTORTED WAVEFORMS

The meter responds to the average value of the voltage under test and is calibrated in terms of the r.m.s. value of a sinusoidal input. Waveform distortion has little effect on meter reading accuracy. From Table 2.1 it will be seen that even with the extreme examples of square and triangular waveforms the inaccuracy of the r.m.s. value does not exceed 10%.

The true r.m.s., average or peak value in each case is obtained by multiplying the meter reading by the appropriate factor.

TABLE 2.1

	RMS Value	Average Value	Peak Value
Sinusoidal Waveforms	Correct Reading	Reading x 0.9	Reading x 1.414
Square Waveforms	Reading x 0.9	Reading x 0.9	Reading x 0.9
Triangular Waveforms	Reading x 1.04	Reading x 0.9	Reading x 1.8

2.5 USE AS A WIDE-BAND AMPLIFIER

The output of the amplifier section of the instrument is made available at a pair of front-panel terminals. This provides a convenient preamplifier facility which may be used to extend the sensitivity of other equipment such as cathode-ray oscilloscopes and pen recorders. The response of the amplifier is similar to that of the voltmeter as a whole, and the output available is approximately 160 mV for full-scale deflection on any range, with a maximum of about 300 mV when f.s.d. is exceeded.

Since the voltage input to the amplifier section is maintained at the same level for each range by an attenuator the output will also be the same. At low signal levels in the amplifier some waveform distortion occurs; in order to minimize this distortion, together with any hum and noise, the meter indication should be kept above one-third full scale by using the RANGE switch. The output impedance is 51 Ω.

If voltmeter readings are being observed while using the amplifier output, check for any error resulting from the output connections by temporarily disconnecting them.

3 TECHNICAL DESCRIPTION

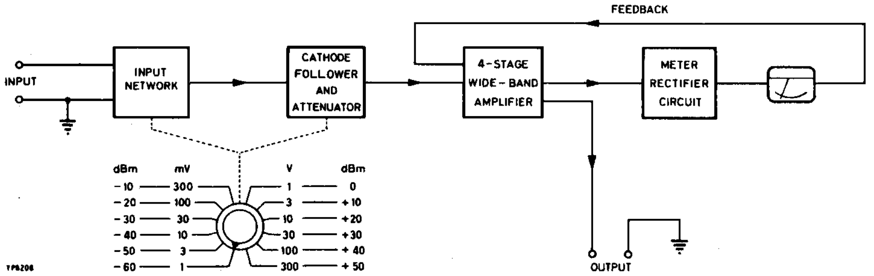
It is suggested that the following sections be read in conjunction with the Circuit Diagram included at the end of this handbook.

3.1 INPUT CATHODE FOLLOWERS AND ATTENUATORS

Fig. 3.1 shows a Block Schematic Diagram of the Voltmeter. The circuit consists of a cathode follower input stage feeding a four-valve amplifier, the output of which energizes a moving-coil meter via a full-wave crystal rectifier.

The input cathode follower is used to provide a high input impedance. It is preceded by an attenuator that reduces the input by 60 dB on ranges above 300 mV. This attenuator comprises a 10 MΩ carbon film high stability resistor, R2, with compensating capacitors C10 and C3, and resistors R3, RV1, and thermistor TH1, used to match the temperature coefficient of R2. Above about 10 kc/s the attenuation is determined by the capacitors C10, C3 and C4. Resistors R5, R67 and R68 in parallel are added to damp out any series resonance effect at 5 Mc/s due to residual inductance.

The output of the cathode follower is fed to another compensated attenuator which, in conjunction with the first attenuator, maintains a constant input to the amplifier section for each voltage range. This second attenuator is made up of special close tolerance wire wound resistors to minimize switching errors between ranges. The high accuracy of the attenuators enables the measurement of gain in amplifiers to be made with precision.



3.2 AMPLIFIER

The four-valve R-C coupled amplifier, V2 to V5, employs a system of staggered time constants so that the required overall response is achieved without recourse to stage-by-stage corrective feedback. This system gives a controlled fall-off in gain at the extremities of the frequency range without excessive phase shift (see Fig. 3.2). The amplifier gain, however, is controlled by overall negative feedback taken from the meter rectifier circuit and applied to the cathode of the first amplifier valve. This is adjusted by RV4 to give correct meter indication for a standard signal.

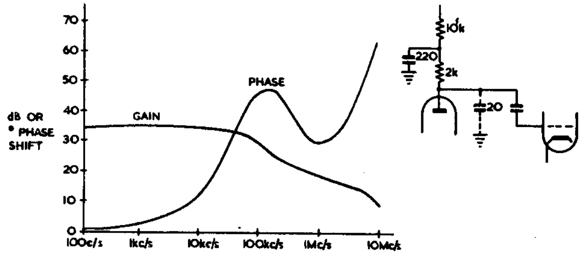


Fig. 3.2 Gain and Phase Shift curves of a typical amplifier stage.

The low-frequency response is controlled by RV2 and RV5; RV2 setting the phase shift and RV5 the gain. These two interact, and correct adjustment will give the required response down to 10 c/s whilst giving good meter damping at the lowest frequencies.

Phase shift at high frequencies is controlled by the valve capacitances, and also by L1, L2 and C28 in the feedback network. The bias for V3, V4 and V5 is set by RV3 to even out effects of valve variations, a nominal setting of +3 V is used with slight adjustments to suit the h.f. response.

The amplifier output is made available at a pair of front-panel terminals, giving approximately 160 mV for full scale deflection on any range. The output is taken from across a 51 Ω resistor in the cathode circuit of V5.

3.3 METER RECTIFIER

The output from V5 anode is applied to a full-wave bridge comprising two silicon diodes and two capacitors. Each diode conducts on alternative half-cycles, and the capacitors are continually discharged by the meter to give average level rectification. At the crossover point neither diode conducts properly, and their impedance is very high. Since the amplifier feedback voltage is taken from the rectifier circuit this non-linearity will cause some waveform distortion in the amplifier output. This distortion, together with any hum and noise, will be minimized by keeping the signal level in the amplifier of sufficient amplitude to give a meter deflection above one-third full scale.

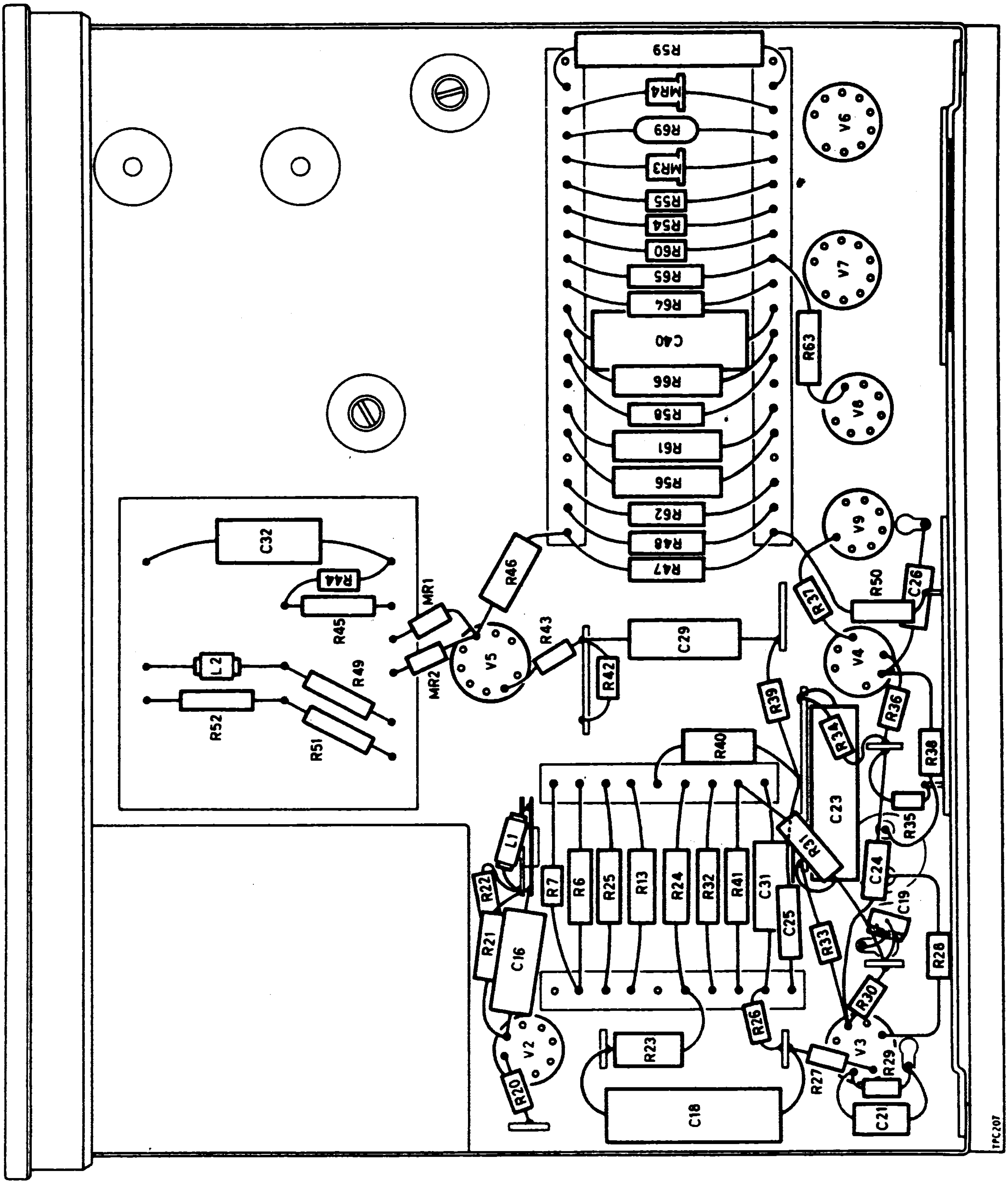
3.4 INTERNAL POWER SUPPLIES

Good stability of meter indication is ensured by the use of a series-valve stabilizer circuit to regulate the h.t. supply for the instrument. The heater supply for the cathode follower and first three amplifier valves is rectified, smoothed, and fed to the heaters in a series-parallel connection in order to minimize hum pick-up in the valves. The heater supply for the h.t. regulator valves is biased positively to reduce the heater-cathode voltage to a safe level.

The mains transformer has been given a generous-sized core and has been specially orientated so that a minimum amount of mains hum is induced into the circuit.

4.1 ACCESS AND COMPONENT LAYOUT

The main case assembly is clamped to the front-panel frame by the rear case panel. This panel may be removed after unscrewing the two centrally located knurled-head screws, and the main case then separated from the chassis. This gives access to all components except those on the 60 dB input network board. The input network is made available by removing the small cover on the bottom of the instrument.



SUPPLY VOLTAGE PANEL

Masking plate and links must be positioned according to supply voltage, as shown :-

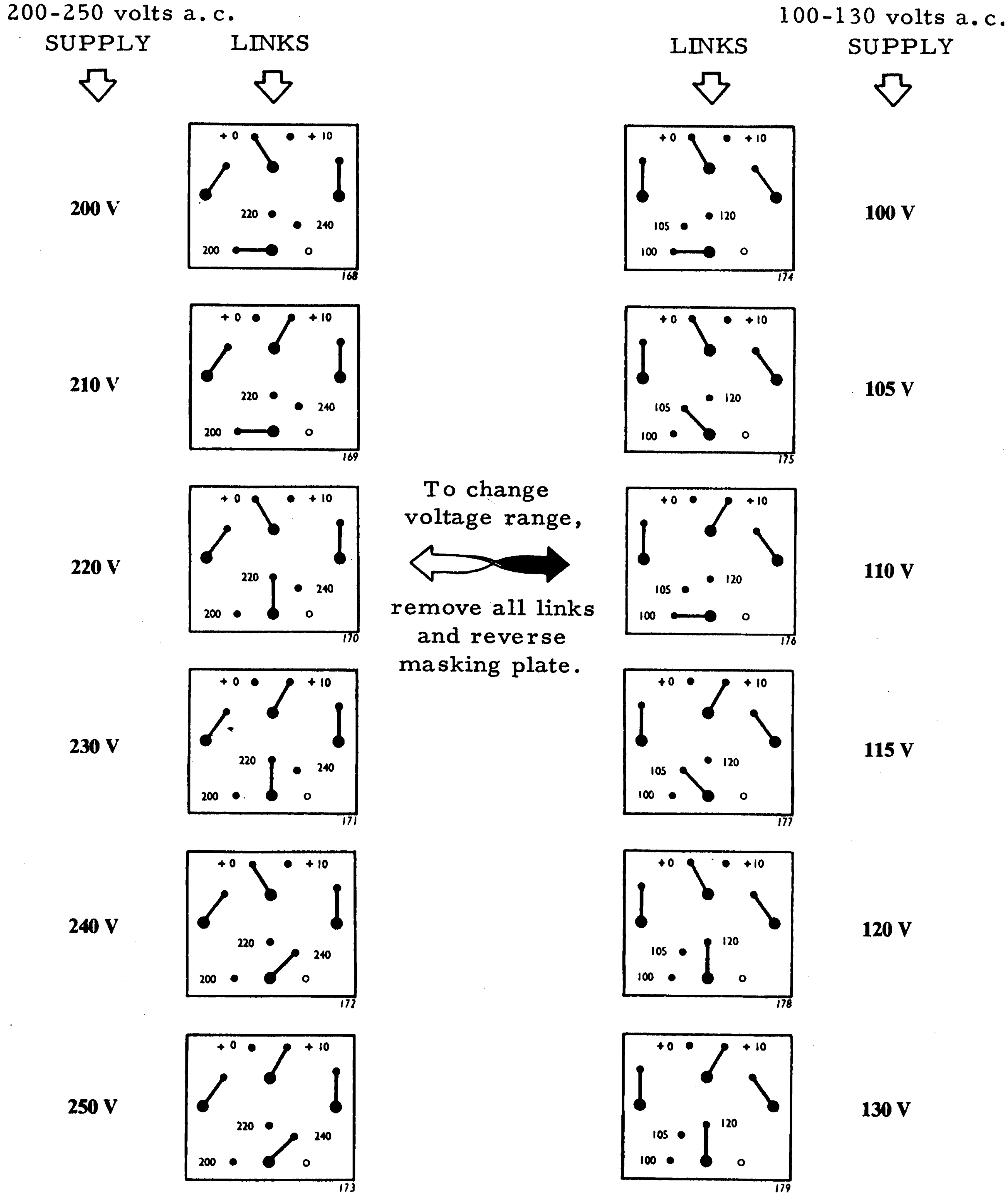
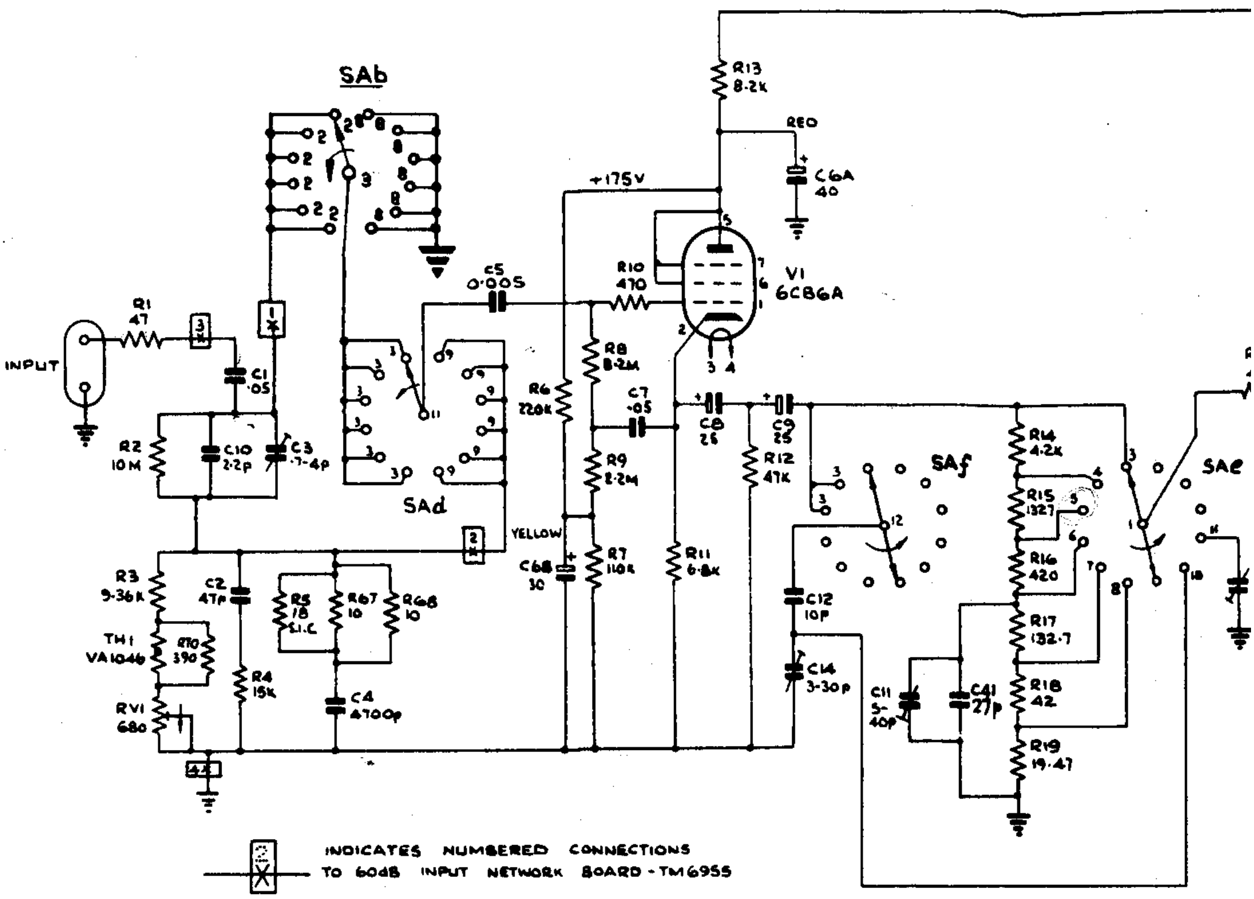


Fig. 4.2 Supply Voltage Plug Settings



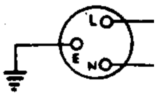
NOTES

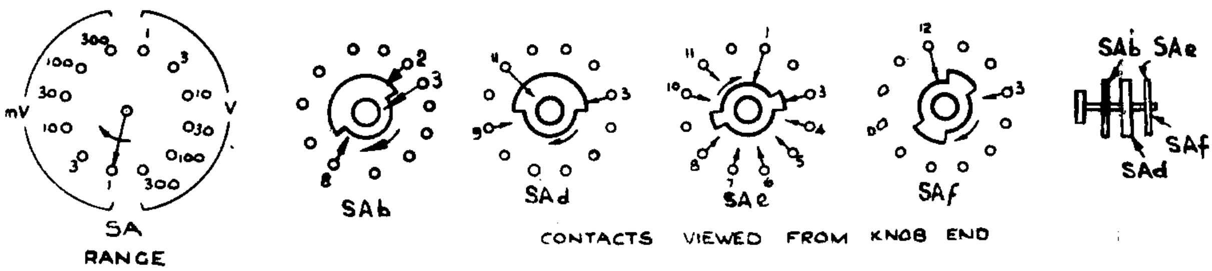
1. COMPONENT VALUES

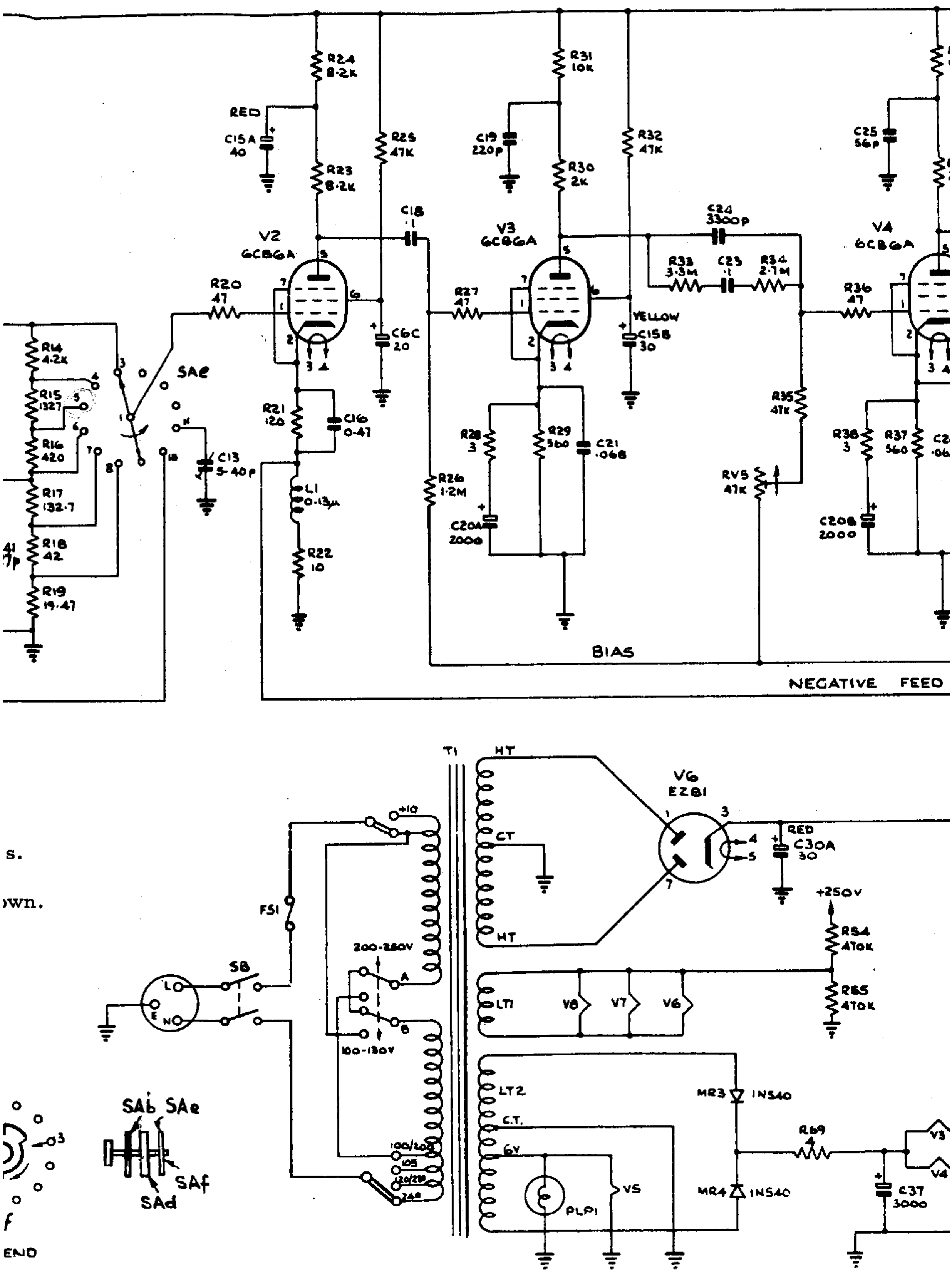
Resistors: No suffix = ohms. k = kilohms. M = megohms.
Capacitors: No suffix = microfarads. p = picofarads.
SIC: Value selected during calibration; nominal value shown.

2. SYMBOLS

↑ arrow indicates clockwise rotation of knob.






R24
8·2K
RED
C15A
40
R25
47K
R23
8·2K
C18
·1
V2
6CBGA
R20
47
C6C
20
R14
4·2K
R15
1327
R16
420
R17
132·7
R18
42
R19
19·47
SAe
C13
5-40P
R21
120
C16
0·47
L1
0·13μ
R22
10
R26
1·2M
R31
10K
C19
220P
R32
47K
R30
2K
V3
6CBGA
R27
47
YELLOW
C15B
30
R28
3
R29
560
C21
·068
C20A
2000
C24
3300P
R33
3·3M
C23
·1
R34
2·7M
R35
47K
RV5
47K
V4
6CBGA
C25
56P
R36
47
R38
3
R37
560
C20B
2000
BIAS
NEGATIVE FEED
T1
HT
CT
V6
EZ81
RED
C30A
30
+250V
R54
470K
R55
470K
+10
FS1
SB
200-250V
100-130V
LT1
V8
V7
V6
LT2
C.T.
6V
PLP1
VS
MR3
1N540
MR4
1N540
R69
4
C37
3000
V3
V4
105
240
SAb
SAe
SAf
SAd
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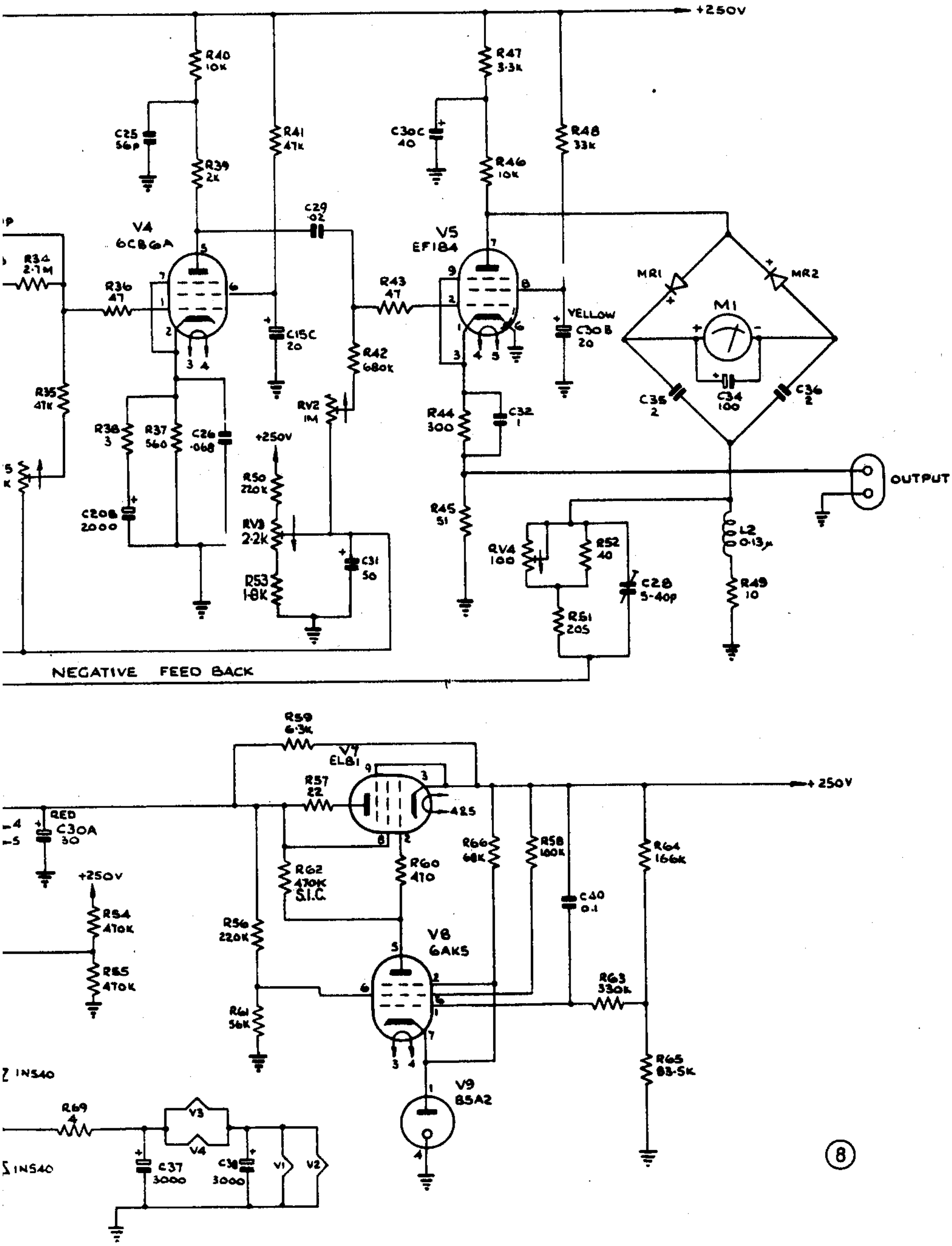

SENSITIVE VALVE VOLTMETER

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