RADIO INSTRUMENTS AND THEIR CONSTRUCTION

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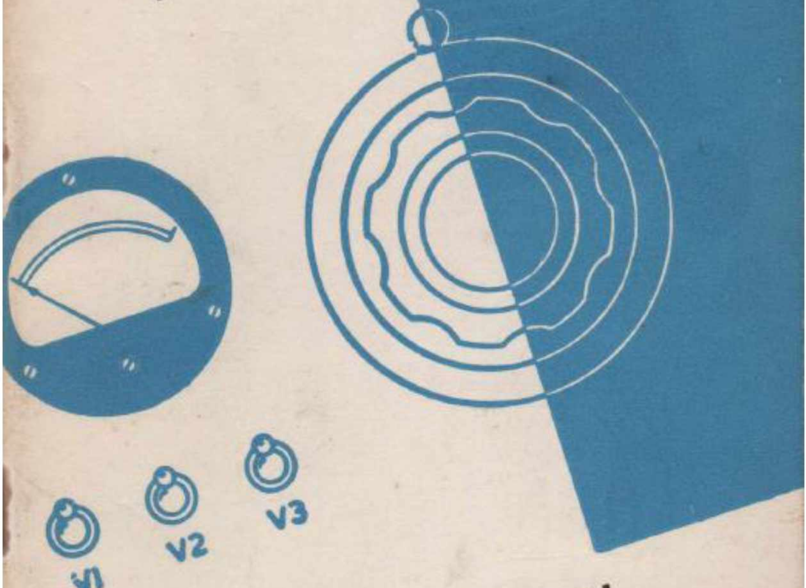

by D. ALLENDEN

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AND
THEIR CONSTRUCTION

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CONTENTS

CHAPTER ONE

A VERSATILE AUDIO-OSCILLATOR

AN AUDIO OSCILLATOR is not normally considered by the amateur experimenter as being an instrument having a wide enough range of application to justify its acquisition. The high cost of commercial audio-oscillators (usually of the beat-frequency type), does, if anything, support this conviction. The instrument to be described however, puts a low-cost instrument of exceptional utility within the range of every amateur. The equipment has been designed round valves which are obtainable from ex-Govt. sources at very low prices. Cost, therefore, need not be a deterrent. The instrument possesses an invaluable feature in that it incorporates three separate outputs.

(*a*) An output of sine waveform at eighteen spot frequencies between 20c/s and 10kc/s.

(*b*) An output of high-harmonic content, continuously variable between 10c/s and approx. 20kc/s.

(*c*) A modulated untuned R.F. output.

These three outputs may be used simultaneously or independently. The first output is provided by a pentode dynatron oscillator and buffer amplifier, whilst the (*b*) and (*c*) outputs are obtained from a multivibrator running off the same power pack as the dynatron.

A glance at the circuit diagram will reveal most of the fundamental points. A few words on the dynatron oscillator may not be out of place at this stage. When a tetrode is operated with its anode voltage much lower than its screen voltage, increases in anode volts cause decreases in anode current. In other words, the A.C. resistance of the valve is negative. This negative resistance may be utilized to compensate for the resistance of a tuned circuit in series with the anode. Variation of grid bias affords an easy means of varying the negative anode resistance. The SP61 used in this circuit is tetrode-connected by commoning the screen and suppressor.

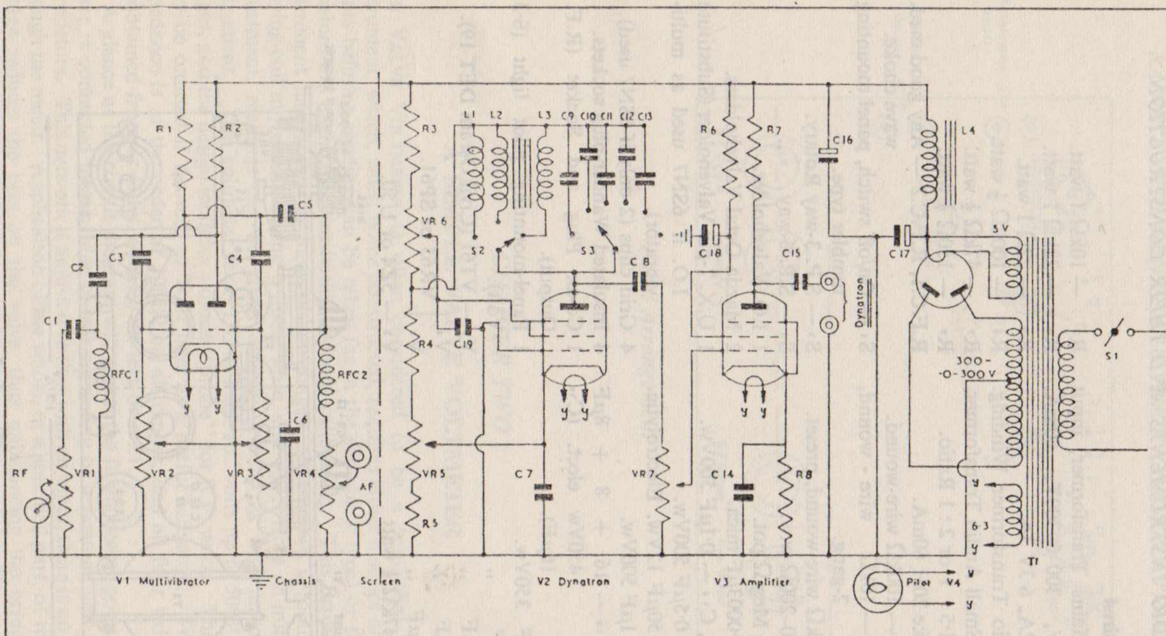
It is important that the potential dividing network which feeds the anode should be of low resistance, or the valve will not stay on the working-point. The use of large coupling condensers is essential if the lower frequencies are not to be attenuated. It will be noticed that values of 1μF are used.

A word as to the tuned circuits. It will be seen that any one of five condensers may be paralleled with any one of three inductances by means of the two selector switches S2 and S3, making fifteen frequencies. A further 3 frequencies are obtained by allowing the coils to oscillate with their own self-capacities. Any small A.F. transformer may be used for the iron-cored coil. The second coil may be formed by the winding from a similar transformer. The frequencies obtained will, of course, depend on the coils used, but if extreme accuracy is required, a trimmer across each condenser can be used to tune to the exact frequencies required. In the prototype instrument three commonly used test frequencies—400c/s, 1000c/s and 5000c/s were accurately trimmed, other frequencies being accepted as they stood. Both valves used in the dynatron circuit are ex-Govt. SP61's (VR65's), but normal 4V SP41's could be used equally well, provided that the lower heater voltage is catered for.

The multivibrator is a double-triode R-C coupled Oscillator, which produces a wave-form of approximate square shape, at a fundamental frequency determined by the values of coupling condensers and grid leaks. A variable frequency is thus easily provided by varying the leaks. The output may be taken from either anode via a coupling condenser. This irregular wave-form possesses harmonics extending deep into the radio-frequencies, thus if a second output is taken, via an audio filter from the vibrator, this output can be used as a source of a "broad" R.F. signal, modulated at fundamental frequencies. This output may be used for ganging T.R.F. sets, adjusting oscillator padders, injecting R.F. signals into sets, etc. With the particular valve used, an ex-Govt. VT61 (Civil equiv. DET19) signals are receivable as high as the 10 metre band. This valve may not be easily available, but a 6SN7 forms a good substitute if its separate cathodes are linked.

The power pack is of conventional design. Smoothing must be efficient, as the load on the H.T. supply is heavy. Layout is not critical, but the multivibrator should be screened from the oscillator, and screened leads used on the R.F. output. The original was built on a chassis-panel assembly as shown in the diagram, and a case of 20s.w.g. sheet steel was made to enclose it. Aluminium, however, could be used equally well. All the wire-wound potentiometers were Govt. surplus stock, including the 2-gang multivibrator grid leak. The dynatron screen potentiometer is a pre-set type, and once adjusted, need not be touched again unless the valve is changed.

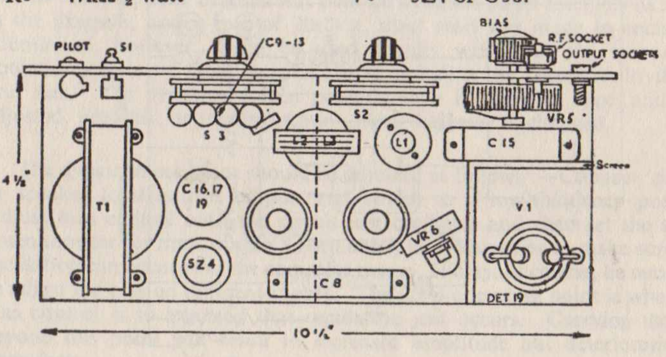
The dynatron oscillator should be adjusted as follows :—Connect 'phones or speaker to dynatron output, and switch to a low-frequency position. Adjust bias control until the circuit just oscillates and then set the screen potentiometer for max. output Then check all frequencies to make sure that oscillation can occur over the complete range. It may, of course, be necessary to adjust the bias on different ranges. The ideal operating point is where the bias control is so adjusted that oscillation just occurs. Carrying the bias beyond this point will result in increased amplitude but deterioration of wave-form.



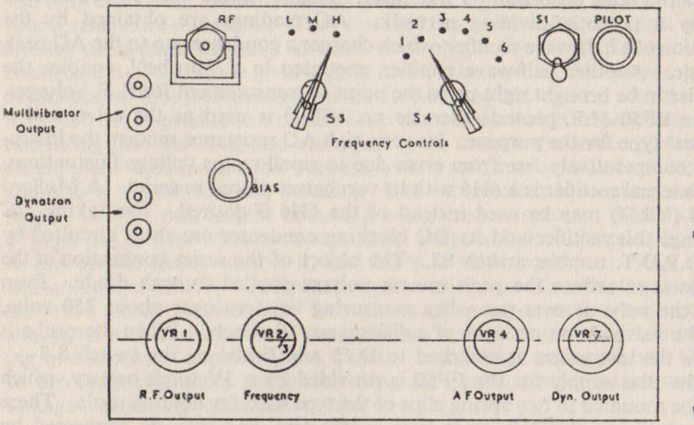
AUDIO OSCILLATOR

Parts Required

T_1 — I. Mains Transformer, input 230V, 300–0–300V, 60mA, 5V 2A, 6·3V 3A
L_1 — Audio Transformer Winding.
L_2, L_3 — Small Audio Transformer, 1·5 : 1 or 2 : 1 Ratio.
L_4 — Choke 20H 60mA.
VR_1, VR_4 — 100kΩ wire-wound.
VR_2, VR_3 — 10kΩ wire - wound, 2-gang.
VR_6 — 10kΩ wire-wound, preset.
VR_5 — 150–200Ω w.w.
VR_7 — 0·5 Meg Ω pot.
C_1, C_6 — ·0003μF mica.
C_2, C_3, C_4, C_{18} — 0·1μF 500Vw.
C_5 — 0·5μF 500Vw.
C_7, C_{14} — 50μF 12Vw. Electrolytic.
C_8, C_{15} — 1μF 500Vw.
C_{16}, C_{17}, C_{19} — 16 + 8 + 8μF 450Vw elect. (C_{17} 16μF).
C_9 — ·2μF 350Vw.
C_{10} — ·1μF ,,
C_{11} — ·05μF ,,
C_{12} — ·01μF ,,
C_{13} — ·001μF ,,
R_1, R_2 — 47kΩ ½ watt
R_3 — 10kΩ 1 watt.
R_4 — 22kΩ 1 watt.
R_5 — 22Ω 1 watt.
R_6 — 100kΩ ½ watt.
R_7 — 47kΩ ½ watt.
R_8 — 150Ω ½ watt.
R.F.C.1, R.F.C.2 — Any good med. wave choke.
S_1 — On/off switch, panel mounting tumbler type.
S_2 — S.P. 3-way Rotary.
S_3 — S.P. 6-way ,,
1 I.O. Valveholder.
2 Mazda Octal Valveholders.
1 U.X. 7-pin Valveholder (Substitute I.O. if 6SN7 used as multi-vibrator).
4 Grid clips (2 only if 6SN7 used).
4 Insulated Wander-plug sockets.
1 Co-ax Plug and Socket (R.F. Output).
1 Panel-mounting pilot light (6·3 Volt).
V_1 — VT61 (Civil Osram DET 19).
V_2, V_3 } VR65 or SP61.
V_4 — 5Z4 or U50.



Chassis Layout



Panel Arrangement

CHAPTER TWO

A SIMPLE VALVE VOLTMETER

THE VALVE VOLTMETER is often considered to be a somewhat delicate instrument, which, when home constructed, requires either a series of adjustments before a reading can be taken (as in the slide-back type) or the scale divisions are unequal, necessitating arduous calibration. This mains-driven instrument has neither of these disadvantages. It employs a robust 5mA moving-coil movement having a linear scale, and, apart from an initial zero adjustment, readings can be taken directly, exactly as with an ordinary instrument. The voltmeter reads DC or Peak AC volts up to 500V in four ranges, and the design includes a diode "probe" for R.F. work. This probe may be omitted if desired, or built later as a useful accessory. The input impedance is of the order of 10MΩ on all ranges, and all four valves can be obtained from ex-Govt. sources for less than £1.

A glance at the circuit diagram will reveal the fundamental points. The meter is connected in a bridge circuit consisting of a pentode and a series of resistors. This network is adjusted so that with no input, there is no current through the meter. Application of the whole, or a specified part, of the input voltage reduces the bias on the valve, thus unbalancing the bridge, and causing the meter to read. The instrument is so designed that 1V on the grid causes full scale deflection on the meter. Higher ranges than 1V are catered for by a potential-dividing network. AC readings are obtained by the insertion of a half-wave rectifier, which charges a condenser up to the AC peak voltage. Another half-wave rectifier, mounted in a "probe", enables the rectifier to be brought right up to the point of measurement for R.F. voltages.

An EF50 H.F. pentode (Service no. VR91) is used as the valve, and is an ideal type for the purpose. Its very high AC resistance renders the instrument comparatively free from error due to small mains voltage fluctuations. The internal rectifier is a 6H6 with its two halves placed in series. A Mullard EB34 (VR54) may be used instead of the 6H6 if desired. For taking DC readings this rectifier and its DC blocking condenser are short circuited by the D.P.D.T. tumbler switch S3. The object of the series connection of the diodes is to reduce the peak inverse voltage applied to each diode. Even then the valve is over-run when measuring voltages over about 350 volts, but the valve shows no signs of suffering any ill effects. When the probe is in use the instrument is switched to D.C. and Probe by the switch S.3

The Bias supply for the EF50.is provided by a 3V torch battery, which may be mounted in two spring clips of the type used for holding tools. There is no drain on this cell, so it lasts indefinitely, and may be connected by soldering the leads directly to its electrodes.

The meter *must* be a low resistance job, if accuracy is to be secured. It may even be preferable to acquire a 1mA movement and shunt it for 5mA. In any case, about 50Ω is the max. meter resistance permissible, consistent with really good results.

CONSTRUCTION

Layout is not critical, apart from the desirability of making the EF50 grid lead as short as possible. The instrument was actually built, using chassis-panel construction, into a case (aluminium) 8″ × 11″ × 5″ deep, but these dimensions were only chosen because a number of test instruments were being built, and it was desired to have all cases of a similar pattern. In actual fact some reduction is possible in size. However, for the guidance of readers, a chassis layout plan is shown. It cannot be over-emphasised that the accuracy of the instrument depends on the resistors R_1, R_2, R_3 and R_4 being of correct value, and for this purpose Welwyn precision carbon types are recommended. The 8meg. R_1 may have to be built up of two or three single resistors in series.. Again, the resistors R_5, R_6 and R_8 should be as accurate as possible, and VR_9 should be a good wire-wound potentiometer. If accurate results are desired, good components must be used.

THE PROBE UNIT

If the rectifier is mounted in a small screened container together with its condenser and associated components, it is possible to connect it to the input of the valve voltmeter by means of a screened cable, and thus all wiring and components which normally would be carrying R.F. currents, giving rise to by-passing and circuit unbalance, can be on the remote side of the rectifier and only carry DC. Such a unit is known as a probe, and is often used in commercial valve voltmeters. The valve used is a Mullard EA50 midget diode, and the cable terminates in a screened octal plug. The diagram showing the construction of the probe gives a good idea of the layout. 1½″ copper, brass, or aluminium tube is recommended for the housing, and the end which carries the "hot" R.F. prod is best made of two discs of a suitable low-loss material, one fitting into the tube, and one equal to its outside diameter. Perspex is an excellent material for this purpose, as it is soft, can be drilled and tapped, and also is a good low-loss material. The valve holder is mounted on two lengths of 4BA rod, lengths of tubing being used as spacers. The prod, of ⅛″ brass rod, is screwed at one end, and fits a tapped hole in the perspex discs. A nut on the inside secures it, and holds a soldering tag carrying about half-an-inch of flexible wire terminating in a miniature clip, which goes on to the valve anode connection. Two pieces of spring brass are arranged as shown, to contact the inside of the housing. A short length of wire terminating in a crocodile clip forms the "earth" connection to the probe. Owing to the small clearances inside the valve, the probe should not be used on voltages exceeding about 50 Volts.

SETTING UP AND CALIBRATION

After completion the instrument must be set up, the procedure being as follows :—

Switch "range" switches to 1V. DC.

Throw S4 to "SET" and adjust VR2 until the meter reads about half scale; throw S4 back to "operate".

Adjust VR3 control until the meter zeros, and apply a known voltage of 1V DC to the terminals. The meter should now read about full scale. If it does not, slightly vary VR2, re-zero, and repeat the test. It may be necessary to make several attempts before the correct setting of VR2 is obtained. When VR2 is correctly set, throw S4 to "SET" and note the reading on the meter. Carefully mark this position on the dial in red. Once the instrument is adjusted for the 1V DC range as described, it will, if resistors R_1, R_2, R_3 and R_4 are of correct values, be correct for the 5V, 50V and 500V ranges. The operating procedure will then be as follows:—

(1) Switch on and allow the instrument to warm up.

(2) Switch S4 to "set", and adjust VR2 until needle coincides with calibration mark on scale, switch S4 to "Operate".

(3) Select voltage range desired.

(4) Zero meter (VR3).

(5) Apply voltage to be measured to terminals.

It may be necessary to make a slight adjustment to the "Zero" Control whenever the range is changed.

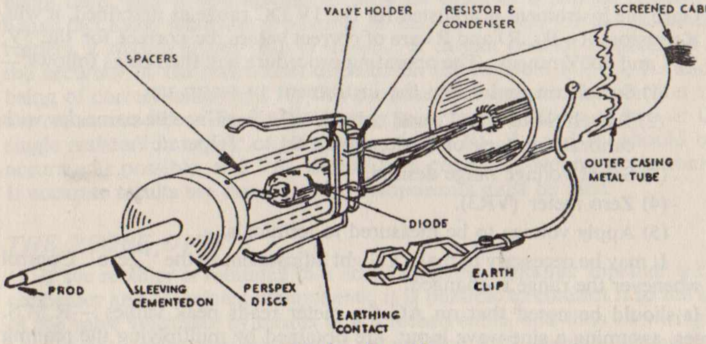
It should be noted that on AC the meter reads peak values :—R.M.S. values, assuming a sine-wave input, are obtained by multiplying the reading by 0·707. Where AC is superimposed on a DC carrier, as at a valve anode, the meter will read the DC + the peak AC. If the value of the AC alone is desired, it is merely necessary to switch to "DC" and repeat the reading. In this second case the reading will be the value of the DC only, and this reading, subtracted from the previous one, will give the peak AC. In actual fact it will usually be possible to obtain the AC only by suitable selection of the measuring point. Thus, the signal value on a valve anode may be obtained by connecting to the side of the coupling condenser remote from the anode.

1 5mA Moving Coil Meter Model No. S20, Sangamo-Weston Ltd., Gt. Cambridge Road, Enfield, Middx.

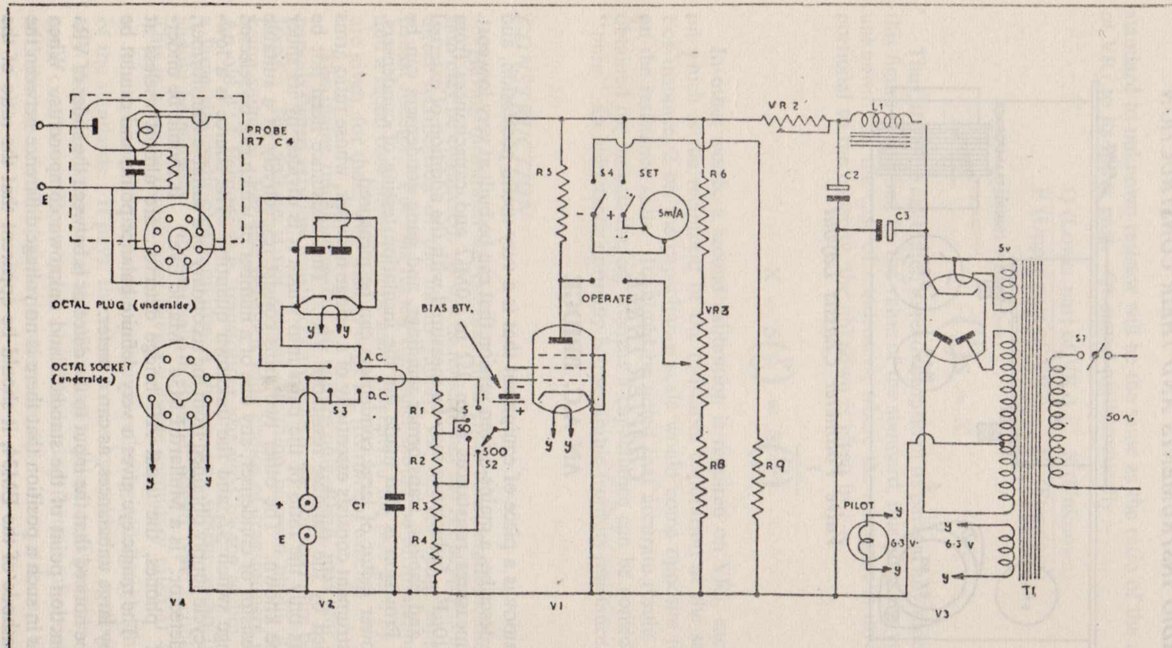
Parts Required

T_1 — Mains Transformer, 230V Pri., Sec. 250–0–250 40mA, 6·3V 1A, 5V 2A,.
L_1 — Choke 20h 40mA.
3 Int. Octal Valveholders.
1 B9G Valveholder.
1 Screened I. Octal Cable Plug.
1 EA50 Diode Valveholder.
1 EA50 Anode Connector.
1 6·3V Pilot Lamp and Holder.
1 3V Flashlamp Battery.
2 Insulated Terminals.
S_1 — S.P. Tumbler Switch.
S_3, S_4 — D.P.D.T. Tumbler Switches.
S_2 — S.P. 4-way Yaxley type switch.

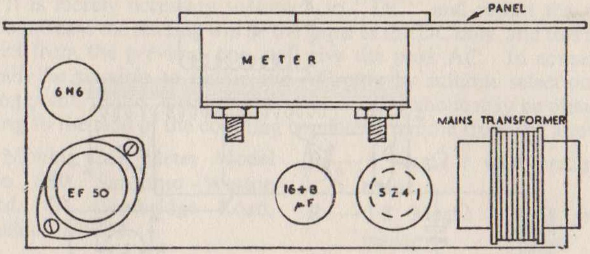
R_1 — 8 MegΩ 1 watt precision resistor.
R_2 — 1·8 MegΩ 1 watt precision resistor.
R_3 — 180kΩ 1 watt precision resistor.
R_4 — 20kΩ ,, ,, ,,
R_5 — 12·5kΩ ,, ,, ,,
R_6 — 2·5kΩ ,, ,, ,,
R_8 — 8kΩ 2 watt ,, ,,
R_9 — 100kΩ 1 watt Carbon.
R_7 — 5 MegΩ ¼ watt.
C_1 — 0·1μF 1000Vw.
C_2, C_3 — 16 + 8μF 450Vw Electrolytic.
C_4 — ·0005μF mica.
VR_1 — 5kΩ wire-wound pot.
VR_2 — 5kΩ wire-wound 5 watt.
V_1 — EF50 (VR91).
V_2 — 6H6 or EB34 (VR54).
V_3 — 5Z4 or U50.
V_4 — EA50 (VR92).
Chassis, panel, wire, etc.



Probe Details



VALVE VOLTMETER



Valve Voltmeter Chassis Layout

CHAPTER THREE

AN A.C. BRIDGE

AN AC BRIDGE is a piece of equipment that is a very useful possession, and this article describes a mains-driven version that can be built at very low cost. This one measures resistances from 1Ω to 10MΩ and capacitances from 10μμF to 10μF. Inductance may be measured with the addition of external standards, and chokes, transformer windings, and gang condensers can be matched. Provision is also made for the insulation testing of condensers, and the power factor of large condensers can be measured.

The instrument consists essentially of a bridge network, whose ratio arms are provided by the variable resistance VR_1. This resistance need not be accurate, as only the ratio of the parts into which it is divided by its slider needs to be known. The other two arms consist respectively of a suitable standard resistor or condenser, any one of a number of which can be selected by the range switch S2, and the unknown quantity. The source is a low-voltage 50-cycle supply obtained from the secondary of a suitable transformer, and the "detector" is a Mullard EM34 "Magic Eye". It should be understood that 'phones, the usual AC bridge detector, are almost useless at 50 cycles. The magic eye gives a very definite balance point, and cannot be damaged by large unbalances, as can a meter.

It will be noticed that the input to the detector is between the slider of VR_1 and the junction point of the standard and unknown components. When the slider is in such a position that there is no voltage difference between the grid and cathode of the EM34, it should be apparent that the ratio of the

standard to unknown resistor will be the same as the ratio of the upper part of VR_1 to its lower part. Or stated mathematically :—

$$\frac{\text{Q (Lower part of } VR_1)}{\text{P (Upper part of } VR_1)} = \frac{\text{X (Unknown)}}{\text{S (Standard)}}$$

From which :—

$$\left(\frac{Q}{P}\right)S = X$$

Thus, if VR_1 is calibrated to read the ratio of its parts at any slider position, this figure multiplied by the value of the standard, this gives the value of the unknown. In the case of condensers, where the reactance is inversely proportional to the capacity, the unknown is given by :—

$$X = S\left(\frac{P}{Q}\right) = S\frac{1}{\left(\frac{Q}{P}\right)}$$

In other words, a second calibration is required on VR_1, each position on which is the reciprocal of the resistance calibration at the same point. For instance, 2 on the capacitance scale would come opposite to ½ or 0·5 on the resistance scale. It should be noted that accurate results cannot be obtained for inductance, as, whereas a capacitance can be considered to be "pure", an inductance normally is inseparable from its resistance.

CONSTRUCTION

Having mentioned the essential theoretical considerations, the construction may be considered. It will be noticed that the HT supply is obtained by direct rectification of the mains supply, the heaters being supplied via a ballast resistor. For this reason the panel should be of insulating material, and a metal case should not be used. Details of the case used by the author are given, for those who wish to copy the instrument exactly.

The mains transformer has to deliver only 40mA max. for very short periods (when very low resistances are tested), the normal figure being nearer 10mA. The voltage is not critical, anything between about 30 and 60V being suitable. For this reason a wide choice of transformers is possible. An old 4 : 1 Ferranti A.F. transformer was used by the author. Provided a large size, with plenty of iron is chosen, any similar audio transformer should be suitable. Alternatively, a Premier Radio type 2 could be used. This is a mains transformer having a single secondary rated at 40V 2A.

The accuracy of the bridge, quite naturally, depends largely on the values of the standards. It pays, therefore, to use low-tolerance components here. VR_1 should be wire-wound and of as large a diameter as possible. There are some excellent ex-Govt. types available, having formers of about 3″ diam., and the use of one of these is recommended. The value can be anything between 1,000Ω and 5,000Ω. The scale should be made from card, and may be protected by a disc of ⅛″ perspex fixed over it. A good pointer can be made by attaching a perspex strip to the knob VR_1 and ruling or scribing a radial line on its underside.

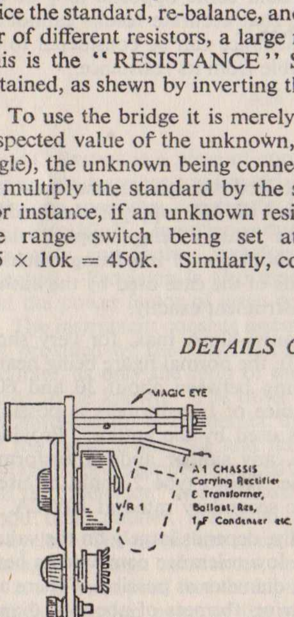
The small condensers and the 1 meg resistor should be mounted as close as possible to the output terminals. The magic eye and neon lamp should be mounted so that they are screened from the light. The author used pieces of 1½″ ebonite tubing mounted on the panel. It should be noted that an aluminium sub-chassis fitted to the panel carries the larger components.

CALIBRATION

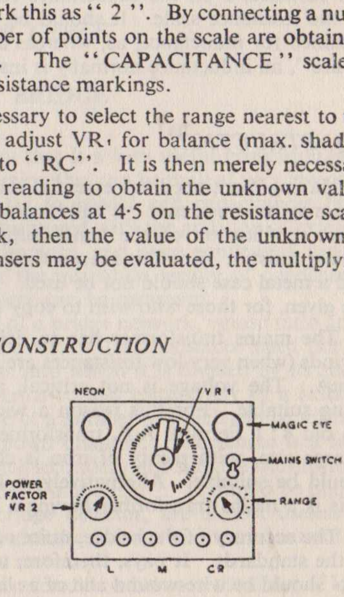
The facsimile scale shown is correct for any type of variable resistor having the same degree of rotation, and may be directly copied. However, instructions are given to enable the builder to calibrate his own scale :— After allowing the instrument to warm up, switch to a resistance range, preferably the 10k or 100k range. Connect a resistor having a value equal to that of the standard to the " CR " terminals, and adjust VR_2 for max. shadow angle. Mark this position on the scale as " 1 ". Now connect a resistor of twice the standard, re-balance, and mark this as " 2 ". By connecting a number of different resistors, a large number of points on the scale are obtained. This is the "RESISTANCE" Scale. The "CAPACITANCE" scale is obtained, as shewn by inverting the resistance markings.

To use the bridge it is merely necessary to select the range nearest to the suspected value of the unknown, and adjust VR_1 for balance (max. shadow angle), the unknown being connected to "RC". It is then merely necessary to multiply the standard by the scale reading to obtain the unknown value. For instance, if an unknown resistor balances at 4·5 on the resistance scale, the range switch being set at 10k, then the value of the unknown is $4{\cdot}5 \times 10k = 450k$. Similarly, condensers may be evaluated, the multiplying

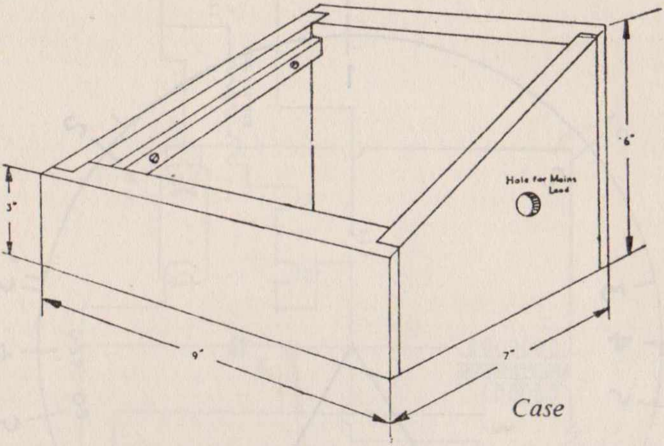
DETAILS OF CONSTRUCTION



Panel : Side View



Panel Layout



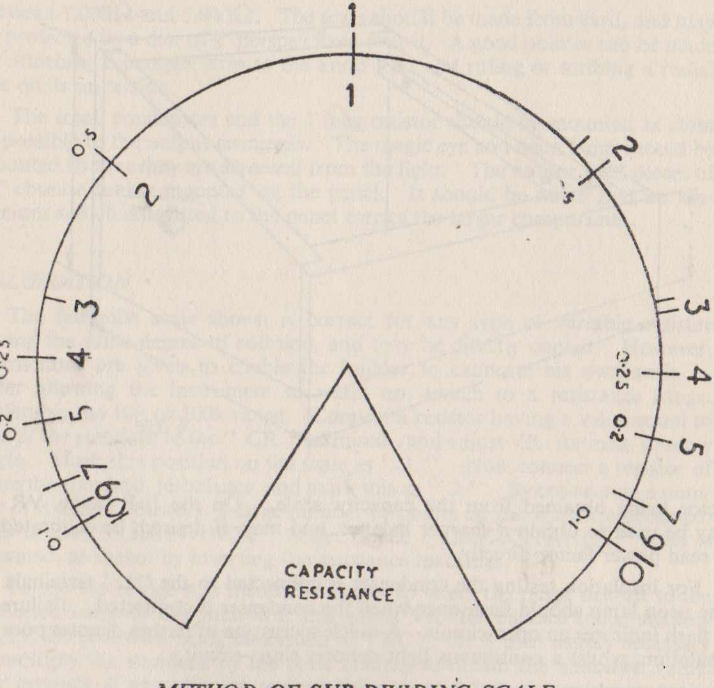
Case

factor being obtained from the capacity scale. On the 1μF range, VR may be used to obtain a sharper balance, and may, if desired, be calibrated to read power factor directly.

For insulation testing the condenser is connected to the "L" terminals. The neon lamp should flash once when the condenser is connected. Failure to flash indicates an open-circuit. A quick succession of flashes denotes poor insulation, whilst a continuous light denotes short-circuit.

Parts Required

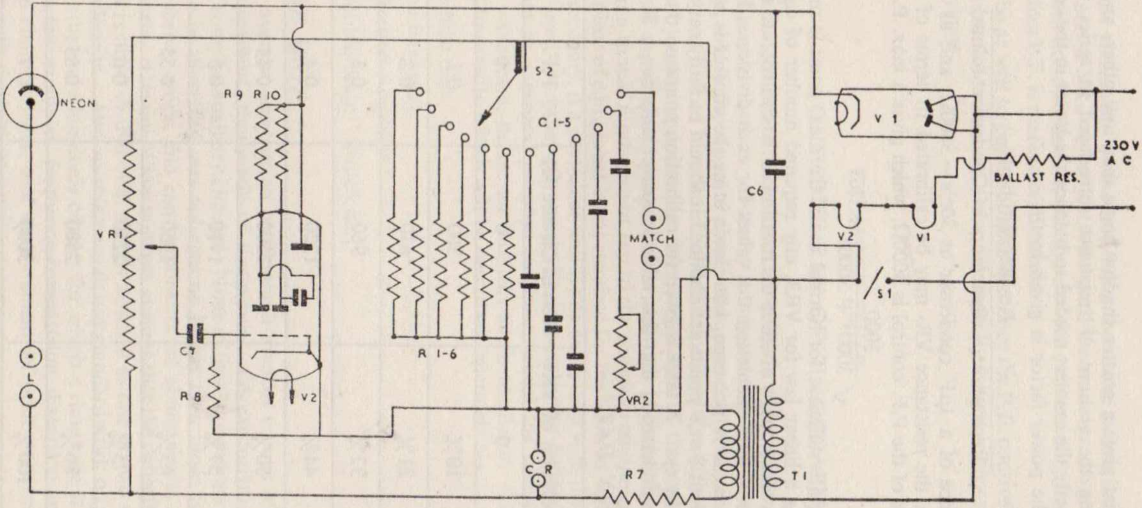
T_1 — Transformer 230V Prim. Sec. 30/60V 10mA.
S_1 — S.P. Tumbler Switch.
S_2 — S.P. 12-way Yaxley Switch.
VR_1 — 1000–5000Ω wire-wound (large diameter).
VR_2 — 3000Ω w.w. pot.
R_1 — 1 meg.Ω 1 watt precision.
R_2 — 0·1 meg.Ω „ „
R_3 — 0·01 meg.Ω „ „
R_4 — 1kΩ „ „
R_5 — 100Ω „ „
R_6 — 10Ω „ „
C_1 — ·001μF. 1%
C_2 — ·01μF. 1%
C_3 — ·05μF. 1%
C_4 — ·1μF. 1%
C_5 — 1μF. 1%
R_7 — 1000Ω 3 watt.
R_8, R_9, R_{10} — 2·2 meg.Ω ½ watt.
C_6 — 8μF 350VW Electrolytic.
C_7 — 0·1μF paper.
V_1 — CY31.
V_2 — EM34.
1 Miniature Neon Lamp 230V and holder.
2 Int. Octal Valveholders.
6 Insulated Terminals.
Ballast Resistor ·2 Amp. 1000Ω.



METHOD OF SUB-DIVIDING SCALE

CALIBRATION OF THE P.F. CONTROL

For the benefit of those readers who wish to calibrate the power factor control, the following details are given. The power factor of a condenser is the cosine of the phase angle between its charging current and the applied voltage, and is a measure of the efficiency of the condenser. In an ideal condenser having no losses, the current leads on the applied voltage by 90°, and cos 90° = 0. Hence the P.F. of a perfect condenser is zero. If there are energy losses in the condenser (such as that due to leakage current in electrolytics) the P.F. is greater than 0, and the condenser behaves not as a pure condenser, but as a combination of resistance and capacitance. The P.F. control is placed in series with the 1μF standard in the instrument in order that any desired amount of resistance may be placed in series with the standard to simulate the effect of an imperfect capacitor. If a condenser having appreciable losses is measured on the 1μF range, it will be found that the balance point is not well defined on the magic eye. If, however, the P.F. control is advanced, the balance point becomes more marked and a far better and sharper balance is obtainable. There will be one setting of the


NEON
VR1
L
C7
R8
R9 R10
V2
R 1-6
S2
C 1-5
C R
MATCH
VR2
R7
C6
T1
V1
V2
V1
S1
BALLAST RES.
230V
A C

A.C. BRIDGE

P.F. control that gives a greater shadow angle than any other, and at this optimum setting the amount of resistance introduced in series with the standard is exactly the amount needed to balance the losses in the condenser under test. The power factor is given by:—

$$\text{P.F.} = \frac{\text{Resistance (ohms)}}{\sqrt{\text{Resistance}^2 + \text{Reactance of Condenser}^2}\text{ (ohms)}}$$

The reactance of a $1\mu F$ condenser at $50c/s = 3000\Omega$, and as this is a constant value, the resistance VR_3 may be calibrated in terms of the P.F. The max. value of the P.F. control is 3000Ω, which gives a max. P.F. of:—

$$\frac{3000}{\sqrt{3000^2 + 3000^2}} = \cdot 707$$

It will be quite sufficient for normal use if the max. point is marked as 0·7. Assuming a linear law for VR3, any required number of calibration points can be worked out by dividing the rotation of the control into a number of even divisions, and calculating the values for each division. It will be noted that the scale is not even, but closes in as the control is advanced. However, if about 8 or 9 points are obtained it should be fairly easy to complete the scale by eye. A table is given for calibration points on the control, but it must be understood that this table is correct only for a 3k control.

CALIBRATION DATA

% Rotation of VR_3	Res. in Circuit (Ω)	P.F.
0	0	0
10%	300	0·1
21%	630	0·2
32%	960	0·3
44%	1320	0·4
50%	1500	0·45
57%	1710	0·5
65%	1950	0·55
75%	2250	0·6
86%	2580	0·65
100%	3000	0·7

The most convenient method of fixing the above points is to connect an ohmmeter across VR_1, and adjust VR_2 until the readings shown in the resistance column are obtained on the meter. As each reading is obtained, the corresponding P.F. is marked on the scale.

It may be as well to point out here that once the P.F. control is calibrated, its calibration holds for any value of capacity which is measured on that particular range.

CHAPTER FOUR

A CATHODE RAY OSCILLOGRAPH

THIS EXTREMELY FLEXIBLE C.R. OSCILLOGRAPH is a departure from normal practice in several respects. Firstly, it follows the "unit" form of construction, in which the separate pieces of equipment (tube unit, time bases. amplifiers, etc.) form a number of self-contained units, which are connected by means of jumper connections. The advantages of this construction for amateur and experimental purposes are two-fold. Firstly, the units can be built one at a time if funds do not run to the complete equipment. Or if any individual piece of equipment is not required for the work in hand, it need not be built. Secondly, if a particular unit is not being used with the oscillograph, it may be used for other purposes. For example, the deflection amplifiers can be used as a general purpose amplifier, whilst the time-base, with its saw-tooth wave-form, makes an excellent audio oscillator. The equipment consists of four units, which will be described separately :—

(*a*) The tube unit.

(*b*) Time Base unit.

(*c*) Deflection Amplifier.

(*d*) "Double-beam" Switch unit.

THE TUBE UNIT

To the average amateur an oscillograph invokes visions of delicate and sensitive apparatus, thousands of dangerous (and expensive) volts, and a number of complex auxiliary circuits. None of these conditions is a necessity. The unit to be described uses voltages no higher than those encountered in ordinary receiver work, and can be constructed almost in its entirety from standard parts. The use of low voltages ensures that the deflection sensitivity of the tube is high, so that even signals as small as one or two volts will give a useful deflection. And, as reference to any standard work on oscillography will reveal, there are hundreds of uses for which a time base is unnecessary. To quote a few examples, frequency comparision, distortion and phase-shift tests, valve characteristics, and measurement of peak voltages, can all be carried out with the tube unit only.

The main item, naturally, is the tube. The tube used by the author was a 3½″ ex-Govt. VCR138, but no dimensions for the tube unit are given as they will be mainly dependent on the size and type of tube. The HT voltage on the higher tapping is about 900, and on the lower one about 450. Very good results are obtainable on the whole with any type of 3″ or 4″ tube at these voltages, whilst the under-running is conductive to long tube life. Even the 6″ VCR97, which is rated for 3·5kV on the final anode, has been found to perform well at this low voltage without any trace of bulb charge. Other suitable types are the American 3BP1, an easily obtainable ex-Govt. type, which is used in the U.S. AN–APA/1 unit; the Mullard ECR30 and G.E.C. E4205–B–5 and E4412–B–9

Details of the heater voltages and connections of all tubes mentioned are given at the end of the article.

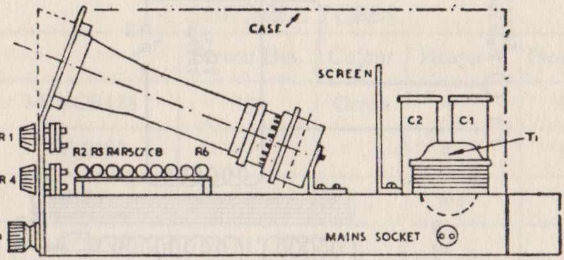
The mains transformer is an ordinary 350–0–350V type, with the lowest current rating obtainable. Total HT consumption is only about 1½mA The LT winding should suit the tube to be used. The smoothing condensers should be 1 or 2μF rated at least 1000V working. Ex-Govt. mansbridge oil-filled types are eminently suitable. The resistors in the potential divider chain should be mounted on a group board, and potentiometers having an earthed slider connection should not be used. Terminals are provided whereby grid and cathode of the tube may be used for injecting signals for brilliance modulation. When no signals are being applied to grid or cathode, these terminals should be linked together and earthed, or trouble may be experienced due to stray signal or mains voltages modulating the beam. Switches are provided so that the input can be made either directly or via blocking condensers, to the X and Y plates. The on/off switch is ganged to the brilliance control, and should be wired so that the switching occurs when the tube bias is a maximum. This simple precaution ensures that the brilliance control is turned right back at the commencement of operations.

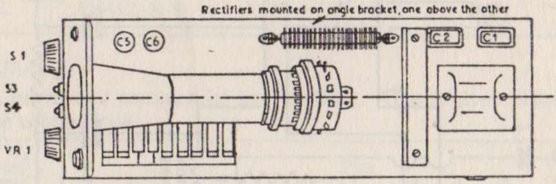
The mains transformer should be mounted behind the tube, so as to reduce stray fields which might distort the trace. If the tube used is ex-Govt. it will probably be purchased as part of a unit, and will be complete with a mumetal screen. If not, a screen, which can be made of sheet steel, is highly desirable.

To overcome the disadvantage, when using more than one unit, of having a number of units all plugged into the same outlet, the idea has here been devised of fitting each unit with a 2-pin socket energized from the unit's own mains input. Thus, each unit may be plugged into an adjacent one.

SUGGESTED LAYOUT

As previously stated, the size of the tube unit will depend largely on the tube used. The layout shown was that used by the author using a VCR138 tube, which, it should be pointed out, is very long in proportion to its diameter. For the majority of 3″ tubes it should be possible to shorten the unit by several inches. It is considered advantageous to mount the tube at an angle as this, although complicating the constructional work, makes for easier viewing.

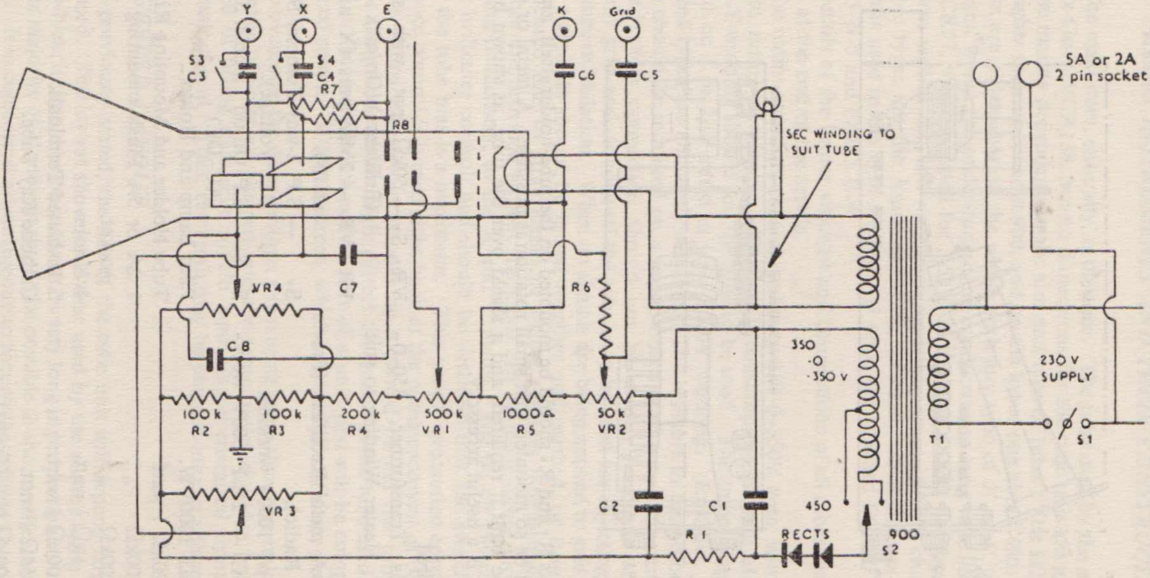




The leaks R_7 and R_8 should be mounted on the tube-holder itself, and the tube should be so mounted that small rotation is possible. A metal or wood case may be built if required, and a shield over the tube, as shown by the dotted line, is a useful accessory.

Parts Required

T_1 — Mains Transformer, 350–0–350V, Heater Winding to suit tube.
2 600V 8mA metal Rectifiers (Premier Radio).
C_1, C_2 — 2μF 1000V working.
C_3, C_4, C_7, C_8 — ·25μF 500V working.
C_5, C_6 — 1μF 1000VW.
R_1 — 20kΩ 1 watt.
R_2, R_3 — 100kΩ ,,
R_4 — 200kΩ ,,
R_5 — 1kΩ $\frac{1}{2}$ watt.
R_6 — 100kΩ $\frac{1}{4}$ watt.
R_7, R_8 — 2MΩ $\frac{1}{4}$ watt.
VR_1 — 500kΩ pot. (Focus).
VR_2, S_1 — 50kΩ pot. with switch (Brilliance) (On/off).
VR_3, VR_4 — 2MΩ pots (X and Y shifts).
S_2 — S.P. 2-way Tumbler Switch (HT Voltage).
S_3, S_4 — S.P. On/off Tumbler Switch (AC–DC)
Pilot Lamp and Holder.
Tube Holder and Mounting Ring.
1 2A or 5A Flush mounting 2-pin socket.
4 Knobs.
5 Insulated Terminals.
Cathode Ray Tube.


Y
X
E
K
Grid
S3
C3
S4
C4
R7
R8
C6
C5
5A or 2A
2 pin socket
SEC WINDING TO
SUIT TUBE
VR4
C7
R6
C8
230 V
SUPPLY
350
-0
-350 V
100 k
R2
100 k
R3
200 k
R4
500 k
VR1
1000Ω
R5
50 k
VR2
T1
S1
VR 3
C2
C1
450
RECTS
R 1
900
S2

TUBE UNIT

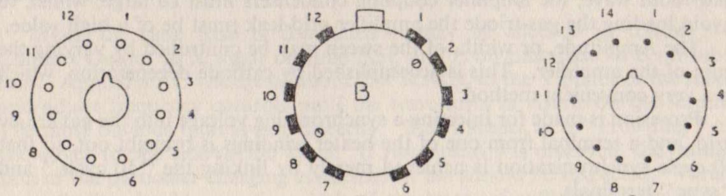
SUITABLE TUBES

		Screen Dia.	Colour	Heater V	Heater A
ex-Govt. M	VCR138	3½″	Green	4	1
,,	VCR97	6½″	,,	4	1
,,	3BP1	3″	,,	6·3	0·6
Mullard	ECR30	2¾″	,,	4	1
	E4205–B–7	2¾″	,,	4	1
G.E.C.	E4412–B–9	3½″	,,	4	1·1

TUBE DATA

Data on several commercial and ex-Govt. types is given below, together with base connections.

Type	Base Type	Pins 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mullard ECR30	A.	Cath.	Grid.	h.	h.	A_2	Blank	Y_2	X_2	A_1A_3	X_1	Y_1	Blank	/	/
G.E.C. E-4205B7	A.	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	/	/
Mullard ECR60	B.	Grid	Cath.	h.	h.	blank	A_2	blank	Y^2	X^2	A_1A_3	X_1	Y_1	/	/
G.E.C. E4412B9	B.	Grid	,,	h.	h.	A_1	A_2	Graphite	Y^2	X^2	A^3	X_1	Y_1	/	/
(Govt.) VCR97	B.	Grid	,,	h.	h.	A_1	A_2	Graphite	Y_2	X_2	A^3	X_1	Y_1	/	/
Govt. VCR138	B.	Grid	,,	h.	h.	A_1	A_2	Graphite	Y^2	X^2	A^3	X_1	Y_1	/	/
Govt. 3BP1	C.	h.	,,	g.	/	A_2	/	Y_1	Y_2	A_1A_3	X_2	X_1	/	/	h.



A — 12 PIN OCTAL B — 12 CONTACT C — 14 PIN OCTAL

CHAPTER FIVE

A GASFILLED TRIODE TIME BASE

Nowadays one hears so much about the hard-valve time base and its advantages that the older gas time base is often regarded as a relatively useless piece of equipment. This however, is far from being true, and the merits of the type ought to be more fully appreciated. Firstly, the thyratron is limited as to frequency, about 10kcs being the upper limit. For general radio work, this is no disadvantage. With a time-base running at 10kcs, frequencies of 100kc/s are easily visible; and the envelope pattern of R.F. signals (which is all that is normally required) is obtainable at far lower frequencies. The frequency of the time-base is, of course, limited by the time taken for the gas in the triode to de-ionise; in practice this effect is only apparent at the upper frequencies, when it manifests itself as a vertical line at one end of the trace; this is not a serious matter. Secondly, the gas triode is capable of carrying such heavy discharge currents (of the order of 1 amp) that the condenser discharge occurs in an infinitesimally short time. The effect of this is that the flyback is so rapid as not to leave any visible trace on the tube. Thirdly, the gas time base is inherently simple, and contains no valves operating under critical conditions.

The principle of operation should be clear from the circuit diagram. The gas-triode V_1, is originally biased by the potentiometer network R_3 and R_2 to about 1½V. One of the condensers C_{3-8} is charged via VR_2, at a rate depending on the values of C and VR_2. When the voltage across the condenser reaches about 25–30V the gas-triode becomes conducting, and the condenser is discharged. A linear charge is ensured by restricting the condenser voltage to this low value. Oscillograms of the time base output fail to show any observable departure from linearity. The output of the gas-triode being too small to operate the tube directly, is passed through an amplifier. It must be remembered that owing to the transient qualities of the saw-tooth wave, the amplifier coupling condensers must be large, whilst, to avoid loading the gas-triode the amplifier grid-leak must be of a high value.

The Amplitude, or width, of the sweep may be controlled by varying the gain of the amplifier. This is accomplished by cathode degeneration, which is a very convenient method.

Provision is made for injecting a synchronizing voltage into the gas-triode grid, and a terminal from one of the heater windings is brought out, so that 50 cycle synchronization is achieved merely by linking the "50 cycle" and "sync" terminals.

With earlier forms of gas triode or thyratron (the name "Thyratron" was originally the trademark of the B.T.H. Company) it was necessary to apply a delay in the H.T. line so that the cathode had time to heat up before the valve was put to work. Failure to observe this measure would result in a stripped cathode which, of course, rendered the valve useless. Usually, a relay operated by a valve working at low heater voltage was employed, sometimes a bi-metal strip delay unit such as used in mercury rectifier power-packs was used. The valve chosen for this circuit is the Mazda T.41, which has found almost universal application in television soft valve time base circuits due to its reliable performance coupled with the fact that no time delay circuit is necessary. It will be obvious to the constructor that a considerable all round saving on the original expenditure can be effected by the omission of this delay network.

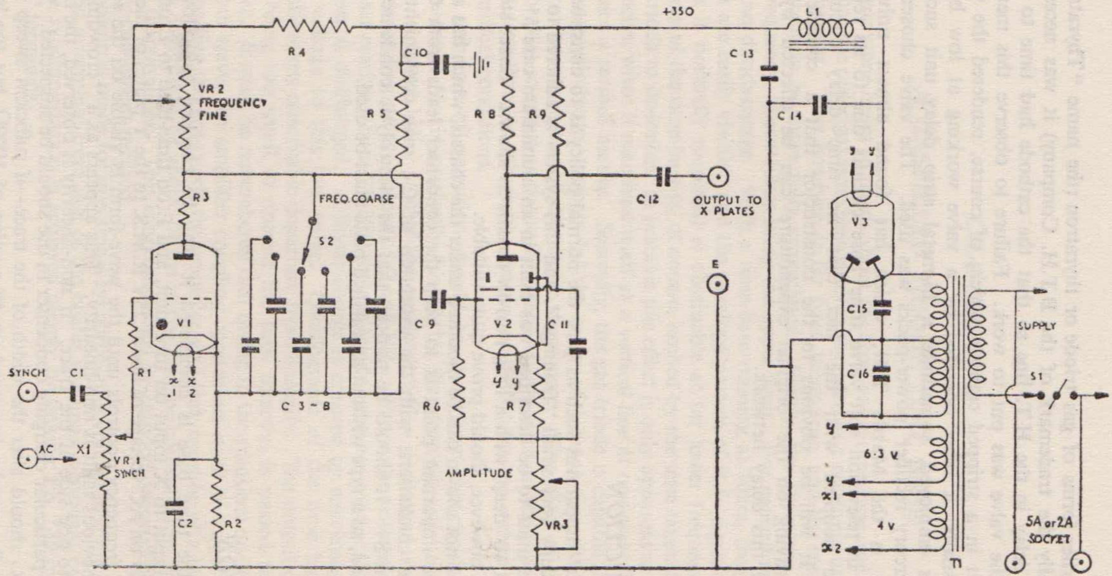
CONSTRUCTION

In "unit" apparatus such as this, the normal policy is to construct the units to occupy very small "frontage", and this system is adhered to here. Each of the units to be described was built in an aluminium case 5″ wide, 8″ high and 10″ deep, with a long narrow chassis as shown. Sheet steel or wood cases however, should prove quite suitable.

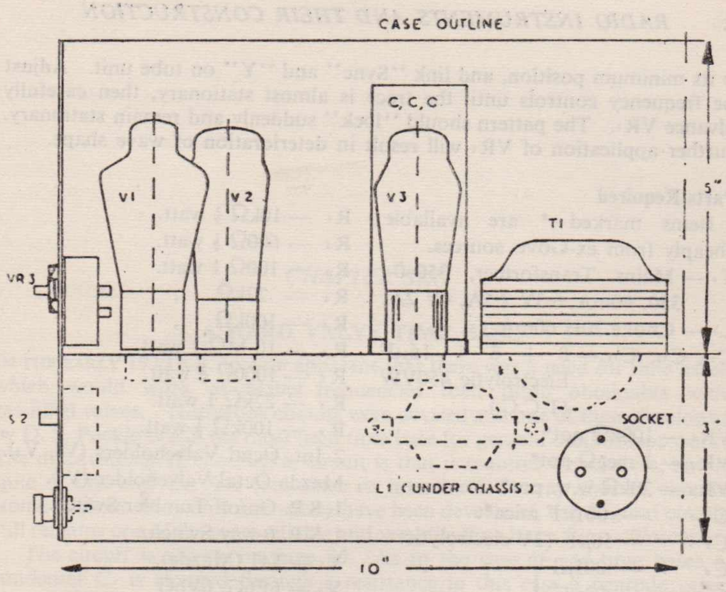
All parts not shown can be mounted under the chassis, which has ample depth. The important point is to keep the condenser leads from C_3-C_8 short. The condensers, with the exception of C_8, may conveniently be mounted on S_2. It should be noticed that the electrolytic condenser C_{11} is not earthed, so a type without an earthed plate must be used.

OPERATION

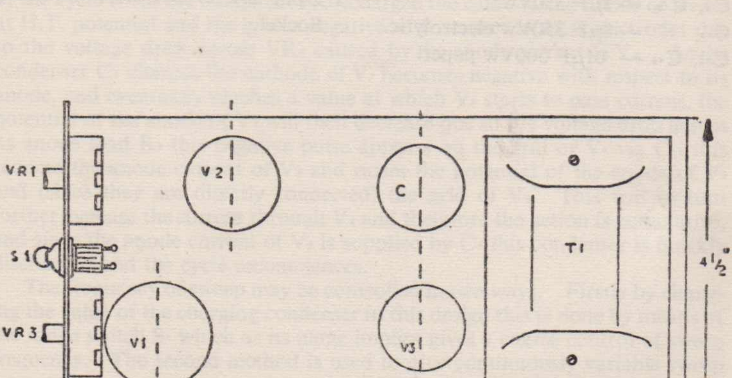
When the time base is completed it may be checked as follows:— Connect Output to X input on tube unit, and E on time-base to E on tube unit. Apply on AC voltage of about 25V R.M.S. to the Y plates of the tube, and adjust frequency controls until the wave-form is visible on the screen. The most obvious fault is non-linearity. This appears as a "crowding" of the waves to one side of the trace. If non-linearity is observed, the insulation of the particular charging condenser in use should be suspected. Variation of VR_3 should alter the width of the trace—if sufficient sweep is not obtainable, R_2 may be increased up to a value of 1000Ω, but too large a value may bring about non-linearity. To check synchronization, adjust VR_1



THYRATRON TIME BASE



Side View of Chassis



Plan of Chassis

to its minimum position, and link "Sync" and "Y" on tube unit. Adjust the frequency controls until the trace is almost stationary, then carefully advance VR_1. The pattern should "lock" suddenly and remain stationary. Further application of VR_1 will result in deterioration of wave shape.

Parts Required

Items marked * are available cheaply from ex-Govt. sources.

T_1 — Mains Transformer, 350–0–350, 60mA, 6·3V 2·5A, 4V 2A.

L_1 — Choke 20H 60mA.

C_{10}, C_{13}, C_{14} — 8 + 8 + 16μF Electrolytic 450VW (T.C.C.).

VR_1 — 100kΩ pot*.

VR_2 — 1 megΩ pot*.

VR_3 — 20kΩ w.w. pot*.

C_1 — ·001μF mica*.

C_2 — 50μF 12V electrolytic.

C_3 — ·005μF
C_4 — ·02μF
C_5 — ·1μF
C_6 — ·2μF
C_7 — ·5μF
C_8 — 1μF
} 350Vw.*

C_9, C_{12} — 1μF 350Vw*.

C_{11} — 8μF 350Vw electrolytic.

C_{15}, C_{16} — ·01μF 500Vw paper.

R_1 — 10kΩ ½ watt.

R_2 — 600Ω ½ watt.

R_3 — 100Ω 1 watt.

R_4 — 22kΩ ,,

R_5 — 100kΩ ,,

R_6 — 10 MΩ ¼ watt.

R_7 — 1000Ω ½ watt.

R_8 — 22kΩ 1 watt.

R_9 — 100kΩ ½ watt.

2 Int. Octal Valveholders (V_2, V_3).

Mazda Octal Valveholder (V_1).

1 S.P. On/off Tumbler Switch.

1 S.P. 6-way Switch.

V_1 — T41 (Mazda).

V_2 — 6F6G. 6V6G

V_3 — 6X5G* or OZ4 (no heater supply necessary for OZ4).

4 Knobs.

4 Insulated Terminals.

1 2-pin 2A or 5A flush-mounting Socket.

CHAPTER SIX

A HARD VALVE TIME BASE

IN THE EARLY 1930's it became apparent that there was a need for time bases which would work at higher frequencies than those obtainable with gas-filled valves. Numerous circuits were devised and one of these developed by O. S. Puckle is still the most used time base for general oscilloscope work. The disadvantage of the Puckle circuit is that it requires three valves, but in spite of this and the fact that since its introduction many simpler circuits (some of them using only one valve) have been developed, the original circuit still remains one of the most reliable and versatile time bases for oscilloscopes.

The circuit is shown on page 35. As in the case of gas time bases a condenser C_1 is charged through a resistance in this case a pentode valve V_1, after the condenser is charged to a predetermined point it is discharged by the joint action of valves V_2 and V_3.

The action of the circuit is as follows—the condenser C_1 is charged through the pentode valve V_1, since a pentode valve is very nearly a constant current device the potential across C_1 rises linearly with time. At the commencement of the cycle when the condenser is discharged the cathode and anode of V_2 are at H.T. potential and the grid is negative with respect to these electrodes due to the voltage drop across VR_2 caused by the anode current of V_3. As the condenser C_1 charges the cathode of V_2 becomes negative with respect to its anode, and eventually reaches a value at which V_2 starts to pass current, the potential of the anode of V_2 will then decrease due to the voltage drop across its anode load R_2 this negative pulse appears on the grid of V_3 via C_{10} this reduces the anode current of V_3 and raises the potential of the anode of V_3 and (since they are directly connected) the grid of V_2. This will in turn further increase the current through V_2 and therefore the action is cumulative, and since the anode current of V_2 is supplied by C_1 this condenser is quickly discharged and the cycle recommences.

The frequency of sweep may be controlled in two ways. Firstly by changing the value of the charging condenser in this design this is done by means of the range switch S_1 which as its name implies gives a coarse control of sweep frequency. The second method is used to give continuously variable sweep frequency on each range and consists of altering the charging current by changing the screen potential on the charging valve by means of VR_1.

The amplitude of sweep is controlled by the value of VR_2 the anode load of V_3 the setting of this potentiometer determines the initial bias on V_2 and hence the maximum voltage to which C_1 can be charged before V_2 conducts.

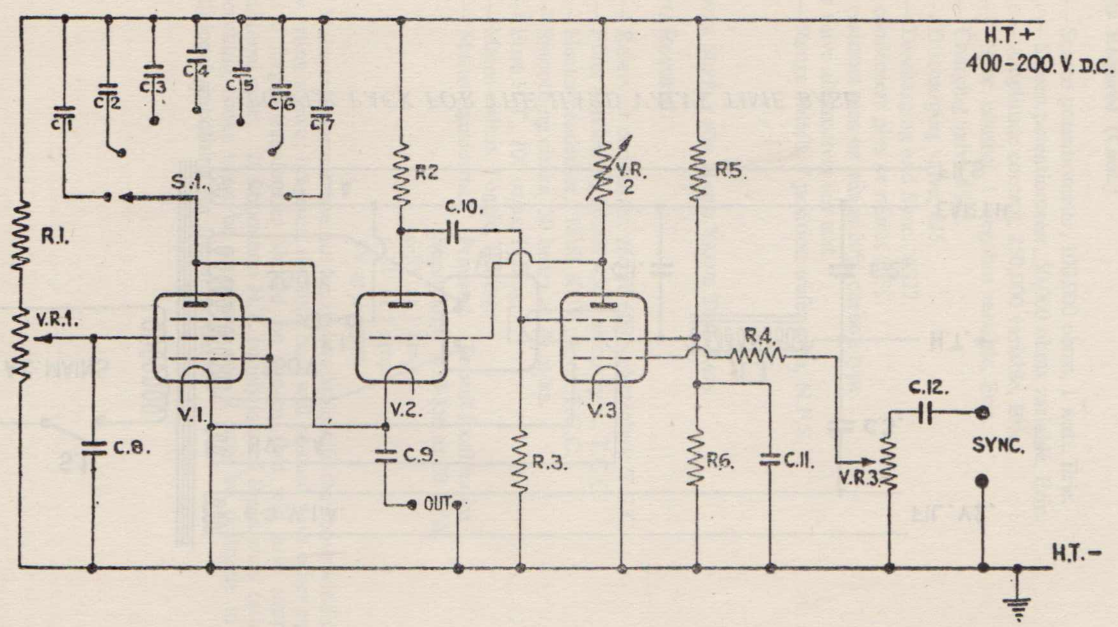
Synchronization is applied to the grid of V_3 and is controlled by potentiometer VR_3. The frequency range of the time base is approximately from 10 sweeps per second up to 300,000 sweeps per second. The highest frequency is determined by the stray capacities in the anode circuit of V_1, no other capacity being used on the top position of the range switch. The lowest frequency is determined by the value of the largest charging condenser, and, should a lower sweep frequency than 10 cycles per second be required additional contacts may be used on the range switch S_1 to switch in larger condensers.

The home constructor should experience no difficulty in constructing this time base from the circuit diagram and parts list. The pentodes V_1 and V_3 may be any small short grid base pentode valves such as :—6J7, 6SJ7, 6C6, KTZ63, OM5, 6F12, 6SH7, in the 6·3 volt range and MSPEN, MSP4, ACSP, A50A, AC/S2Pen, SP4, HP1AC, S435N, HP4101, 8A1, TE464, SPt4A, in the 4 volt range. The triode V_2 may be any medium or low impedance valve such as 6C5, 6J5, 6SN7, L63, 76, 6C4, in the 6·3 volt range and ML4, ACP, 104V, 4PAC, 41MP, MHL4, PA1, in the 4 volt range of valves. The circuit requires a smoothed H.T. supply between 200 and 400 volts depending on the maximum sweep amplitude needed. The current taken depends on the H.T. volts, the frequency and amplitude settings, but is in the order of 20 m/a. The filament supply must of course suit the valves chosen, and where possible V_2 should be supplied from a separate unearthed filament winding in order to minimise the risk of cathode-heater leakage or breakdown.

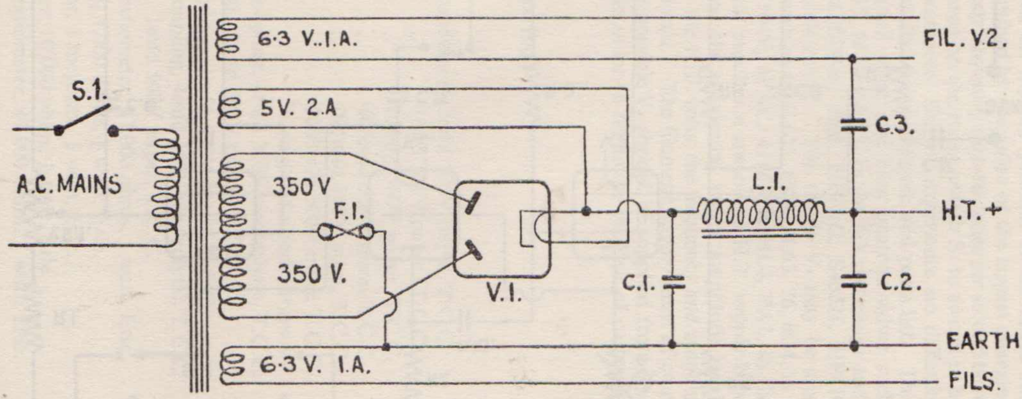
Hard Valve Time Base

Parts Required

C_1 — Charging condenser, ·5mfd 500V paper, T.C.C.
C_2 — ,, ,, ·1mfd 500V paper, T.C.C.
C_3 — ,, ,, ·02mfd 500V paper, T.C.C.
C_4 — ,, ,, ·005mfd 500V mica, T.C.C.
C_5 — ,, ,, ·001mfd 500V mica, T.C.C.
C_6 — ,, ,, ·0002mfd 500V mica, T.C.C.
C_7 — ,, ,, Wiring and anode strays V_1
C_8 — Screen decoupling, 4mfd 300V electrolytic, T.C.C.
C_9 — Output feed, ·1mfd 500V paper, T.C.C.
C_{10} — V_2, V_3 coupling, 1mfd 500V paper, T.C.C.
C_{11} — Screen decoupling, 4mfd 350V electrolytic, T.C.C.
C_{12} — Sync. feed, ·1mfd 500V paper, T.C.C.
R_1 — Screen potentiometer, 47,000 ohms, 1 watt, Erie.
R_2 — Anode load, 1,000 ohms, ¼ watt, Erie.
R_3 — Grid resistor, 1 megohm, ¼ watt, Erie.
R_4 — Grid stopper, 10,000 ohms, ¼ watt, Erie.
R_5 — Screen potentiometer, 47,000 ohms, 1 watt, Erie.



HARD VALVE TIME BASE



POWER PACK FOR THE HARD VALVE TIME BASE

Parts Required (Cont.)

R_6 — Screen potentiometer, 100,000 ohms, 1 watt, Erie.
VR_1 — Screen potentiometer, 50,000 ohms variable, Erie.
VR_2 — Amplitude control, 250,000 variable, Erie.
VR_3 — Sync. control, 1 megohm variable, Erie.
V_1 — Charging valve 6SJ7.
V_2 — Discharging valve, 6J5.
V_3 — Discharging and Sync., 6SJ7.
All condensers plus or minus 20%.
All resistors plus or minus 20% carbon type.
For valve alternatives see text.
S_1 — Range switch, 7 position wafer type, N.F.S.

POWER SUPPLY FOR HARD VALVE TIME BASE

Parts Required

C_1 — Reservoir condenser, 16mfd 600V electrolytic T.C.C.
C_2 — Filter condenser, 16mfd 450V electrolytic, T.C.C.
C_3 — Heater condenser, 1mfd 500V paper, T.C.C.
L_1 — Smoothing choke, 30 henry at 20 m/as.
F_1 — Fuse H.T., 100 m/as, Belling.
S_1 — Mains switch, Toggle, Belling.
T_1 — Mains transformer. Primary. To suit local mains
Secondary. 350-350 at 20 m/A.
6·3V at 1 amp.
6·3V at 1 amp.
5V at 2 amps.

Mains transformers are not usually available with the above windings at the low rating shown; however, the time base will be used with other equipment and a larger transformer should be chosen that will also supply these additional units. If a common H.T. supply is used the current rating of the smoothing choke must be increased and it may be desirable to provide additional smoothing for the other units.

CHAPTER SEVEN

A USEFUL BEAM-SWITCHING UNIT

HERE IS A SIMPLE DEVICE that transforms the ordinary oscillograph into a double-beam job. With this device you can feed two inputs into your oscillograph, and view them together simultaneously, either separated or superimposed. Curves can be compared for distortion, phase shift, etc. There is no inter-action between the two supplies, and the gain of each input can be adjusted independently.

A brief description of the operation of the circuit should not come amiss. Each input is fed, via a gain control, to the grid of a triode. The two triodes have a common anode load, from which the output is taken. The triodes are biased by potential dividers so that the normal bias on them is far beyond the cut-off value. A synchronous vibrator is so arranged that it short-circuits part of the bias resistor of each valve in turn, thus putting the valves into action alternately, at a high speed. The resultant output from the linked anodes, which consists of alternate pulses, is fed to the oscilloscope input, where the combined effects of the screen afterglow and persistence of vision give an effect of the two inputs superimposed. They may be separated to give two independent traces by the application of a shift voltage to the plates whenever any one of the two triodes is operating. The same synchronous vibrator performs this function also.

The only condition for the device to perform successfully is that the frequency of the vibrator shall not be an exact multiple or sub-multiple of the frequency of the waves being analysed. If this condition is not met, visible gaps will appear in the traces. The output from the device may be fed to the plates via a further amplifier if desired. It will be noticed that two output terminals are shown. One of these supplies the signal, and the other the separation bias. For normal use these two may be linked as shown by the dotted line, and a single lead taken from the common terminal to the Y plates of the tube. This lead must go *direct* to the plate, with no condensers interposed. Those who build the device for use with an existing oscilloscope not provided with this connection will need to modify theinstrument by the addition of a terminal connected directly to the Y plate connection on the tube socket. If an amplifier is used with the device, the bias terminal should be taken by a direct connection to the Y plate, and the signal output is connected to the amplifier input, the link joining the terminals being removed.

A similar construction to that employed for the time-bases and deflection amplifier is employed, the chassis and panel being of aluminium and the case of aluminium, steel, or wood.

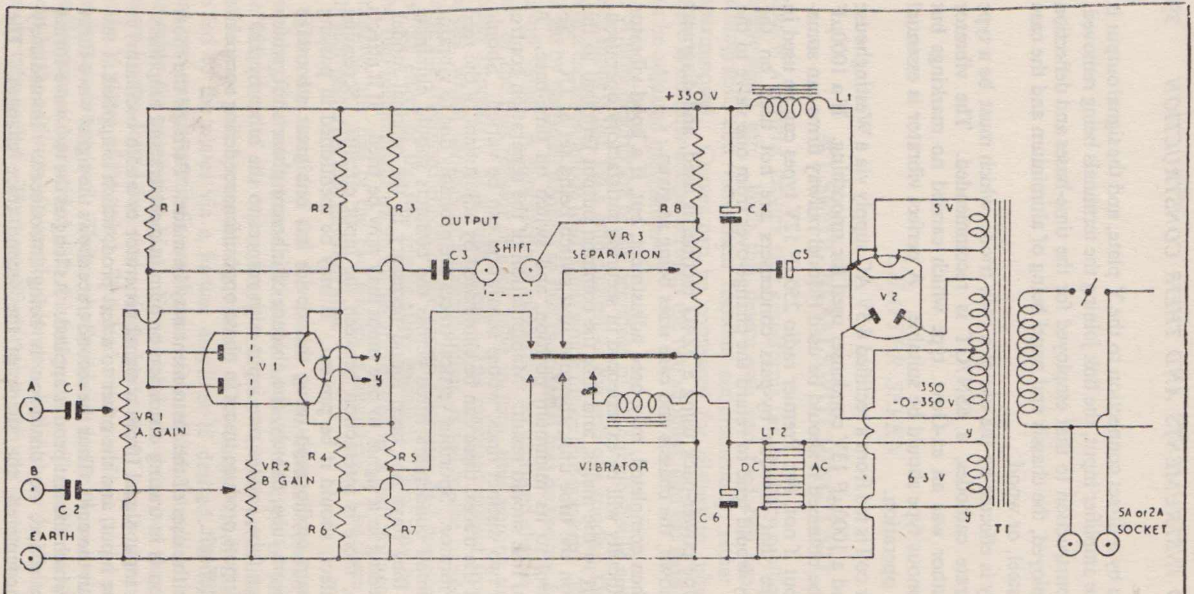
An economy is effected by the use of a twin triode, which must be a type with two separate cathodes, a 6SN7GT is recommended. The vibrator used by the author was an ex-Govt. type which carried no markings but any 6V synchronous type should be suitable. A perfect vibrator is essential for satisfactory operation.

The vibrator coil is fed from a rectified 6·3V AC supply via a Westinghouse LT2 rectifier and a 1000μF 13V condenser used for smoothing. If a 1000μF condenser can be obtained it should be used (Model railway firms can sometimes supply), but if not, two Premier radio 250μF 12V types can be used in parallel. Notice that cathode by-pass condensers are not used on the amplifier as they would tend to retard the change-over from one valve to the other.

A normal-type power-pack using a 5Z4G rectifier is used, and diagrams of layout are shown, the chassis and case sizes being as given.

The unit, when completed, may need adjustment, but, if a good vibrator is used, little difficulty will be experienced in securing satisfactory operation. Connect the unit to the mains, and link the common output terminal to the "Y" terminal on the tube unit, the tube unit switch being set at DC. Set separation control to its minimum position, and switch on time-base. A single horizontal line should result. Manipulation of the separation control should produce two distinct lines, whose separation can be varied. Should there be gaps in the traces, these can be eliminated by adjustment of the reed contact on the vibrator. Spurious vertical traces are probably due to vibrator sparking, and small condensers fitted across the contacts should eliminate this effect, but they have not been found necessary in the original model. The effect of feeding in a signal to one input may now be tried. If it affects the other beam, there is interaction between the input circuits. Screening will cure this effect, should it be present. It may be mentioned in passing that a single-beam oscillograph using this device has one great advantage over a double-beam tube, namely, the absence of inherent phase shift, which in a double-beam tube, rotates one input with respect to the other by 180°. Thus, identical inputs produce traces in phase opposition, rendering comparison somewhat difficult.

Reference to the uses of the instrument may be made. Perhaps the most useful application is in tracing distortion or hum in receivers and amplifiers. In this case the input signal (from a signal generator or audio oscillator) is connected to one input, and the other to a test prod, which is applied at test points throughout the unit. Thus the second trace shows the signal wave-form at any point to which the test prod is applied. As long as the two wave-forms are identical in shape, no distortion is being introduced. Immediately distortion is encountered, the shape of the second trace changes. The



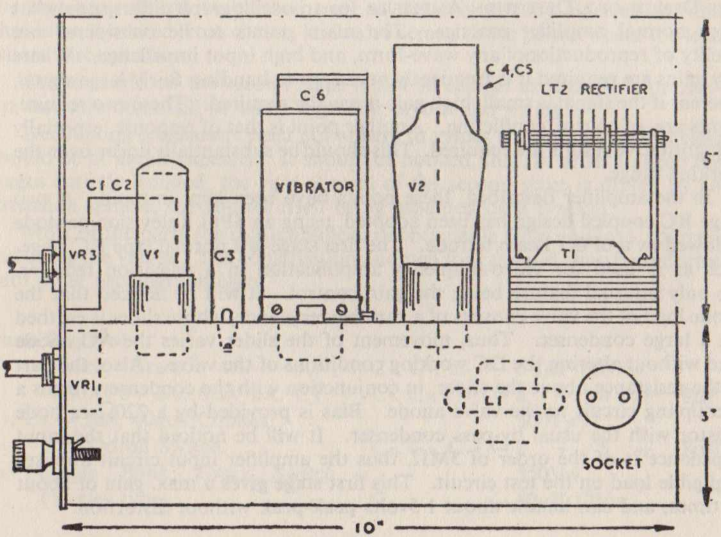
BEAM SWITCHING UNIT

advantage of the double trace here is that the input signal wave-form is always on the screen as a visual reference.

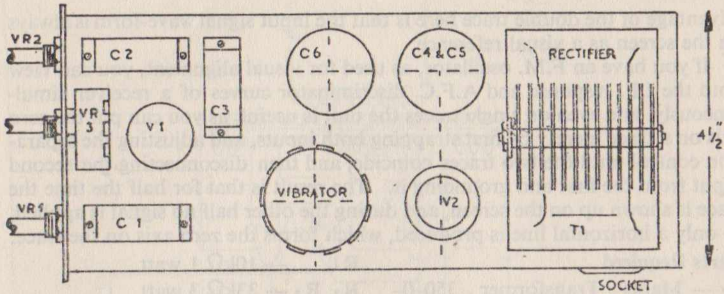
If you have an F.M. oscillator, as used for visual alignment, you can view both the I.F. response and A.F.C. discriminator curves of a receiver simultaneously, and even on single traces the unit is useful, as you can put the zero axis on a trace merely by first strapping both inputs, and adjusting the separation control until the two traces coincide, and then disconnecting the second input from the first and grounding it. The result is that for half the time the trace is shown up on the screen, and during the other half no signal is applied, so only a horizontal line is produced, which forms the zero axis on the trace.

Parts Required

T_1 — Mains Transformer 350–0–350V, 60mA, 6·3V 2A and 5V 2A.
L_1 — Choke 20H 40mA.
1 6V Synchronous Vibrator.
C_1, C_2 — 0·25μF 350Vw.
C_3 — 1μF 500Vw.
C_4, C_5 — 16 + 8μF 450V Electrolytic.
C_6 — 1000μF 12V.
VR_1, VR_2 — 100kΩ pot.
VR_3 — 1 MΩ pot.
R_1 — 10kΩ 1 watt.
R_2, R_3 — 33kΩ 3 watt.
R_4, R_5 — 390Ω 1 watt.
R_6, R_7 — 4·7kΩ „
R_8 — 1 MΩ „
1 Westinghouse L.T.2 Rectifier.
5 Insulated Terminals.
2 Int. Octal Valveholders.
1 Vibrator Holder.
1 S.P. Switch.
1 2A or 5A Flush-mounting Socket.
V_1 — 6SN7GT.
V_2 — 5Z4G or U50.



Side View of Chassis



CHAPTER EIGHT

A DEFLECTION AMPLIFIER

THE DESIGN OF A DEFECTION AMPLIFIER for an oscillograph differs somewhat from normal amplifier practice. The main points to be considered are fidelity of reproductionof any wave-form, and high input impedance. Where low gains are required it is frequently necessary to handle a fairly large signal, whereas if the signal is small, high gain is usually required. These two requirements are, of course, conflicting. Another point is that of response, especially if quantitative results are required. This should be substantially linear over the working range.

In the amplifier described, these points have been kept in mind. A two stage RC coupled design has been adopted, using an SP61 Television pentode followed by a 6F6G Beam tetrode. The first stage is a normal type RC stage, such as is used for video-frequency amplification in a television receiver. the only unusual feature being the gain control. It will be noticed that the anode load of the valve consists of a variable resistance, whose slider is earthed via a large condenser. Thus, movement of the slider varies the AC anode load without altering the DC working conditions of the valve. Also, the part of the resistance above the slider, in conjunction with the condenser, forms a decoupling circuit to the valve anode. Bias is provided by a 220Ω cathode resistor with the usual by-pass condenser. It will be noticed that the input impedance is of the order of 5MΩ, thus the amplifier input circuit imposes negligible load on the test circuit. This first stage gives a max. gain of about 60 times, and can handle about 1·5volts peak-peak without distortion.

The 6F6 stage is designed to handle a large input, and in actual fact, as will be seen, is very similar to the amplifying stage in the Gas Time-base Circuit. The input impedance is again kept high. In the interests of signal-handling capacity, however, the gain of this stage is controlled by cathode degeneration. The gains is, of course, much lower than that of the previous stage, about 8 times in actual fact, but a signal of about 15 volts can easily be handled at max. gain, and a proportionately larger signal at lower gains. This has been found to give about twice screen deflection with the tube unit described.

When a large signal is being amplified, the second stage only may be used, as an additional terminal to the 6F6 grid is brought out.

The power unit follows normal design, but smoothing must be good, and two stages are fitted. A high HT voltage of 450V is used, although 350V could be used with suitable modification of anode and screen resistors, but the gain would be reduced by about half.

Grid stoppers are shown fitted to both stages. In the case of the 6F6, the stopper should be mounted as close to the grid pin of the valve as possible. Regarding the SP61, the stopper should be mounted on the grid connector, and the whole enclosed by the valve screen. Readers may wonder as to the reason for screening an all-metallized valve, but it has been found that the grid cap of the valve is the danger point, this electrode is very susceptible to hum pick-up, and the easiest way to screen the grid and its lead is to screen the whole valve. The input to the grid is made by means of co-ax cable and socket. A small screening-can should be made of sheet brass and arranged to enclose the grid condenser and leak. The grid lead itself is screened, but the screening should be earthed only to the can already referred to, and should be insulated from chassis and valve screen at the points where the lead passes through them.

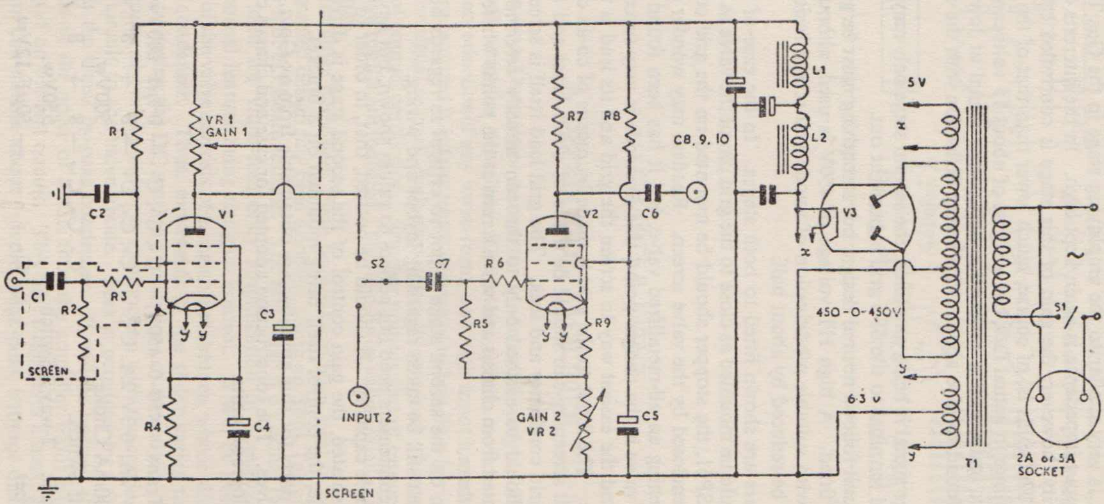
Construction on the second stage is not so critical as regards hum pick-up, but care must still be taken regarding layout and wiring.

Decoupling condensers need not adhere to values shown, but nevertheless should be of ample capacity. It should be noticed, that, in order to keep the stages entirely isolated, the gain control of the second stage is driven by an extension spindle, the control itself being mounted on a bracket.

Most of the parts for this amplifier are obtainable from ex-Govt. sources, including the valves. The construction adopted for case and chassis conforms with other oscillograph units.

Parts Required

T_1 — Mains Trans. 450–0–450V, 40mA, 5V 2A, 6·3V 2A. CT.	C_6, C_7, C_1 — 0·1μF 600Vw.
L_1, L_2 — 20H, 40mA Chokes.	C_2, C_3, C_4 — 8 + 8 + 8μF 500Vw.
S_1 — S.p. On/off Switch.	C_8, C_9, C_{10} — 8 + 8 + 8μF 550Vw.
S_2 — Single Bank 2-way Switch (Yaxley type).	C_5 — 50μF 12Vw.



DEFLECTION AMPLIFIER

Parts Required (Cont.)

R_1 — 82kΩ 1 watt.
R_2, R_5 — 4·7 MΩ ¼ watt.
R_3, R_4 — 4·7kΩ ¼ watt Carbon.
R_6 — 220Ω ½ watt.
R_7 — 22kΩ 1 watt.
R_8 — 220kΩ 1 watt.
R_9 — 1000Ω
VR_1, VR_2 — 20k wire-wound pot.
1 Grid cap.

1 Coax Plug and Socket.
2 Insulated Terminals.
1 Mazda Octal Valveholder.
2 Int. Octal Valveholders.
V_1 — SP61 (Govt. no. VR65).
V_2 — 6F6G.
V_3 — 5Z4G.
1 3-piece Valve Screen.

CHAPTER NINE

A STRAIGHTFORWARD VALVE TESTER

A Valve Tester, if of sufficient utility, can be put to many other uses apart from that of the routine checking of valves. This one has been used as an HT and LT power pack, as a supply source for taking characteristics and as an adaptor for the comparison of valves having different bases under actual working conditions. It can check valves directly for mutual conductance, shorts (including heater-cathode) and tests rectifiers and diodes for emission. Anode current can also be checked. The arrangement of valveholders renders the instrument immune to the danger of obsolescence. As all connections to the valve under test are made by plugs and sockets, any electrode arrangement can be accommodated, even tubes having overhead or tapped heaters, dual grids and other unusual features.

Now refer to the schematic diagram. A resistance smoothed power pack incorporating a half-wave metal rectifier supplies anode current to the valve under test at 250V. A three position switch inserts resistances in series with the anode for checking emission. The anode current is read directly on the meter, and a switch is incorporated which changes the bias by one volt. Thus to measure mutual conductance it is merely necessary to read the anode current, throw the switch and note the change in current. This change is the mutual conductance in ma/v. Heater-cathode leakage is checked by a switch which disconnects the cathode. Should there be any leakage, a current will still flow via the heater, and this is indicated on the meter.

All heater voltages are catered for by a selector switch on the LT circuit. Battery type valves may be checked in the tester, and 1·4V and 2V tappings are provided to facilitate this. Pentodes and tetrodes are tested as triodes, and multiple valves may be checked section by section.

The mains transformer is a 250–0–250V 60mA type, and must be modified in the following way:—Remove the LT windings, carefully counting the turns per volt. This is normally between 7 and 10. Now remove the HT sec.

as far as the centre tap, leaving the centre tap lead-out intact. Insulate the bobbin with a layer or two of Empire Cloth, and carefully wind on a 25V secondary, using 24 s.w.g. enamelled copper wire. Bring tappings out at 1·4V, 2V, 2·5V, 4V, 5V, 6·3V, 12·6V, and 25V, each lead out being carefully insulated and marked for reference. Now reassemble the transformer.

The ideal case for this instrument is a wooden box with a deep lid. The author used an old crystal-set box, about 8″ × 10″ × 6″ deep. The power unit and controls are fitted into the box, and the balve-base panel in the lid, the two being connected by a multiple cable. The feeds from the power unit terminate in sockets, labelled "Anode", "Screen", "Suppressor", "Cathode", "Grid", "Heaters". The valve sockets are wired to a line of 10 sockets, numbered 1–10, in this manner :—Pins no. 1 of all sockets are linked and taken to socket no. 1, Pins no. 2 to socket no. 2, etc. Naturally the higher numbered pins will not link with all valveholders, for instance, socket no. 8 would have no connection to a valveholder having less than eight pins. Socket no. 10 takes care of top caps, side terminals, etc., and merely feeds one or two other socket spaced over the panel. A short lead fitted with a crocodile clip or grid connector may thus be plugged in to the panel at one of these points. Both panels were made from ⅛″ black satin paxolin, but any other suitable material could be used. Metal was not considered owing to the non-availability of wander plug sockets suitable for mounting on a metal panel. The holes may be cut with either a chassis cutter or a fretsaw. The valveholders should be high quality types, preferably amphenol or ceramic. The number and variety of holders used will of course, depend on individual needs. The author used British 5, 7 and 9 pins, Octal, Mazda Octal, and Loktal; B7G, B9G and B8A; 5 and 8 pin side contact, UX4, 5, 6 and 7, and Continental 7-pin—a total of 16.

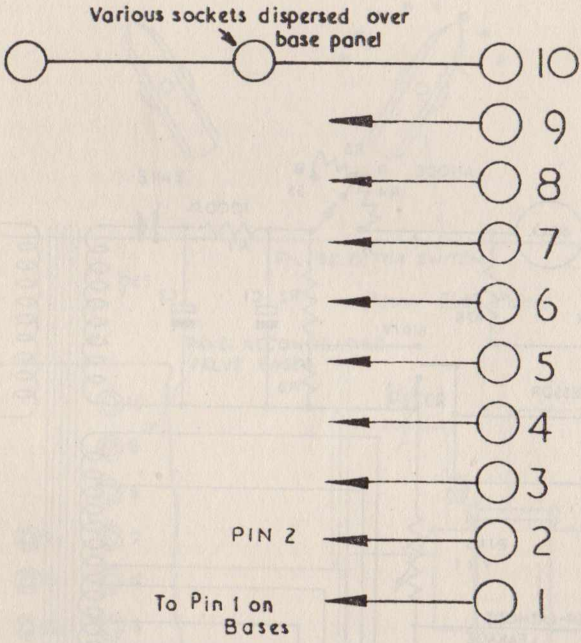
The details of construction should be apparent from the diagram. The meter is a 0–40mA ex.Govt. type having a 2″ scale.

For making the connections between the power unit socket and the base panel, a number of short leads should be made up, having wander plugs at each end, and also one with a crocodile clip at one end and a wander plug at the other for top caps and side terminals.

The tester should be used in conjunction with a reliable valve data book. Bernard's valve manual covers all the normal types of valve, and is very suitable. If a large number of unusual types is likely to be met, however, a more comprehensive work, such as Bernards International Tube Encyclopedia, is to be recommended.

As an example of the method of testing, the procedure for testing a 25A7 Output-pentode-rectifier will be explained. This is a multiple valve, and should be tested in two parts. The valve is plugged into the requisite socket. Set the heater voltage at 25V, connect Heater sockets to sockets 2 and 7. To test the rectifier, connect cathode to socket 1 and Anode to socket 6, the Anode switch being set to "R". Meter should read about 10mA if emission is normal. Depress Heater-Cathode switch. If insulation is sound, reading should fall to zero. Now for the pentode. Connect Cathode to 8, Anode to 3, Screen to 4 and grid to 5. Adjust Bias control until meter reads normal anode current as obtained from valve data. (In this case, 30mA.) Throw mutual conductance switch and note change in anode current. If this is reasonably close to the makers' value, the valve is sound in this respect. Check heater cathode insulation as before. For this test Anode res. is cut out by S_3.

When testing diodes, the 22kΩ res R_4 is insufficiently large to limit heavy current, and the Anode switch must be turned to position D where 44kΩ is inserted. Battery and low voltage valves should be tested with S_3 in position R.

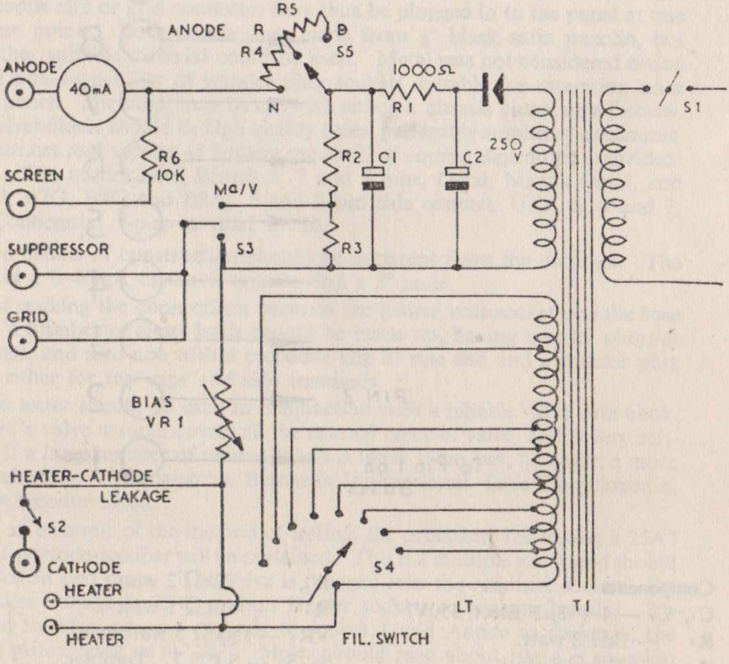


Components

C_1, C_2 — 4 + 8μF Elect. 350V.
R_1 — 1kΩ 2 watt.
R_2 — 220kΩ ¼ watt.
R_3 — 1kΩ ,,
R_4, $_5$ — 22kΩ 2 watt.
R_6 — 10kΩ 1 watt.
VR_1 — 1500Ω 3 watt w.w.
S_1, S_2 — S.P.S.T. Tumbler.
S_3 — S.P.D.T. ,,

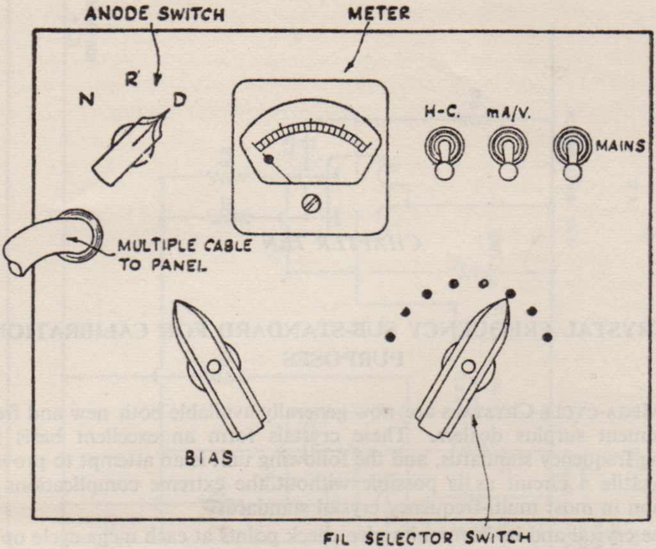
S_4 — 1 pole 8-way.
S_5 — ,, 3-way.
T_1 — Mains Trans. See Text.
Rect. 250V 60mA metal (Premier Radio).

Meter. 0–40mA moving coil.
21 Sockets.
Wander Plugs as required for links.
Valve Bases as required.
3 Pointer Knobs.

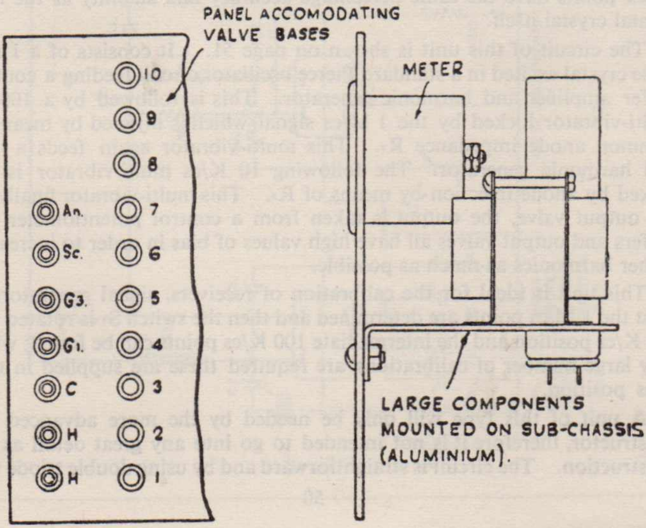


VALVE TESTER

LAYOUT OF VALVE TESTER



Power Unit Panel



CHAPTER TEN

A CRYSTAL FREQUENCY SUB-STANDARD FOR CALIBRATION PURPOSES

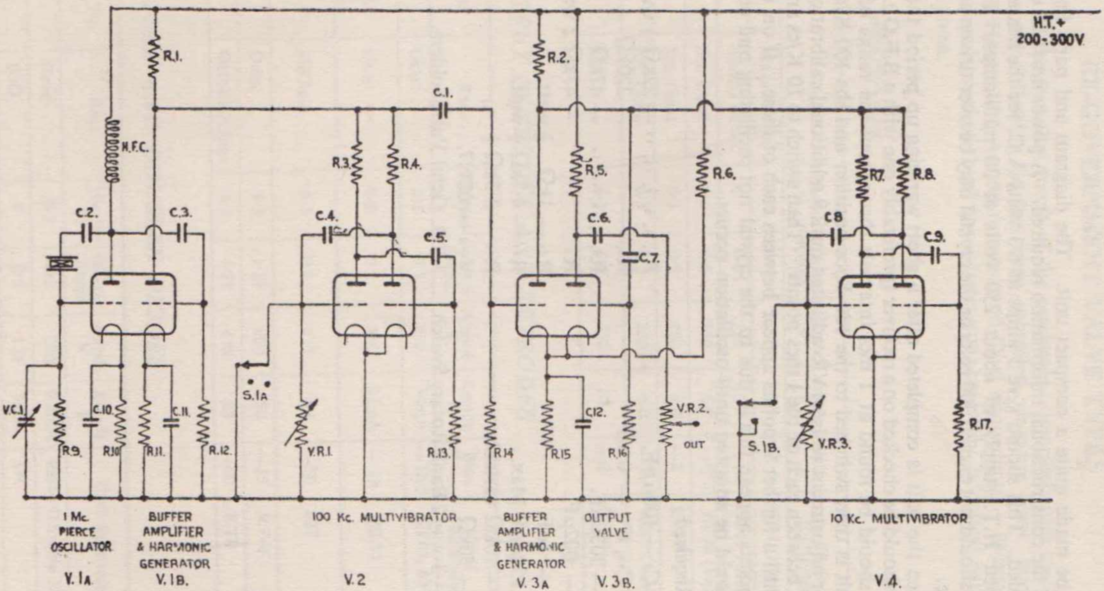
ONE MEGA-CYCLE CRYSTALS are now generally available both new and from government surplus dealers. These crystals form an excellent basis for making frequency standards, and the following unit is an attempt to provide as versatile a circuit as is possible without the extreme complications so common in most multi-frequency crystal standards.

The crystal and its harmonics give check points at each mega-cycle up to about 50 mega-cycles and it is followed by two multi-vibrators to subdivide the 1 mega-cycle points into 100 or if desired into 10 K/cs points. All these check points have the same percentage accuracy and stability as the fundamental crystal itself.

The circuit of this unit is shown on page 51. It consists of a 1 mega-cycle crystal excited in a standard Pierce oscillator circuit feeding a combined buffer amplifier and harmonic generator. This is followed by a 100 K/cs multi-vibrator locked by the 1 M/cs signal which is injected by means of a common anode impedance R_1. This multi-vibrator again feeds a buffer and harmonic generator. The following 10 K/cs multi-vibrator is again locked by anode injection by means of R_2. This multi-vibrator finally feeds the output valve, the output is taken from a control potentiometer. The buffers and output valves all have high values of bias in order to increase the higher harmonics as much as possible.

This unit is ideal for the calibration of receivers, signal generators, etc. First the 1 M/cs points are determined and then the switch S_1 is rotated to the 100 K/cs position and the intermediate 100 K/cs points can be found; where a very large number of calibrations are required these are supplied in the 10 K/cs position.

A unit of this type will only be needed by the more advanced home constructor, therefore it is not intended to go into any great detail as to its construction. The circuit is straightforward and by using double triode valves



A CRYSTAL FREQUENCY SUB-STANDARD

it can be made quite a compact unit. The diagram and parts list should give all the constructional information required. A power unit will of course be needed. This should give 3 amps at 6·3 volts A.C. for the heaters and a smoothed H.T. supply of about 250 volts at 30 milli-amps. The H.T. supply should not exceed 300 volts or the crystal may be over-driven and suffer damage.

When the unit is completed after a short warming up period the 1 M/cs output should be checked on a receiver (preferably one with a B.F.O.). Check points should be found at 1 mcs intervals throughout the range of the set. The unit is then switched to the 100 K/cs position and the 100 K/cs multi-vibrator adjustment resistor VR$_1$ adjusted until 9 additional calibration points appear between each of the 1 mcs points. Then switch to 10 K/cs and adjust VR$_3$ until a further 9 points appear between each of these. If on test no 1 M/cs points appear this is due to the crystal not oscillating and condenser VC$_1$ should be adjusted until oscillation occurs.

Parts Required

C$_1$, C$_6$, C$_7$ — 100$\mu\mu$F.	R$_{1, 2, 3, 7, 13, 17}$ — 22kΩ ½ watt.
C$_2$, C$_3$, C$_{10}$, C$_{11}$ — ·01μF	R$_{4, 6}$ — 220kΩ ,,
C$_4$, C$_5$ — 300$\mu\mu$F.	R$_{5, 9, 12, 14, 16}$ — 47kΩ ,,
C$_8$, C$_9$ — ·002μF.	R$_8$ — 47kΩ 2 watt.
C$_{12}$ — ·1μF.	R$_{10}$ — 1kΩ ½ watt.
VC$_1$ — 150$\mu\mu$F Max.	R$_{11}$ — 4·7kΩ ½ watt.
VR$_{1, 3}$ — 10kΩ variable	R$_{15}$ — 3·3kΩ ½ ,,
VR$_2$ — 50kΩ ,,	V$_{1-4}$ — 6SN7.
S$_1$ a-b — 3-way 2 Bank Rotary Switch.	4 Int. Octal Valveholders.

EX-GOVERNMENT VALVE TYPES

In view of the fact that much of the equipment described uses ex-Govt. valve types, the following list has been compiled, showing Govt. number, type, bases, Heater and Anode ratings, and Civil equivalents. Where the civil equivalent is marked thus* the valve is not absolutely indentical with the equivalent given.

(1) *H.F. PENTODES*

Govt. No.	Base	Heater V	Heater Amps.	Anode V	Anode I	Bias	Civil Equivalent
VR65	Mazda Octal	6·3	0·65	250	10·9	–1·5	SP61 (Mazda)
VR65A	Mazda Octal	4	0·95	250	10·9	–1·5	SP41 (Madza)
VR53	Int. Octal	6·3	0·2	250	6·0	—2·5	EF39 (Vari-*u*)
VR56	Int. Octal	6·3	0·2	250	3·0	—2	EF36
VR100	Int. Octal	6·3	0·3	250	6·0	—3	*6K7 (Vari-*u*)
VR91 / ARP35	B9G	6·3	0·3	250	10	—2	EF50

(2) *OUTPUT PENTODES AND TETRODES*

Govt. No.	Base	Heater V	Heater Amps.	Anode V	Anode I	Bias	Civil Equivalent
CV1186	Octal	6·3	0·7	250	34mA	— 16·5	KT63, 6F6G
VT52 / CV1052	Octal	6·3	0·2	250	32mA	— 18	EL32
VT60 / CV124	UX5pin	6·3	0·9	475	83	—50	807
CV1075	Octal	6·3	1·27	400	850	—15	KT66
VT79	Octal/UX5pin	6·3	1·27	475	83	—50	KT8

(3) *DIODES AND DOUBLES DIODES*

Govt. No.	Base	Heater V	Heater Amps	Anode V	Anode I	Civil Equivalent
VR54	Octal	6·3	0·2	200	0·8mA	EB34 (Double Diode)
VR78	B3G	4	0·2	125	5mA	D1
VR92	B3G	6·3	0·15A	50	5mA	EA50

(4) *TRIODES AND DOUBLES TRIODES*

Govt. No.	Base	Heater V	Heater Amps.	Anode V	Anode I	Civil Equivalent
CV1573	Brit. 5-pin	6·3	0·9	300	40mA per triode	*TV03-10 (Double triode)
VT61	U.X. 7-pin	6·3	0·8	300	37 per triode	4074A, DET19, RK 34 (D. Triode)
CV181	Octal	6·3	0·95	250	6·0mA per triode	ECC31 (Double Triode)
CV6	Octal	6·9	0·45	300	/	*E1148 (U.H.F. Triode)
VR67	Octal	6·3	0·3	250	8	L63, 6J5
VT25	P.A.	6·0	1·28	1200	300mA	DET25 (D.H. Power Triode)
VT73	Octal	6·3	0·3	250	1mA	H63

(5) *SPECIAL TYPES*

Govt. No.	Base	Heater V	Heater Amps.	Civil Equivalent
CV3723	Mazda Oct.	4	1·5	T41 Thyratron
CV1128	5-pin	4	1·2	G.T.1C Gas-filled Relay
VI77	Octal	6·3	0·2	Em31 Tuning Ind.
VI103	Octal	6·3	0·3	Em35 Tuning Ind.
CV45	4-pin	/	/	S130 Stabilizer
CV1070	4-pin	/	/	7475 Stabilizer

BERNARDS RADIO BOOKS