PORTABLE OSCILLATORS *(continued)*

PTS/10

The PTS/10, which was developed for use by Lines Department, is a battery-operated portable oscillator with continuously-variable frequency, from 25 c/s to 15 kc/s approximately. It has three different output impedances, 75, 300 and 600 ohms, and a number of output levels in discrete steps up to a maximum of + 12 db with 1 per cent distortion. The instrument is thus suitable for use over the complete range of line tests, the only limitation on its performance being the necessity to avoid long periods of continuous duty because of the small size of the self-contained batteries.

The oscillator employs a resistance-capacitance frequency-controlling network which takes the form of a Wien bridge, and is connected between the output and input of a two-valve amplifier whose gain and phase characteristics are stabilsed by negative feedback. The generated signals are maintained at a level well within the handling capacity of the amplifier by the inclusion in the bridge network of a lamp whose resistance varies steeply with current. The frequency of oscillation is controlled in each range by varying the resistive elements of the bridge, and the range required is selected by switching the capacitive elements. The three ranges are:—(1) 25 c/s to 250 c/s, (2) 250 c/s to 2·5 kc/s, and (3) 2·5 kc/s to 15 kc/s approximately, above which frequency the level rapidly falls off.

The single-valve output stage feeds into one arm of a resistance bridge, the load being connected across one of the bridge diagonals. The e.m.f. of the generator is measured across the other diagonal; with this arrangement the value of load impedance does not affect the generator e.m.f. ,and the measuring instrument is left continuously in circuit while testing.

Power is supplied to the oscillator via a non-locking plunger-key which prevents unnecessary drain on the batteries; these latter are mounted as a separate unit and can be replaced without disturbing the rest of the instrument. The three valves employed are all of the same type, and a spare is provided. The total weight of the oscillator in its attaché type carrying case is about 23 lb.

Principles of Operation

General

A simplified diagram of the PTS/10 is given in Fig. 9.4 and the complete circuit in Fig. 20.

The output of the two-stage amplifier, V1, V2, is coupled back to the input through the Wien bridge, in one arm of which is a lamp with a non-linear current/voltage characteristic. The phase-shift through the amplifier is approximately 180 degrees per stage, or altogether about 360 degrees, while the bridge introduces zero phase-shift between the amplifier output and input at a frequency fixed by the component values. Positive feedback therefore takes place at around this frequency, and provided that the gain in the amplifier is sufficient to offset the loss in the bridge, oscillations are generated.

Due to the presence of the lamp, the loss occurring in the bridge is dependent upon the value of the applied voltage, and thus, for a certain gain in the amplifier, the circuit may be adjusted so that the oscillations are maintained at an amplitude which can be handled without an undue amount of distortion. If the oscillation amplitude tends to alter for any reason, the loss in the bridge also alters and tends to compensate for the change; the output therefore remains sensibly constant in spite of any variations which may occur in the circuit external to the bridge.

The oscillatory voltage at the anode of V2 is applied to the grid of the output valve, V3, and thence via a resistance bridge, used for level calibration, and a variable attenuator to the output terminals of the oscillator.

The full mathematical details relating to the design of the frequency-control and output networks are contained in Lines Department Report No. 81.1. A simplified treatment of the Wien bridge is given below.

Wien Bridge

This bridge has two adjacent arms containing resistance only, and two containing resistance together with capacitance. Referring to Fig. 9.3 the resistive arms consist of the fixed-value resistor R_5 and the non-linear resistance RL provided by the lamp. One of the reactive arms comprises a resistor in series with a capacitor and the other a resistor in parallel with a capacitor; the values of these elements, denoted by R and C, are kept the same for both arms at all frequency settings.

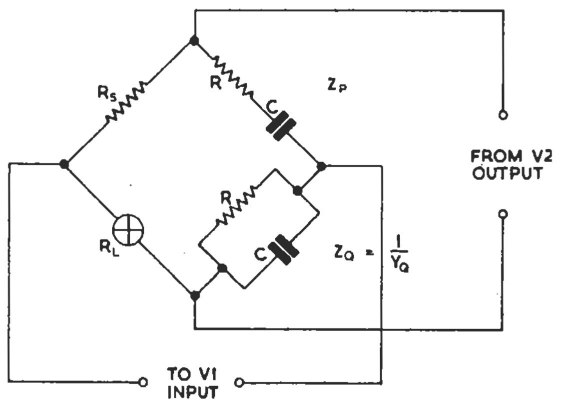


Fig. 9.3. Wien Bridge incorporating Lamp Resistance

When employed as a frequency-controlling unit the bridge operates very near balance, and it is therefore useful to investigate the condition under which balance obtains. If the branches containing reactance are denoted by P and Q then, in the notation of Fig. 9.1, the balance condition is:

$$\frac{R_5}{R_L} = \frac{Z_P}{Z_Q}$$
$$= Z_P.Y_Q$$
$$= (R - j/\omega C)(1/R + j\omega C)$$
$$= 2 + j(\omega CR - 1/\omega CR).$$

Separating the equation into its real and imaginary parts,

$$\frac{R_5}{R_L} = 2, \text{ and}$$

$$\omega CR - 1/\omega CR = 0.$$

Whence

$$\omega^2 = \frac{1}{C^2R^2}$$

and since the frequency f is equal to $\omega/2\pi$,

$$f = \frac{1}{2\pi RC.}$$

It follows that, providing R_5 has twice the resistance of the lamp, balance occurs at a frequency $1/2\pi RC$. (See also page A.1.)

Circuit Description (Fig. 20)

Oscillator Amplifier

This unit comprises V1 and V2. V1 is an l.f. pentode, connected as a high-gain amplifier with a resistive load, and is capacitance coupled to V2. In order to stabilise the gain and to minimise the distortion produced for a given output power, negative feedback is applied to V2 via R11. A transformer, T1, in the anode circuit of V2 steps down the valve impedance to approximately 40 ohms, with a phase-angle varying with frequency. The gain from the grid of V1 to the secondary of T1 is about 26 db.

The filaments of V1 and V2, taking 100 mA each, are connected in parallel and are supplied from a single 1·5-volt cell. Except for the p.d. across the filament, no negative grid bias is applied to V1. V2 is biased by R18 de-coupled by C12.

Frequency-determining Network

In explaining the action of this network, it will first be supposed that the lamp constituting a non-linear resistance is replaced by a normal linear resistor of value half R5. Under these circumstances the bridge is in balance and has zero output at a frequency, $f_o = 1/2\pi RC$, where R and C are the resistance and capacitance in each reactive arm. In addition, when the bridge is balanced, its phase-shift is zero.

If the resistance replacing the lamp is now reduced by a small amount, there will be a certain definite output from the bridge, approximately zero phase-shift through the network being still maintained. When an amplifier of suitable gain and zero phase-shift is connected between the output and input of the bridge, oscillations are set up at a frequency of approximately f_o. The phase-shift through the bridge increases very rapidly as the frequency changes from $1/2\pi RC$, and hence the effect of changes in phase external to it is kept small; a further advantage is that harmonics of the oscillatory frequency are fed back in a negative sense, and are thus reduced in amplitude.

If the lamp is now restored, an exactly similar condition can be set up by a suitable adjustment, with the added advantage that the circuit now tends to maintain the oscillations at a pre-determined fixed level. The reason for this can be explained by considering a possible increase in the amplitude of the oscillations due, say, to an increase in the gain of the amplifier. More current then passes through the lamp, whose resistance increases, bringing the bridge nearer balance and increasing its loss, and thus tending to maintain the oscillations at their original amplitude. Similar compensation occurs for a decrease in amplitude.

In the PTS/10, the Wien bridge consists of R1, R2, R3, R4, C1-C6, R5 and the lamp. R1 and R2 are ganged wire-wound 100-kilohm variable resistors. The fixed resistors, R3 and R4, are connected in series with R1 and R2 in order to limit the minimum values of these latter to 6 kilohms. A ten-to-one frequency change is available by varying R1 and R2, with an adequate overlap between the three frequency ranges, which are selected by switching the capacitances C1-C3 and C4-C6 in the reactive arms.

The lamp is a 6-v P.O. switchboard type No. 2 manufactured by Ediswan, and other makes of lamp must not be used; due to its very robust construction and the low temperature at which it operates it is unlikely to require replacement, and is therefore soldered directly in the circuit. Since the temperature of the lamp does not vary over the time occupied by a half-cycle at any of the frequencies generated by the oscillator, the lamp resistance depends on the r.m.s. value of the current flowing, and the lamp does not therefore introduce distortion.

Output Stage

The output valve, V3, is an l.f. pentode of the same type as those used in the oscillator amplifier. The filament supply is from a separate 1·5-volt cell and the bias is obtained by means of R22 de-coupled by C15. To obtain a satisfactory frequency response and the required output level with low harmonic distortion, negative voltage feedback is applied between the anode and grid of V3 via R20 and C14. The grid of the valve is fed from the anode of V2 through a level-control R34 and a fixed resistor R50; the purpose of this fixed resistor is to make the degree of negative feedback independent of the level-control setting, and also to ensure that variations in the input impedance of V3 do not affect the oscillatory frequency. The transformer T2 in the anode circuit of the valve is connected to give an output impedance of 300 ohms. The value of C14 is adjusted on test to compensate for a tendency towards a fall in output level at the extreme lower frequencies.

Output Networks

There are two resistance networks between the secondary of the output transformer and the output jack and plug (which are in parallel). The first is a straightforward square-type attenuator with three loss settings: 0 db, 4 db and 8 db. The second is a network consisting of a resistance bridge and appropriate resistors for changing the output impedance.

The bridge (Fig. 9.2) which is formed by the resistors R43, R44, R45 and the resistance seen looking back toward the secondary of transformer T2, acts like a hybrid transformer in that the power delivered to an external circuit connected across one diagonal is independent of the power delivered across the other, provided that the resistance ratio between the pairs of adjacent arms is the same for opposite pairs. Unequal arms are used, making the loss through the bridge from T2 to the output jack 2 db, and the loss to the meter rectifier 13 db. With the arrangement employed the reading of the meter is proportional to the output e.m.f. of the oscillator and is independent of the load conditions.

Both the output attenuator and the bridge work at an impedance of 300 ohms. On the first. setting of the output switch, an additional resistor, R46, is connected in parallel to give an output impedance of 75 ohms. The e.m.f. of the generator is adjusted so that when the meter is reading mid-scale a power of 1 mW is delivered by the oscillator when a 600-ohm load is connected to the output terminals. In the second position of the output switch the bridge remains in circuit, but the parallel resistance is replaced by a balanced-L pad which raises the output impedance to 600 ohms, and is of such a value that for the same generated e.m.f. a power of +4 db above 1 mW is delivered when a 600-ohm load is connected. In the third position of the output switch the bridge is cut out of circuit and the transformer secondary connected directly to the output terminals. In this condition the oscillator will deliver + 12 db into a 300-ohm load from an output impedance of 300 ohms.

The reason for the choice of an output impedance of 300 ohms is that a suitable transformer, Type AL/13R, is easily obtainable, enabling the oscillator to deliver its maximum power. It is considered that since the impedance of a line at 100 c/s and 1 kc/s will rarely fall below 300 ohms, an oscillator which will establish a power level of + 12 db in that impedance will be adequate for giving a reasonable measure of overload on the line. Reflection loss, due to the impedance of the line being higher than 300 ohms, is small provided that the line impedance does not exceed 1 kilohm the reflection loss with a 600-ohm line, for example being 0·5 db. In using the oscillator, it is important

600 ohms, + 4, 0, −4 into 600 ohms.

The fourth setting of the output switch connects an earth loop to the output jack and plug. Two line jacks are provided, each also connected to terminals, so that the standard method of taking d.c. measurements may be employed.

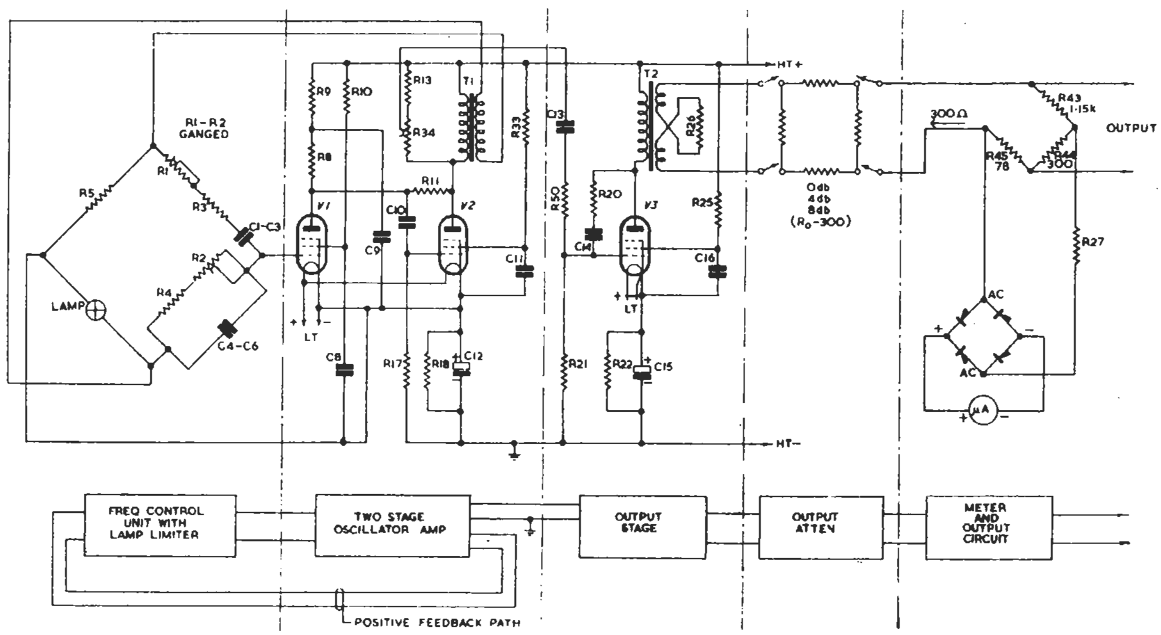


Fig. 9.4. Portable Oscillator PTS/10 : Simplified Circuit

to remember that when sending + 12 db the meter is out of circuit, and the level should therefore be adjusted on either of the two lower settings and the switch then turned to the + 12-db setting.

Since the output attenuator is connected between the e.m.f. and its measuring circuit, the e.m.f. must always be adjusted with the output attenuator set to zero. The output levels and impedances available are then :—

75 ohms, 0, −4, −8 into 600 ohms.
300 ohms, + 12, 8, 4 into 300 ohms

Metering Arrangements

The meter, which has a 200-microamp movement, is inserted at various points in the circuit as required by means of the 6-position meter switch, S3. In the first position of the switch, the meter is connected to the d.c. output of the instrument-rectifier across the output bridge, and therefore reads the tone level. In the second position the meter is connected, through an appropriate resistance, to measure the voltage of the cell supplying the filaments of V1 and V2.

In the third position the voltage of V3 filament cell is similarly measured, and in the fourth the h.t.-battery voltage. In the fifth position the anode plus screen current of V1 and V2 is measured, the current in mA being given by the meter reading multiplied by 5. In the sixth position the anode and screen current of V3 is measured, the current in mA being equal in this instance to the meter reading multiplied by 2·5.

NOTE.—The multiplying factors shown on the face-plates of early models for positions 5 and 6 of S3 were incorrectly given as 4 and 2. Since the meters and metering circuits on all models are identical, these markings on the early models must be ignored.

Frequency Accuracy

Apart from the stability of the components forming the reactive arms of the Wien bridge, there are two factors which affect the frequency accuracy of the oscillator, one being the replacement of a valve, the other a change of filament or anode voltage. The components of the bridge are estimated to have a stability of within 1 per cent or better throughout the range of temperatures likely to be encountered under the conditions in which the oscillator will be used.

Replacing a valve may change the frequency because the varying input and output impedances which different valves possess affect the phase-shift in the amplifier; this trouble is more likely to be serious at the higher frequencies, since valve impedances become lower with increasing frequency. On the frequency ranges 25 c/s—250 c/s and 250 c/s—2·5 kc/s, a change of valve has negligible effect. On the 2·5-kc/s to 15-kc/s range changing V2 has negligible effect, but changing V1 may occasionally produce a frequency variation of as much as 1 per cent at 10 kc/s, although the variation resulting from changing this valve is in general much smaller.

Changes of h.t. and l.t. voltage over the normal range occurring during the life of the batteries, i.e., h.t. from 135 V to 110 V, and l.t. from 1·5 V to 1·25 V, have negligible effect on frequency on ranges (1) and (2). On range (3) at 10 kc/s an h.t.-voltage change of 10 per cent causes a frequency drift of 0·5 per cent, the drift at lower frequencies being proportionately less.

Valve Data

Valve	*H.T. Feed Current mA*	*Fil. Volts*	*Fil. Amps*
Stage 1 DL35	1	1·4	0·1
Stage 2 DL35	3·7	1·4	0·1
Stage 3 DL35	2·7	1·4	0·1

Power Supplies

H.T. supply, 135 V (from three 45-V batteries).
L.T. supply, 1·5 V (from two separate cells, one for V1 and V2 and the other for V3).

General Data

Frequency Ranges

Nominal ranges, ignoring overlaps.
(1) 25 c/s to 250 c/s.
(2) 250 c/s to 2·5 kc/s.
(3) 2·5 kc/s to 15 kc/s approx.

Output Impedances

Selected by output switch S1.
75 Ω, 300 Ω or 600 Ω.

Output Levels

Selected by output-attenuator switch S2, and also dependent upon setting of output switch S1 and on load impedance.

Output Impedance ohms	*Ouput Attenuation db*	*Load Impedance ohms*	*Output Level db*
75	0	600	0
	4		− 4
	8		− 8
300	0	300	+ 12
	4		+ 8
	8		+ 4
600	0	600	+ 4
	4		0
	8		− 4

Potentiometers

Frequency control (R1, R2): Reliance dual ganged, Type TW. Resistance of each half, 100 kΩ.
Level control (R34): Morganite Stackpole, Type LHNAP 10410 24000. Resistance 100 kΩ.

Switches

Output (S1): Plessey rotary Type A.
Output attenuator (S2): Plessey rotary Type B, 4-pole 3-way.

Meter (S3): Plessey rotary Type B, 2-pole 6-way
Range (S4): Plessey rotary Type B, 3-pole 4-way.
On-off plunger key: P.O. No. 229 (black).

Meter
200-μA movement. E.D. 1467

Metal Rectifier
Westinghouse instrument-type, 1 mA.

Lamp in Bridge Circuit
6 V P.O.-switchboard type, No. 2. *Ediswan only.*

Batteries
Housed in detachable battery unit.
H.T. supply: 135 V, obtained from three 45-V Ever Ready deaf-aid batteries, Type B102, connected in series.
L.T. supplies: 1·5 V, obtained from two Siemens 'S' cells, one for V1 and V2, the other for V3.

Dimensions and Weight
Oscillator in carrying case.
Depth: 7⅛ in.
Length: 16½ in.
Width: 10¾ in.
Weight: 23 lb.

Test Data

Output-level/Frequency Characteristic
From 50 c/s to 10 kc/s: ± 0·2 db with respect to response at 1 kc/s.

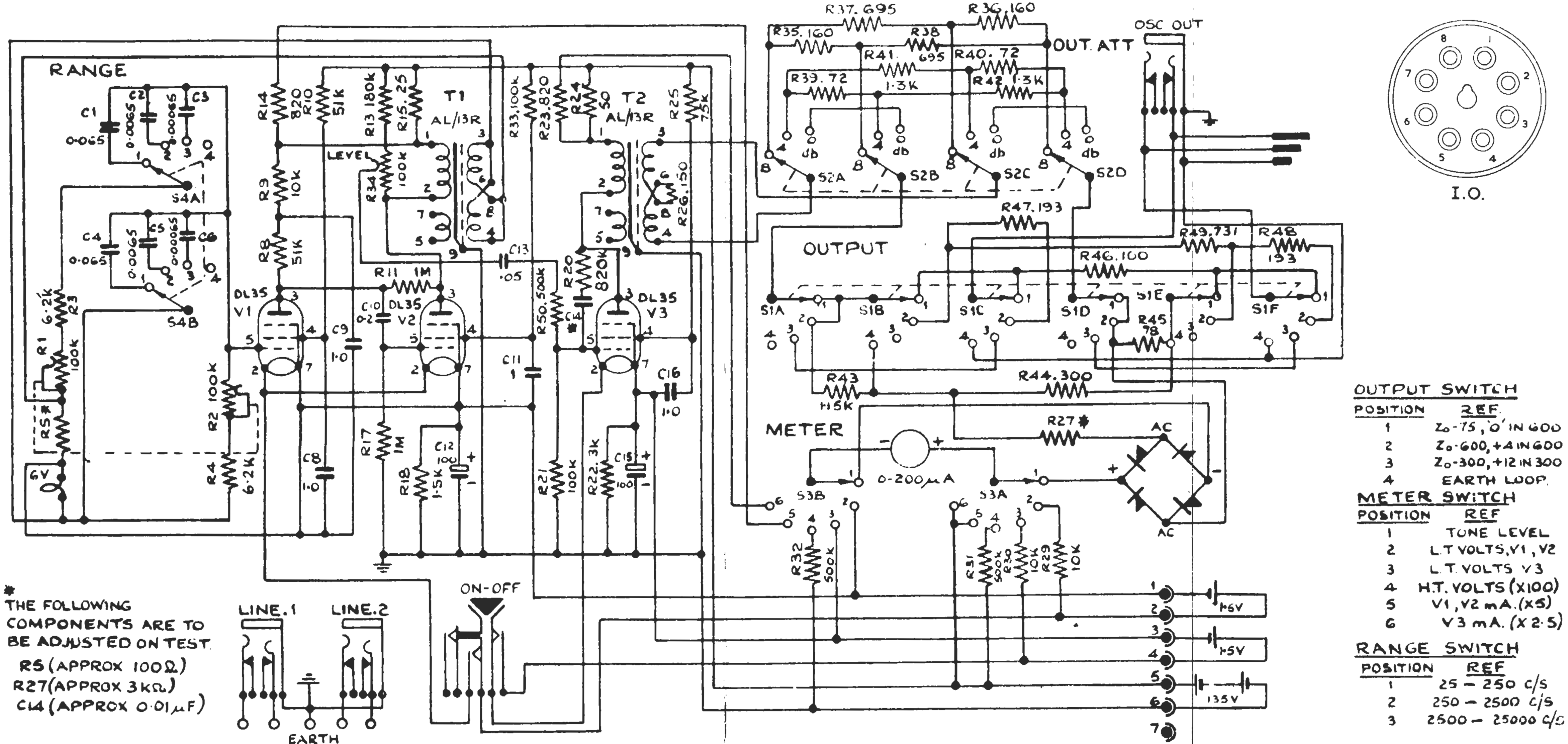
Accuracy of Ouput-level Setting
Absolute accuracy: within ± 0·3 db of nominal setting.
Relative accuracy (i.e. variation with frequency) ± 0·1 db between 50 c/s and 10 kc/s.

Accuracy of Output-impedance Setting
75- Ω and 600- Ω settings: within ± 2 per cent of nominal.
300- Ω setting: within ± 4 per cent of nominal.

Total Percentage Harmonic Distortion
All output levels and impedances.

Frequency	*Distortion*
50 c/s	3% approx.
100 c/s	< 2%
1 kc/s	< 1%
7 kc/s	1% or less.

See also Appendix A.



* THE FOLLOWING COMPONENTS ARE TO BE ADJUSTED ON TEST.
R5 (APPROX 100Ω)
R27 (APPROX 3kΩ)
C14 (APPROX 0·01μF)

OUTPUT SWITCH

POSITION	REF.
1	Z₀-75, '0' IN 600
2	Z₀-600, +4 IN 600
3	Z₀-300, +12 IN 300
4	EARTH LOOP.

METER SWITCH

POSITION	REF
1	TONE LEVEL
2	L.T. VOLTS, V1, V2
3	L.T. VOLTS V3
4	H.T. VOLTS (X100)
5	V1, V2 mA. (X5)
6	V3 mA. (X 2·5)

RANGE SWITCH

POSITION	REF
1	25 – 250 c/s
2	250 – 2500 c/s
3	2500 – 25000 c/s

COMP	LOC	COMP	LOC	COMP	LOC	COMP	LOC	COMP	LOC	COMP	LOC	COMP	LOC
C1	A2	C11	E4	R3	A3	R15	D1	R26	F2	R36	H1	R45	K3
C2	A2	C12	D4	R4	B4	R17	C4	R27	J4	R37	G1	R46	J3
C3	B2	C13	D3	R5	A4	R18	D4	R29	J5	R38	H1	R47	J3
C4	A3	C14	E3	R8	C3	R20	E3	R30	J5	R39	G1	R48	L3
C5	A3	C15	E4	R9	C2	R21	E4	R31	H5	R40	H1	R49	K3
C6	B3	C16	F4	R10	C1	R22	E4	R32	G5	R41	H1	R50	E3
C8	C5			R11	D3	R23	E1	R33	E1	R42	H1		
C9	C3	R1	A4	R13	C1	R24	E1	R34	C2	R43	G4	T1	D2
C10	C3	R2	B4	R14	C1	R25	F1	R35	G1	R44	J4	T2	F2

PORTABLE TONE SOURCE PTS / 10