TECHNICAL DESCRIPTION

MARCONI-E.M.I. SYSTEM OF TELEVISION

PART 6 AUXILIARY APPARATUS

CONTENTS

THE WAVEFORM MONITOR

It is essential to be able to check the shapes and amplitudes of the various waveforms encountered in different parts of the vision circuits, and this may most conveniently be done by observing them upon a cathode ray oscillograph. The Waveform Monitor is a cathode ray oscillograph especially designed to examine the pulses and other vision waveforms, having regard to the frequencies involved.

The monitor provides for other facilities than the simple examination of the waveforms. It has been designed to enable, for instance, two waveforms to be observed at the same time, and therefore directly compared, and also the amplitude in volts of any waveform to be measured. Lastly the waveforms can be examined with their D.C. component either eliminated or retained. The unit contains its own rectifiers to supply the necessary electrode potentials.

155

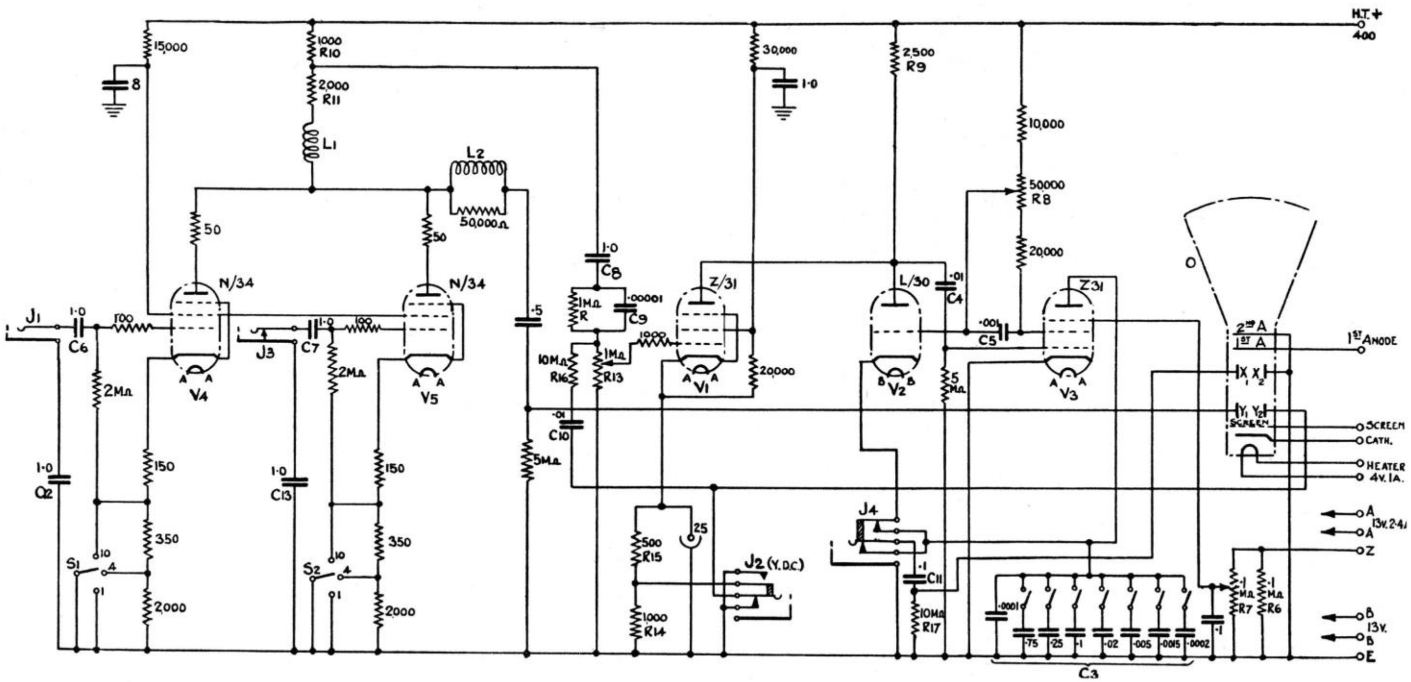
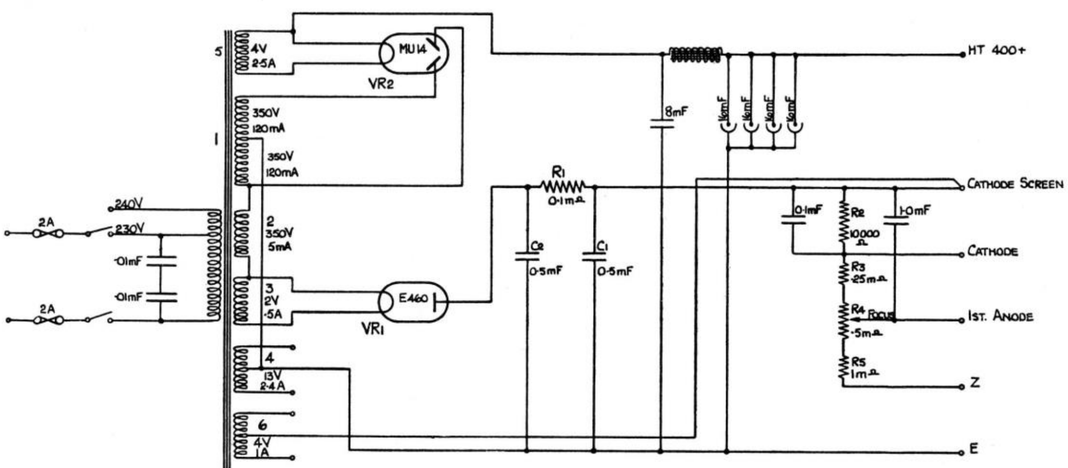


Figure 1. Circuit Diagram of Waveform Monitor



N.B.—The symbol 'mF' where used should read 'μF.'

Figure 2. Circuit Diagram of Associated Power Unit

The circuit diagram is shown in Figs. 1 and 2, of which Fig. 1 gives the circuits associated with the oscillograph itself and Fig. 2 shows the power supplies. Considering the circuit diagram of Fig. 1, O is a $3\frac{1}{2}$ in. cathode ray tube with a green screen, having a heater, a cathode, a screen, a pair of x plates, a pair of y plates, a first anode and a second anode. The tube is of a type in which the second anode is earthed, and therefore the cathode is at a potential of nearly -1000 volts to earth. This potential is generated by the rectifier VR_1 shown in Fig. 2, and smoothed by the circuit $C_1 R_1 C_2$. It is then applied to the potentiometer consisting of the resistances R_2, R_3, R_4, and R_5 of Fig. 2, together with R_6 and R_7 in parallel, of Fig. 1. The screen of the cathode ray tube receives a fixed negative bias with respect to the cathode due to the voltage drop across R_2 of Fig. 2. and the spot is focused by adjustment of the ratio of the first and second anode potentials by means of the potentiometer R_4 of Fig. 2, this control consequently being designated **Focus.**

It is necessary to apply to the x plates of the tube a linear saw-toothed sweep voltage whose frequency can be varied from 25 c.p.s. for examining frame waveforms to at least 20250 c.p.s. for examining twice line frequency waveforms, but actually the circuits are designed to develop a frequency as high as 1 Mc/s in order to examine very high frequency components of the vision waveform if desired. Referring to Fig. 1, the requisite saw-toothed sweep voltage is generated by the valves V_2 and V_3, which therefore constitute a time base, and applied to the plate x_1, the plate x_2 being connected to earth.

The circuit associated with V_2 and V_3 is somewhat unusual in that it is in effect a relaxation oscillator in which the condenser is gradually discharged during the time of the sweep, and rapidly charged to execute the fly-back. It will be remembered that it is more usual to charge the condenser during the sweep period and discharge it during the fly-back period.

The action of the circuit is as follows. At the commencement of the sweep the spot, which scans from left to right, is fully deflected to the left as viewed by the operator due to the existence of a positive potential on the condenser C_3. The upper side of the condenser C_3 is connected to the anode of the pentode V_3, and also by a contact on the jack J_4 to the cathode of the triode V_2. The grid of V_2 is given a positive potential from the potentiometer R_8, the value of which is much less than that existing on the cathode of V_2, so that at this time the grid of V_2 is negatively biassed with respect to its cathode and V_2 is non-conductive. Its anode potential is consequently high, being equal to the H.T. The pentode V_3 is, however, conductive and therefore the potential on C_3 discharges via V_3 linearly, its discharge constituting the sweep period. As the anode potential of V_3 falls, so does the cathode potential of V_2, and eventually the latter falls to a value approaching that of the grid of V_2, when this valve becomes conductive. Anode current
157 therefore flows in V_2, and this charges up the condenser C_3, this charge constituting the fly-back period. Due to the presence of the anode resistance R_9, the anode potential of V_2 falls, thus driving the control grid of V_3 strongly negative via C_4. V_3 is therefore rendered non-conductive, and its screened grid potential rises, this increase of potential being communicated to the control grid of V_2 via the condenser C_5. The action is therefore of the cumulative type, of which once V_2 has started to be conductive, it is driven by the multivibrator action of V_2 and V_3 together to its maximum conductivity. The condenser C_3 is therefore charged in the shortest possible time, because the maximum emission of V_2 is used for this purpose, and the fly-back time is consequently very short. When the condenser C_3 is fully charged, the anode current of V_2 ceases, there is no longer any voltage drop across R_9, the pulse through C_4 therefore reverses, and the control grid of V_3 returns to its normal potential. The potential of the screened grid of V_3 follows suit thus reversing the pulse through C_5, and lowering the control grid of V_2 to the potential determined by R_8, so that the state of affairs is now that which obtains at the beginning of the sweep period, in which the potential of the cathode of V_2 is much greater than that of its grid, and V_2 is non-conductive. The cycle accordingly repeats itself.

The frequency is dependent in part upon the value of C_3, and so a convenient coarse frequency adjustment is obtained by a selector switch which varies the value of C_3 by connecting in a number of individual condensers. The frequency is, of course, also dependent upon the value of the dis charging resistance associated with C_3, this resistance being the anode cathode path of V_3. This is conveniently variable by imposing an adjustable negative potential on the suppressor grid. This potential is controlled by the potentiometer R_7, which is consequently designated **Frequency.** The potential is derived from a 1000 volt rectifier, the output of which is, as has been explained, negative to earth.

The amplitude of the sweep is clearly dependent upon the value of the grid potential of V_2 and the potentiometer R_8 is accordingly designated **Amplitude.**

The waveform to be examined is applied via the jack J_1 to the valve V_4, which is a single video frequency amplifying stage having the usual frequency correction circuits in the anode involving the inductances L_1 and L_2. The output is applied to the plate y_1, the plate y_2 being normally earthed via contacts on the jack J_2. A second waveform may be simultaneously examined by being applied to the jack J_3, when it is amplified by the valve V_5. The anode circuits of V_4 and V_5 are common and so both waveforms appear on y_1. The gain of both V_4 and V_5 may be adjusted to have a value of 1, 4 or 10, by means of individual selector switches S_1 S_2, which vary the value of the cathode resistances of these valves and therefore the feed-back. It will be seen that when the waveform to be examined is applied via J_1 or J_3, the D.C. component will be lost due to the presence of C_6 or C_7.

In order to examine the waveform without losing the D.C. component, it is applied not to J_1 or J_3, but to J_2, when the plate y_2 is removed from earth and receives the waveform. In these circumstances there will be no plugs in the jacks J_1 and J_3, and these jacks then earth the control grids of V_4 and V_5 via the condensers C_{12} or C_{13}, thus preventing any extraneous signal reaching y_1, which is effectively earthed.

In order to synchronise the frequency of the time base with that of the waveform to be examined, the latter is applied to the control grid of the valve V_1. When the waveform is being applied via J_1 or J_3 the input of V_1 is derived from a tapping on the anode resistance R_{10} R_{11} of the amplifiers V_4 V_5, and proceeds via the condenser C_8, which holds off the H.T. and the frequency correction circuit C_9 R_{12}, to the grid potentiometer R_{13} of V_1, this potentiometer being consequently designated **Hold.** This is done for two reasons.

In the first place, if a succession of waveforms is being examined via J_1 or J_3 which require various degrees of amplification from V_4 or V_5, then similar variations in amplification should be provided in the output to be used for holding the time base. Secondly, where a waveform consisting of mixed vision and sync signals is being examined via J_1 or J_3, it is desirable that the **hold** should not be upset by variations in the nature of the vision component of the waveform. In general these waveforms are applied to J_1 and J_3 in such a sense that the vision component is in the positive direction and the sync component in the negative direction. In the anode circuit of V_4 V_5, therefore, they are reversed, and if V_1 is normally over-biassed the vision components will be largely suppressed. This over-biassing is provided by means of the somewhat high value of the total cathode resistance $R_{14} + R_{15}$ normally employed.

When it is desired to examine such signals without losing the D.C. component, the waveforms must be applied via the D.C. jack J_2. In this case V_4 and V_5 will be out of action and an input to the synchronising valve V_1 is provided via the condenser C_{10}, which holds off the D.C. component and the very high resistance R_{16} which gives the input an appropriately high impedance. In these circumstances the synchronising signals will be in the negative sense at the control grid of V_1 and they would be eliminated or weakened by the over-biassed operating condition. It is therefore arranged that when a plug is inserted in the jack J_2 the back contacts short circuit a portion, R_{14}, of the cathode resistance of the valve V_1, thus biassing the valve to the centre of its characteristic. When no plug is inserted in J_2 this short is removed and also the plate y_2 is earthed, thus preventing the entry of extraneous signals via this plate when the plate y_1 is being used via the amplifiers V_4 or V_5.

The synchronising voltage is developed at the anode of V_1 due to the presence of the anode resistance R_9 which is common to V_1 and V_2, and the synchronising pulse is accordingly applied to the grid of V_3. Provision is made by means of the jack J_4 for use of the external sweep generator if required. In the ordinary way when no plug is in J_4, the time base V_2 V_3 supplies the sweep voltage to the plate x_1 via C_{11} and R_{17}. As will be seen from the diagram, J_4 permits of the connection of an external source to C_{11}, at the same time isolating it from the time base V_2 V_3, and suspending the action of these valves by isolating the cathode of V_2 from the condenser C_3, which accordingly remains discharged.

The high tension supply for the valves V_1 to V_5 is derived from the separate rectifier V_{R2} shown in Fig. 2, and has a value of 400 volts.

Operation and Adjustment

The use of the Waveform Monitor will be in general clear from the foregoing text.

It is essential when examining a waveform derived from the jack J_1 in the Line Divider or the jacks J_1 and J_2 of the Frame Divider Panel 1, or the jack J_1 of the Frame Divider Panel 2, to apply them to the D.C. jack J_2, as otherwise the impedance of the input circuits of the valves V_4 and V_5 will disturb the action of the Line and Frame Dividers.

The cathode ray tube may be calibrated by applying known volts from a battery to the jack J_2 and marking the position of a spot on a scale.

Testing

For the purpose of testing a table of the various electrode potentials which should be found is given below.

	Valve	E_a—E	E_s—E	E_c—E	
V_1	Z31	395	150	12.0	Measured on lowest freq. range. Freq. and amp. controls at max.
V_2	L30	395	—	260	
V_3	Z31	360	80	—	
V_4	N.34	240	220	5.4	Measured with gain at 10 : 1
V_5	N34	240	220	5.4	

158

THE POWER SUPPLY STABILISATION SYSTEM

It has been emphasised that the circuits associated with the vision system require anode and screen supplies of a very high standard of excellence in respect of stability of voltage and freedom from electrical disturbances, since any instability or disturbance in the voltage of these supplies manifests itself in unsteadiness and flicker in the picture. The importance of eliminating any such effects will be readily appreciated if it is remembered that a number of the circuits are operating under D.C. conditions, and that the picture itself is finally produced by a direct current.

These supplies are generated from the mains by rectifiers, followed by smoothing circuits, which follow more or less standard practice, but it is found that the voltages so generated cannot then be directly applied to the vision circuits without further treatment, which resolves itself conveniently into two processes.

(1) The internal impedance of the source is in general too high, and it must be given a low impedance so that the ultimate output voltage will not fluctuate due to variation in the current required by the vision circuits.

(2) The mains themselves from which these voltages are derived are found to be subject to disturbances and to various spurious changes of voltage, all of which must be smoothed out so that no effect is produced upon the voltages to be used as anode and screen supplies.

It will be remembered from my technical note on the Cathode Follower that both of the above requirements can be simultaneously carried out by the insertion of such a circuit between the source of H.T. and the load. A cathode follower so used is known as a Stabiliser. The term *stabilisation* however, is generally applied to any process which contributes towards the stability of anode and screen supplies, whether they specifically employ a cathode follower or not.

Considerable use is made of stabilisers in the high tension supply systems for the vision apparatus, and two systems of stabilisation are used, which we will designate *A* and *B*. *System A*, the original design, is largely satisfactory, but has been found to have certain slight disadvantages, which have been overcome in *System B* which was designed later.

The theoretical aspect of the Stabiliser has already been treated in my technical note on the Cathode Follower, and on the assumption that this has been read, the circuits of the two systems will now be considered.

159

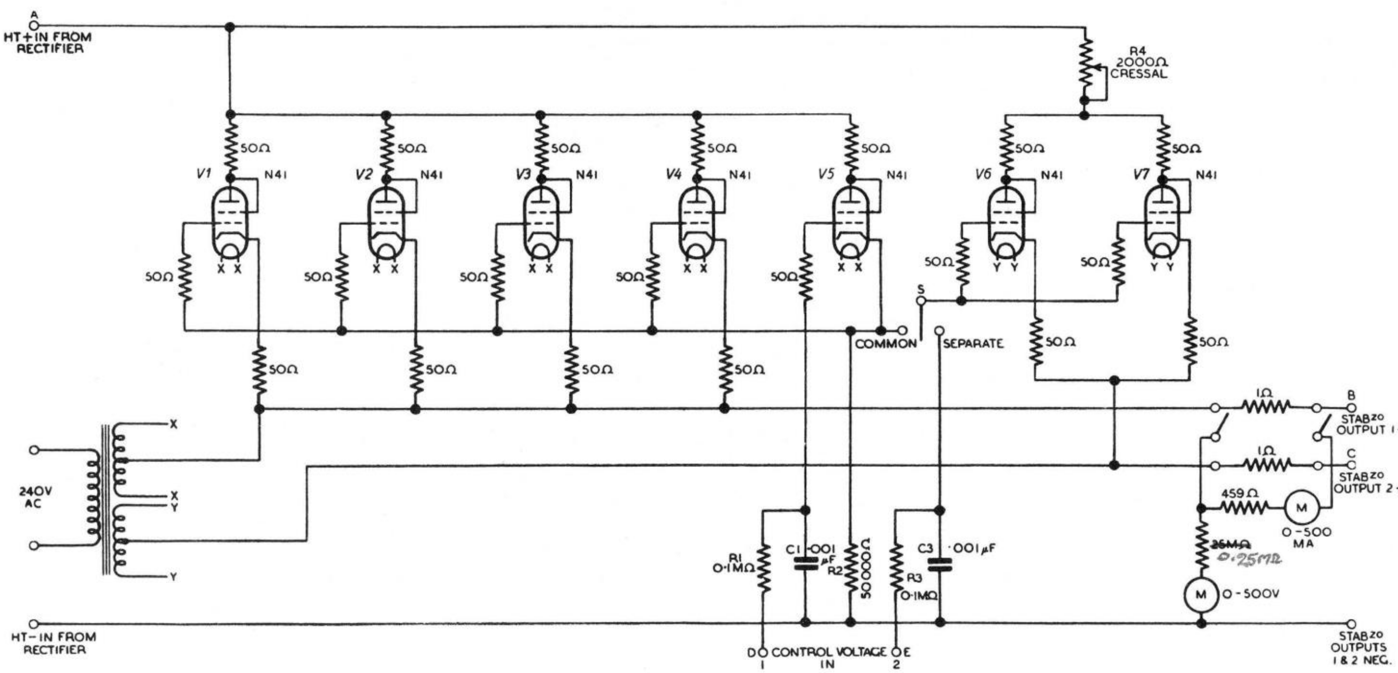


Figure 1. H.T. Stabiliser for All Vision Units except Head Amplifier

Power Supply Stabilisation System 'A'

160

POWER SUPPLY STABILISATION—SYSTEM 'A'

The apparatus comprised in this system may conveniently be divided into three sections.

(1) **The H.T. Stabiliser.** This unit contains a number of cathode followers working under D.C. conditions, which effect the main process of stabilisation.

(2) **The Mains Stabiliser Unit.** This is an auxiliary which enhances the smoothing effect of the H.T. Stabiliser upon mains fluctuations.

(3) **The Control Voltage Panel.** This supplies the necessary steady source of positive grid voltage which the H.T. Stabiliser requires.

The number of H.T. and Mains Stabilisers provided depends, of course, upon the number of supplies to be stabilised, but it will be seen that only one control voltage panel is necessary. Further, the H.T. Stabilisers themselves are of two different types, one type being suitable for all vision units except the Head Amplifiers, and the other being designed for the Head Amplifiers. The various units apertaining to System 'A' will now be described.

H.T. Stabiliser for All Vision Units except Head Amplifiers

The circuit of this type of stabiliser is given in Fig. 1. It is designed to give two separate H.T. outputs, No. 1 being of the order of 300 V, and suitable for the anode supplies of much of the vision apparatus, and supply No. 2 being intended to be of lower voltage suitable for the screened grid supplies of such apparatus.

The valves V_1, V_2, V_3 and V_4 are four cathode followers in parallel, their anodes being supplied from the source of H.T. power via the input terminal A. Their cathodes are, of course, connected to the load via the output terminal B. The valves V_6 and V_7 are another pair of cathode followers in parallel, their anodes being supplied from the main power input, and their cathodes feeding the second output via the output terminal C.

The use of cathode followers in parallel is, of course, due to the fact that the currents which it is required that the outputs B and C shall deliver are greater than can be safely passed by one valve. The controlling factor is, of course, the maximum dissipation which each valve will stand. As an example, in certain instances the stabilisers are adjusted to deliver an output voltage from terminal B of 300 V. The input at terminal A is 430 V., so that across each valve there is a drop of 130 V. The maximum dissipation for the type of valve used is 10 watts, so that the maximum permissible current per valve is 80 mA. Consequently with four valves in parallel, the stabiliser will deliver 320 mA from terminal B.

The output voltage is, of course, determined by the positive grid bias applied to the stabiliser valves. This bias is supplied from a unit known as the Control Voltage Panel. This bias will, from stabiliser theory, be always a few volts ~~greater~~ less than the desired output volts. The stabiliser valves in operation therefore draw grid current. It is desired to isolate this grid current from the control voltage panel, as if this were not done the value of the bias would vary with the amount of apparatus, and consequently with the number of stabilisers in use, due, of course, to differences in the grid current which the Control Voltage Panel would be required to deliver. For this purpose the valve V_5 is provided, which is a cathode follower or stabiliser working on exactly the same principles as the rest of the valves in the unit, but provided for the purpose of isolating the grids of V_1, V_2, V_3, V_4, V_6 and V_7 from the Control Voltage Panel and supplying them at low impedance. In operation the control voltage, or positive grid bias, entering via terminal D, is applied to the grid of V_5 via the decoupling circuit R_1 C_1. The anode of V_5 is similarly connected to the main H.T. supply, and the cathode contains the unshunted resistance R_2. Across R_2 therefore there exists a positive voltage which is now applied to the grids of V_1, V_2, V_3 and V_4, and constitutes the positive bias which will determine the value of their output voltage.

The grids of V_6 and V_7 also require a positive voltage, but since they are intended to deliver a lower output voltage, the effective grid current is less serious, and no intermediate grid bias stabiliser similar to V_5 is provided, the grids being fed directly from the control voltage panel via an input terminal E, and the decoupling circuit R_3 C_3.

The stabiliser can be adapted for use in circumstances where no separate second output (terminal C) is required, but possibly a greater current is required from the first output (terminal B). In this case the switch S is thrown to the position designated **Common,** and the valves V_6 and V_7 are thrown in parallel with the valves V_1, V_2, V_3 and V_4, and the stabiliser should then deliver some 480 mA at 300 V.

When V_6 and V_7 are in use to generate an output voltage of 150, the dissipation will be very heavy and the maximum current per valve, since there is a drop of nearly 300 V. between anode and cathode, will be only 35 mA. The resistance R_4 is therefore included in the anode circuit of V_6 and V_7 in order that the dissipation may occur in it rather than in the valves. The internal impedance, or apparent regulation of the main H.T. supply to V_6 and V_7 is, of course, increased by the amount of R_4, but this is of little account as this increase will appear at the output (terminal C) to have been divided by the magnification factor of the stabiliser valves V_6 and V_7.

It should be noted that the stabiliser is in no way restricted to the particular output voltages and currents mentioned above, which are, however, typical of the conditions under which it is usually required to operate.

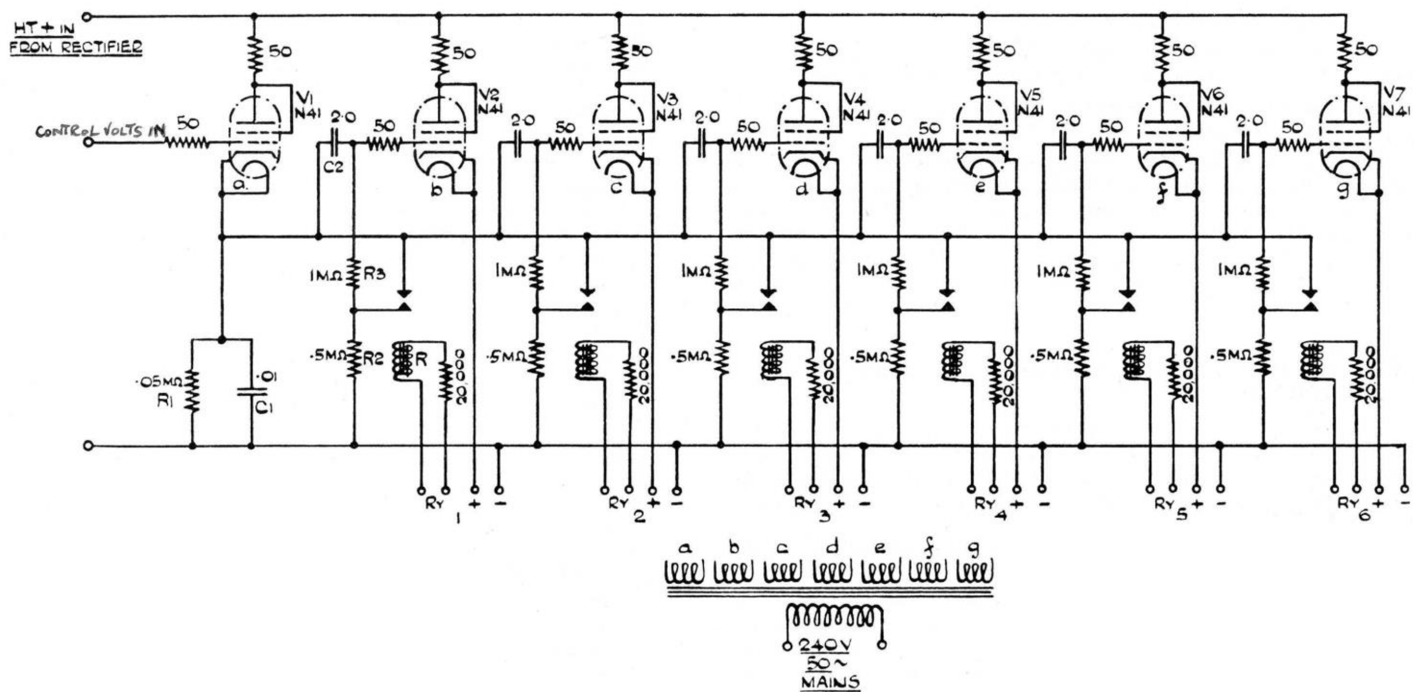


Figure 2. H.T. Stabiliser for Head Amplifiers

Power Supply Stabilisation System 'A'

H.T. Stabiliser for all Vision Units except Head Amplifiers (*Contd*)
The values of the output voltages delivered are entirely controlled by the value of the positive grid bias applied at the terminals D and E, and if it were required that the stabiliser should deliver, for instance, 365 V. from terminal B, at, of course, a correspondingly reduced current, and say, 100 V. from terminal C, in which case the permissible current consumption would be greater, this could easily be arranged by appropriately adjusting the voltages supplied to terminals D and E.

The Studio vision equipment is provided with eight stabilisers of the above type which are connected in the following manner :

Nos. 1 & 2 These supply anode and screen voltages to the Pulse Generators, and the outputs of both stabilisers are paralleled, that is to say, the terminal B of Stabiliser No. 1 is connected to the terminal B of Stabiliser No. 2, and a similar connection applies to the terminals C. The output voltage at terminal B is 285 V., and that at terminal C is 135 V.

No. 3 This supplies the Distribution Amplifier of Picture Channel 2 (Bay 6). In this case the switch S is in the **Common** position as no screen voltage is required, but instead, a somewhat heavy current from one output. The output is at 300 V.

No. 4 This supplies the Distribution Amplifier of Picture Channel 1 (Bay 5), and is connected similarly to No. 3.

No. 5 This supplies anode and screen potentials for the 'C' Amplifier, the Suppression Mixer and the Picture and Sync Mixer of Picture Channel 2 (Bay 6). The output voltage at terminal B is 350 V., and that at terminal C, 200 V.

No. 6 This supplies the 'C' Amplifier, the Suppression Mixer and the Picture and Sync Mixer of Picture Channel 1 (Bay 5) and is connected as in the case of No. 5.

No. 7 This supplies anode and screen voltages for the 'B' Amplifiers of Picture Channels 1 and 2 (Bays 5 and 6). The output voltage at terminal B is 350, and at terminal C is 200.

No. 8 This supplies anode voltage only to all the 'A' Amplifiers, the Fading and Monitoring Mixer and the Phase Reverser. In this case, of course, the switch S is in the **Common** position, and the output voltage is 350.

H.T. Stabiliser for Head Amplifiers

The circuit of this unit is shown in Fig. 2. It will be seen that there are in all 7 valves, of which V_2 to V_7 inclusive are separate stabilisers which feed H.T. individually to each of the six Head Amplifiers. The necessary control voltage for these valves is derived primarily from the Control Voltage Panel via the valve V_1, which acts as an isolation cathode follower and supplies the grid current drawn by the stabiliser valves.

The unit also contains the necessary means for switching the H.T. supplies to each Head Amplifier, and it is preferred to perform this operation by switching the control voltage to the stabiliser valves rather than the H.T. outputs, as in the former case there is negligible current at the relay contacts. It is desired that the H.T. should be applied or removed gradually, as otherwise the switching of one Head Amplifier during a transmission would produce a sharp transient in the H.T. supplies to the other Head Amplifiers, the effect of which would be noticeable in the picture. This is carried out in the following manner, which will be described in connection with the valve V_2 since the circuits of each of the six stabiliser valves are identical.

When the contacts of the relay R are open, the control voltage from the cathode circuit of V_1 is applied across C_2, R_3 and R_2 in series. C_2 is thus fully charged, and there is no voltage across R_2 and R_3. The grid of V_2 is therefore at earth potential and the cathode voltage of this valve which is, of course, the stabilised H.T. supply for the head amplifier is negligible.

It will be evident from cathode follower theory that the stabilised output cannot be reduced to zero by this means. This output constitutes an automatic grid bias for the stabiliser valve, and if it were zero the valve would be in a condition of maximum conductivity. In operation the output voltage takes up a value such that the stabiliser valve is self-biased to a condition in which it passes only that current which, passing through the output impedance, generates the required self-bias voltage. This point is of importance because, although the Head Amplifier H.T. is ostensibly switched off by the action of the relay R, it will still be possible to draw a heavy current from the stabiliser output if this should be accidentally short circuited, since, there being now no cathode impedance, there can be no self-bias, and the stabiliser valve is in a fully conductive condition.

When an operating voltage is applied to the relay R, the contacts close, and the condenser C_2 discharges through the resistance R_3 so that the junction of C_2 and R_3 takes up the same potential as the cathode of V_1. The grid of V_2, which is connected to the junction of C_2 and R_3, therefore receives the positive control voltage from the cathode of V_1. V_2 is now fully conductive, and a value of H.T. nearly equal to the applied control voltage is developed at its cathode and is passed to the Head Amplifier. The values of C_2 and R_3 are 2 μF and 1 megohm respectively, so that the discharge of C, and consequently the application of control voltage to the grid of V_2, is under the control of the time constant of 2 seconds. This voltage and the stabilised output therefore develop gradually.

When the relay contacts are opened, the condenser C_2 charges slowly through R_2 and R_3, and the H.T. is similarly reduced gradually under the control of the time constant $C_2(R_2 + R_3)$ which has a value of 3 seconds. No particular significance attaches to the difference in the two time constants, which only arises because the presence of R_2 is an essential of the circuit. Without R_2 the relay would short circuit the control voltage supply from V_1.

H.T. Stabiliser for Head Amplifiers *(Contd)*

As will be seen from my note on the Focus Panel, the operating voltage for the relay R is derived from the push-button contactor in the appropriate Focus Panel. This arrangement is provided so that the single operation of opening the push-button contactor will remove the emitron gun potentials and theHead Amplifier H.T., and thus remove from the camera cable all dangerous voltages.

The Control Voltage Panel

The necessary positive grid voltage required by the H.T. Stabiliser is generated by a unit known as the Control Voltage Panel, the circuit of which is given in Fig. 3. It consists of a valve rectifier, the output of which is smoothed by the circuit C_1 L_1 C_2, and applied through the resistance R_1 to the series of neons N_1, N_2, N_3. The function of the neon lamps in conjunction with the resistance R_1 is to give a certain degree of preliminary stabilisation to the control voltage before it is applied to the stabiliser grids, even though it is isolated from these grids by an additional cathode follower (V_5 of Fig. 1). It may seem that exaggerated precautions are taken to stabilise the control voltage, but it must be remembered that it is this voltage which determines the value of the final output-anode and screen voltages. The neon lamps operate in the following manner.

A certain minimum voltage must be applied to a neon lamp before any discharge occurs. This having happened, however, the voltage required to maintain the discharge falls, because the current flowing is mainly due to ionisation of the neon molecules by collision with the stream of electrons constituting the striking current. A very slight increase of e.m.f. across a neon will greatly increase the current flowing through it owing to the cumulative effect of the increased number of collisions which are engendered. Conversely, a large change of current can take place without the voltage across the neons being much altered. A resistance (R_1 in Fig. 2) is necessary to limit the current, as if it were not present the cumulative effect would produce a current of sufficient magnitude as to destroy the neon.

It is clear therefore that if a neon or a series of neons be fed through a resistance from a supply, current may be taken from the junction of the resistance with the neons, since such current will pass from the supply to the output instead of passing through the neons, and, as we have seen, there will be little change of voltage across the neon due to this cause. The use of a number of neons in series enables a number of output voltages to be obtained, all stabilised, as the system is equivalent to a single tapped neon.

It will be seen that in the circuit of Fig. 3 the three neons are associated with a potentiometer R_2 to R_{11}, in such a way that any voltage between 50 and 350 in 50 V. steps can be obtained. These voltages are available for connection as required to the grids of the valves V_5, V_6 and V_7 in the stabiliser of Fig. 1, so that the latter can be made to deliver voltages approximating to any of those delivered by the Control Voltage Panel.

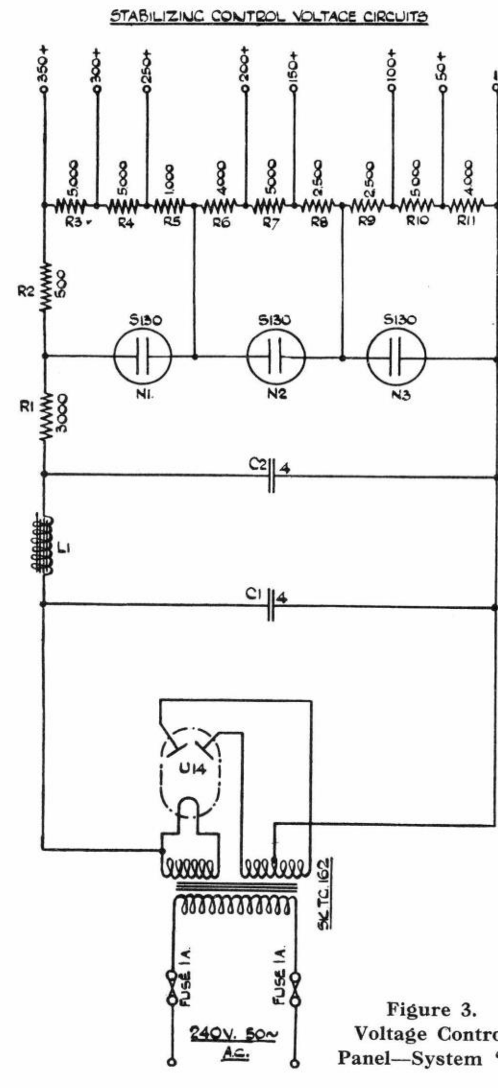


Figure 3.
Voltage Control Panel—System 'A'

Mains Stabilising Panel

An H.T. supply system consisting of (a) a rectifier, (b) a stabiliser, and (c) a control voltage generator for the stabiliser, is all that is fundamentally required to deliver stabilised H.T. to the vision apparatus. It is found, however, that even with the above the degree of stabilisation provided by such a system is not quite adequate, and effects of unsteadiness in the picture due to fluctuations in the mains supply can be observed, and it is desirable that they should be neutralised. In order to effect this, an additional unit known as the Mains Stabilising Panel is provided, the circuit of which is shown in Fig. 4. It will be seen that the unit contains six individual valve circuits which are all identical in principle, and it will therefore suffice to describe one, the circuit associated with V_1.

The voltage from a given eliminator output is applied to the potentiometer R_1, R_2, R_3. A tapping on the potentiometer R_2 is connected via the condenser C_1 to the grid of V_1. C_1 holds off the steady D.C., and any disturbances in the supply will reach the grid. They are amplified and reversed by V_1 and, by means of the condenser C_2 and the resistance R_5, are added in series with the control voltage on its way to the appropriate stabiliser. Here, being in anti-phase, they will energise the grids of the stabiliser valves in the inverse manner to the original disturbances which are entering the stabiliser from the H.T. supply. Clearly, by seeking the correct adjustment of the potentiometer R_2, these fluctuations can be neutralised. It will be seen that the values of R_3 have been individually adjusted in the case of each of the six circuits. This was found to be necessary in order to bring the point of neutralisation properly within the range of adjustment of the potentiometer R_2 in each case. It is found to be unnecessary to apply this process of neutralisation to all the high tension supplies, and the six circuits provided in the Mains Stabilising Panel are allocated as follows:

No. 1 Control voltage supply to the valves V_1 to V_4 in stabilisers Nos. 1 and 2, providing 300 V. output to Pulse Generator anodes.

No. 2 Control voltage supply to the valves V_6 and V_7 in stabilisers Nos. 1 and 2, providing 150 V. output to Pulse Generator screens.

No. 3 Control voltage supply to the valves V_1 to V_4 in stabiliser No. 7, providing 350 V. output to 'B' Amplifier anodes.

No. 4 Control voltage supply to the valves V_6 and V_7 in stabiliser No. 7, providing 200 V. output to 'B' Amplifier screens.

No. 5 Control voltage supply to the valves V_1 to V_4, V_6 and V_7 in stabiliser No. 8, providing 350 V. output to all 'A' Amplifiers, Fading and Monitoring Mixer and Phase Reverser.

No. 6 Control voltage supply to the Head Amplifier stabiliser panel.

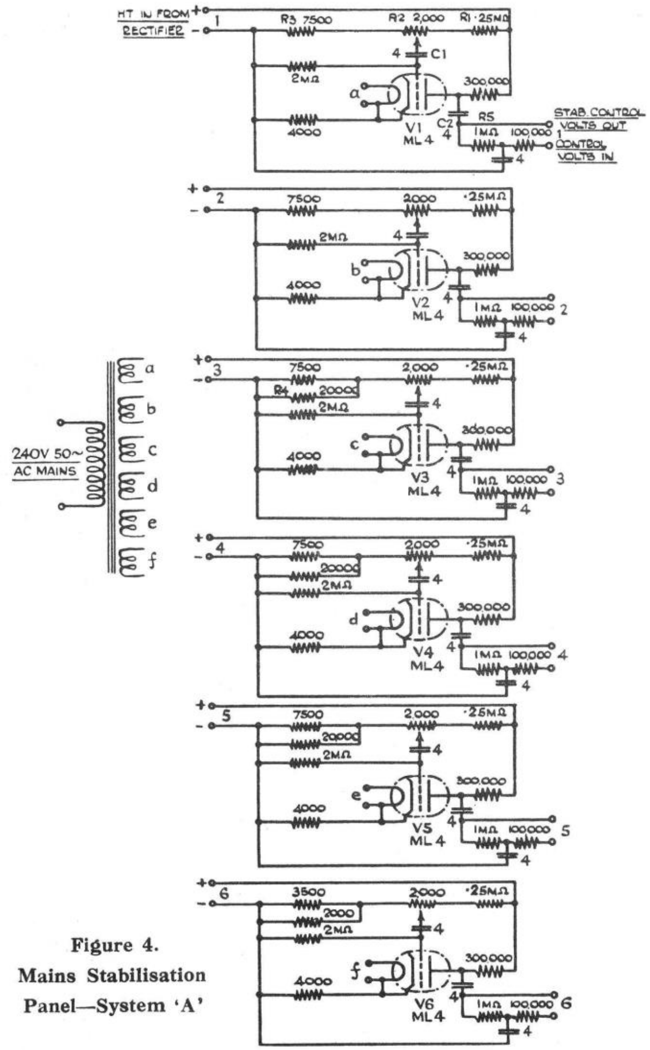


Figure 4.
Mains Stabilisation Panel—System 'A'

POWER SUPPLY STABILISATION—SYSTEM 'B'

The stabilising system described above, though satisfactory from the point of view of providing a low output impedance for the H.T. supply, is not completely effective in removing fluctuations originating in the mains, especially those of low periodicity. It has been found desirable so to design the stabilising system that there is effectively a D.C. coupling in the mains fluctuation neutralisation circuit. It has also been considered that the design might be improved by incorporating in one panel the stabilising and fluctuation neutralisation features, which in the above system are located in separate panels. As a further contribution to complete steadiness of output, the control voltage in the new system is provided by a battery.

This later design of stabilising equipment is incorporated in two units: (1) The H.T. Stabilising Unit, which, as indicated above, incorporates the functions carried out in the older system by the Mains Stabilisation Panel. (2) A battery panel, which substitutes for the Control Voltage Panel.

As before, there are several types of stabilisers for different purposes, and these various types, together with the Battery Panel, will now be described.

H.T. Stabiliser—Type 4c

The circuit of this unit is shown in Fig. 5. As before, it is capable of providing two separate outputs. The H.T. supply enters via terminal *A*, and passes to output No. 1 via the four cathode followers V_3, V_4, V_5 and V_6 in parallel. The stabilised output appears at terminal *B*. In the case of output No. 2, the H.T. from terminal *A* passes through the cathode follower V_7, whose output finally appears at terminal *C*. It may be, however, that a single output is required having a rather larger value of permissible output current. In this case V_7 may be joined in parallel with V_3, V_4, V_5 and V_6 by means of a switching operation to be described later.

The valves V_1 and V_2 are provided to introduce the necessary neutralisation of mains fluctuations, and also to provide the control voltage for the valves V_3 to V_7, while simultaneously isolating it from the battery. The control voltage is applied to the grid of V_1, which valve therefore effectively isolates the stabiliser from the control voltage battery. The elements R_9 and C_1 are added as a refinement to suppress any fluctuations which might arise from the battery. V_1 and V_2 have a common cathode resistance

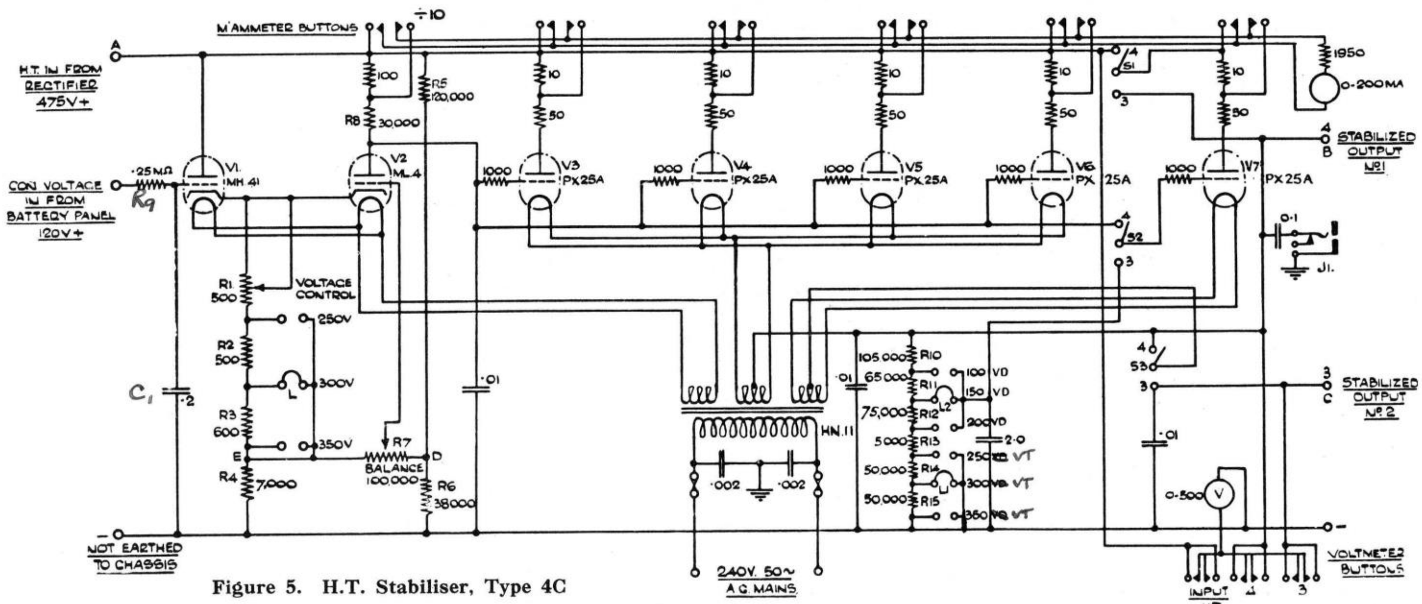


Figure 5. H.T. Stabiliser, Type 4C

$R_1\, R_2\, R_3\, R_4$, across which, since V_1 is a cathode follower, a steady positive voltage will be developed of the same order as the voltage applied by the battery to the grid of V_1, viz. 120 V. The incoming high tension supply from terminal A, which may be presumed to carry fluctuations, is applied to the potentiometer $R_5\, R_6$, so that at the point D there will exist a fraction of the standing H.T. voltage, amounting to approximately 100 V., together with fluctuations of proportionately reduced amplitude. The potential at D is applied to the further potentiometer R_7, the slider of which is connected to the grid of V_2, so that the fluctuations at D are applied to the grid. The lower end of the potentiometer R_7 is returned to a point on the cathode resistance $R_1\, R_2\, R_3\, R_4$, which is dependent upon the position of the link L, but so calculated that at any of the three positions in which the link may be fixed, the standing potential found there is approximately equal to that at D, that is to say 100 V.

The anode circuit of V_2 contains the anode resistance R_8, and therefore any fluctuations applied to the control grid appear magnified and reversed at the anode, whose steady potential, apart from any fluctuations, is proportional to the steady component of its grid voltage, and constitutes the actual control voltage for the valves V_3 to V_7. Clearly, by selecting the correct point on the potentiometer R_7, the amount of reversed fluctuations generated at the anode of V_2 may be so adjusted as exactly to cancel the fluctuations which would pass from the incoming H.T. through the cathode followers V_3 to V_7 to the output. The incoming fluctuations also appear at the anode of V_2, since it derives its H.T. from the common source, and these are also included in the cancellation.

It is to be noted that the form of circuit adopted gives a D.C. coupling between the incoming fluctuations and the grid of V_2, so that fluctuations having very low periodicity are removed. Even a permanent change in the value of the incoming H.T., such as, for instance, from 475 V. to 460 V., will be completely neutralised.

The valve V_2 is a D.C. amplifier, and requires the usual grid bias in order that it may work upon the linear portion of its amplification characteristic. This grid bias is provided automatically from the drop of voltage occurring across $R_2\, R_3$ and that portion of R_1 which is in circuit between the cathode and grid of V_1. Further, the ultimate output voltage of the stabiliser depends upon the control voltage applied to the valves V_3 to V_7, and this is, as has been seen, the standing anode potential of V_2. This is in turn dependent upon the standing automatic grid bias of V_2, and therefore the stabiliser output voltage may be set to any desired figure within the limits of design by adjusting the automatic grid bias. It has been arranged that three output voltages shall be available, viz. 250, 300 or 350 V. To obtain 350 V., the link L is so placed as to allow R_2 and R_3 to remain in circuit. To obtain 300 V., the link is placed so as to short circuit R_3. The standing grid bias of V_2 is thereby reduced, so that its anode current increases and its anode voltage decreases from 350 to 300 V. Similarly by placing the link L so as to short circuit R_2 and R_3, the output is reduced to 250 V. Owing to the fact that the control voltage for the valves V_3 to V_7 is derived from the anode of V_2, it has the comparatively high value which is desired, whereas the initial control voltage from which the whole stabiliser is controlled only needs to be 120 V. In effect, therefore, the circuit associated with V_1 and V_2 magnifies the initial battery control voltage by 3 : 1. The constants of the circuit associated with V_2 are so chosen that the amplification characteristic is linear in whichever of its three positions the link L may be placed.

The object of returning the lower end of the potentiometer R_7 to a point on the common cathode resistance is to enable the balance adjustment to be made without affecting the standing automatic grid bias of V_2, and consequently the output voltage. The potentiometer R_7 operates in effect with reference to the fluctuations only and cannot affect the standing bias, since the potential at each end is approximately the same and there is a negligible flow of D.C. through it. Actually, this statement is only strictly true in the case of the 300 V. setting ; it clearly cannot be true in the case of all three settings, but the divergence in the case of the 250 V. and 350 V. settings is insignificant. The potentiometer R_1 gives a fine control of the output voltage, and is consequently designated **Voltage Control.**

When the ganged selector switch $S_1\, S_2\, S_3$ is in the position designated **4,** the valve V_7 is in parallel with $V_3\, V_4\, V_5$ and V_6, and its grid receives the control voltage provided by the anode of V_2, as in the case of the other valves. The valve V_7, however, can be used separately to provide a stabilised voltage of lower value than that provided by V_3 to V_6. For this purpose the switch $S_1\, S_2\, S_3$ is thrown to the position designated **3,** when the following operations are performed by the various sections of the switch. The section S_1 reconnects the anode of V_7 so that it takes its H.T. supply from the cathodes of V_3 to V_6 instead of from the main incoming supply at terminal A. This is done for two reasons. In the first place, the cathode of V_7 is required to deliver a stabilised output at a much lower voltage than when the valve is used in parallel with V_3 to V_6, and unless means are provided to reduce the initial unstabilised voltage applied to its anode, the dissipation in V_7 will be excessive. Secondly, the stabilised output required from V_7 is sufficiently below the stabilised output from V_3 to V_6 for the latter to be used conveniently as an anode supply to V_7. The supply to V_7 has thus already had any fluctuations neutralised and no separate cancellation arrangements are necessary when V is used to give a separate output.

The section S_2 changes over the grid of V_7 so that it receives a control voltage, not from the anode of V , but from the potentiometer R_{10} to R_{15} which is across the stabilised output from V_3 to V_6. This forms a convenient method of applying a reduced control voltage to the grid of V_7, which is necessary in view of the lower value of output required from this valve,

167

H.T. Stabiliser—Type 4c *(Contd)*

and because, the anode supply to V_7 having already had any fluctuations in it cancelled, the control voltage to the grid is not required to carry anti-phase fluctuations.

The section S_3 of the selector switch removes the filament centre point of V_7 from its parallel connection with those of V_3 to V_6, and connects it to the terminal C, at which the reduced output provided by V_7 will therefore be obtained.

R_{13}, R_{14} and R_{15}, a corresponding adjustment to which is made whenever L is altered, and the current through the potentiometer R_{10} to R_{15} is thereby maintained constant and the calibration of the upper links L_2 is maintained.

The permissible output currents for the various output voltages, assuming the range of input voltage is from 434 V. to about 485 V., are given in Tables 1 and 2.

The adjustment of this stabiliser will be largely clear from the description already given. The required number of outputs and values of these outputs

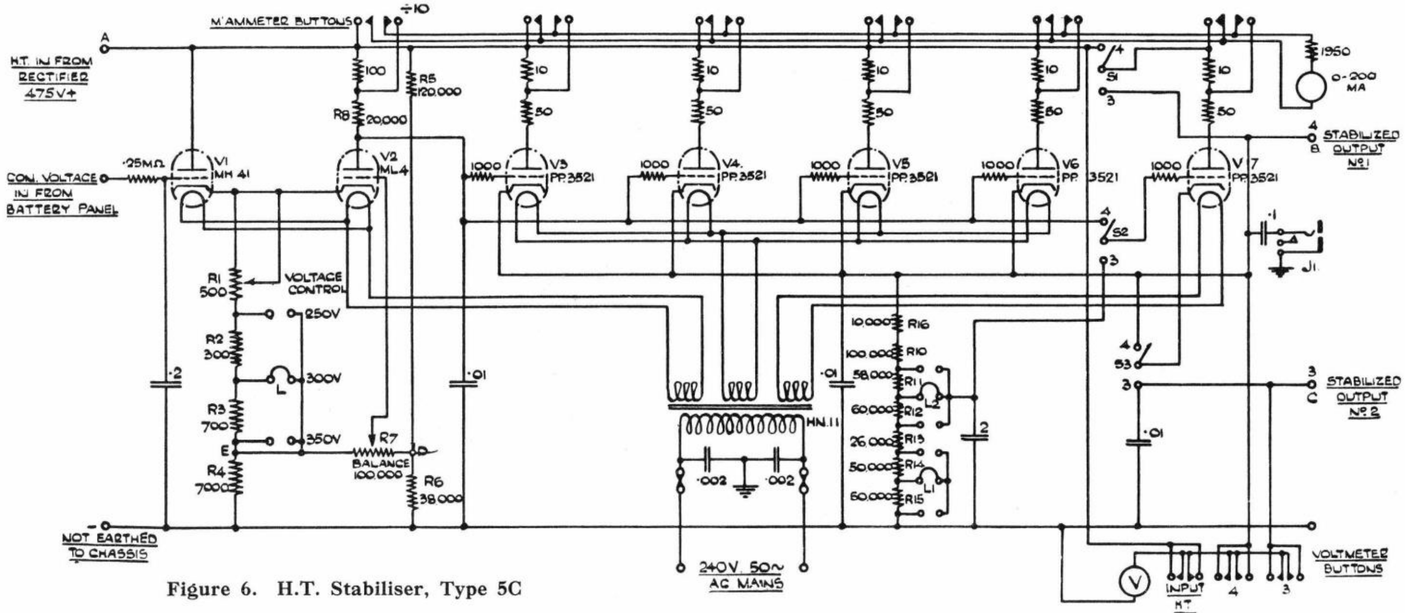


Figure 6. H.T. Stabiliser, Type 5C

The link associated with the resistances R_{10}, R_{11} and R_{12} enables three values of control voltage to be applied to the grid of V_7, so as to enable three values of stabilised output to be obtained. The settings of the link are designated **100 V.d., 150 V.d.** and **200 V.d.**, which means 100, 150 and 200 volts down with respect to the stabilised output from terminal B. It will be noticed that the difference between these voltages is in 50 V. steps, a convenient round figure. This calibration, however, cannot apply in the case of all the three values of stabilised output provided by the link L associated with R_2 and R_3, and to enable this convenient calibration in 50 V. steps to be maintained, the additional link L_1 is provided associated with

will be set by means of the switch S_1 S_2 S_3, and the links L, L_1, L_2, and the fine adjustment of voltage carried out on the potentiometer R_1. The jack J_1 should be plugged to a signal monitor, and any fluctuations present in the main output terminal B will be seen. The **Balance** potentiometer R_7 should now be adjusted until these disappear. A slight readjustment of R_1 may now be necessary, followed possibly by a slight further adjustment of R_7.

This type of stabiliser is fitted with directly heated valves in order to enable the unit to give the largest possible output per valve. The use of this type of valve, however, makes it impossible for this stabiliser to be of universal use, and as there is a vestige of residual hum it is therefore used for

TABLE I. H.T. STABILISER, TYPE 4 C, MAIN OUTPUT. (Terminal B)

Output volts at B	*Output current per valve* mA.	*Total output current for* 5 *valves* mA.	*Total output current for* 4 *valves*, including any output at *C* mA.
250	105	525	420
300	135	675	540
350	*115	*575	*460

TABLE 2. H.T. STABILISER, TYPE 4C, SUBSIDIARY OUTPUT. (Terminal C)

Difference between outputs B *and* C volts	*Current to* C mA.
100	*130
150	150
200	125

TABLE 3. H.T. STABILISER, TYPE 5C, MAIN OUTPUT. (Terminal B)

Output volts at B	*Output current per valve* mA.	*Total output current for* 5 *valves* mA.	*Total output current for* 4 *valves* including any output at *C* mA.
250	64	320	256
300	81	405	324
350	*95	*475	*380

TABLE 4. H.T. STABILISER, TYPE 5C, SUBSIDIARY OUTPUT. (Terminal C)

Difference between outputs B *and* C Volts	*Current to* C mA.
*100	115
150	100
200	75

N.B.—*The current to Terminal* C *must be included in the total permissible current from output* B.

Currents in excess of the above figures are liable either to run the valves into grid current, which will effect the output voltage and the hum balance, or to exceed the rated dissipation.

*The limits marked * are those at which grid current commences, and for safety this limit should not be approached within* 10% *unless it is known that the supply voltage is always higher than* 434 *volts.*

169

supplying stabilised H.T. to those units of the vision chain where the signal level is already high, such as Suppression Mixers, Picture and Sync Mixers, etc.

H.T. Stabiliser—Type 5c

This type of stabiliser is designed for use with those units of the vision chain where the signal level is low, as for example in ' A ' and ' B ' Amplifiers. The circuit which is given in Fig. 6 is almost identical with that of stabiliser Type 4c, except that indirectly heated valves are used, with the result that the hum level is negligible. The permissible values of output, however, are lower than in the case of Type 4c, and are given in Tables 3 and 4.

H.T. Stabiliser—Type 6c

This unit is designed to provide six individual stabilised H.T. supplies for application to the Head Amplifiers. Each of these supplies is required to be remotely switched by operation of the push button contactor in the Focus Panel of the appropriate camera, and, as in the case of stabilisers Types 4c and 5c, the unit must contain its own mains stabilisation features.

The circuit is shown in Fig. 7, and it will be seen that it is a combination of the circuit arrangement of the Head Amplifier Stabiliser of System ' A ' with the method of stabilisation control employed in stabilisers Types 4c and 5c. The circuit is, however, so arranged that the operation of switching off the H.T. supply to a camera ensures a definite suppression on the supply in all circumstances, so that unlike the Head Amplifier Stabiliser in System ' A,' it is not possible to draw any current from the stabiliser when the circuit is in the **Off** condition, due to a short circuit of a stabilised output.

The circuit contains 9 valves, of which those designated V_4 to V_9 are separate stabilisers which feed H.T. individually to each of six Head Amplifiers. They therefore correspond to the valves V_2 to V_7 in the Head Amplifier Stabiliser of System ' A.' The valve V_3 is a cathode follower which supplies the control voltage to the grids of V_4 to V_9, and it is provided so as to isolate from the control voltage supply any grid current which may be drawn by these valves. Its function therefore corresponds to that of the valve V_1 in the Head Amplifier Stabiliser of System ' A.' The valves V_1 and V_2 are provided to introduce the necessary neutralisation of mains fluctuations, and to amplify the control voltage which is derived from the Battery Panel. They therefore correspond in their functions to the valves V_1 and V_2 of stabilisers Types 4c and 5c.

The functions of the various valves in this unit will therefore be clear if the operation of those types of stabilisers which have already been described is understood. For convenience, however, the action of this circuit will be described as far as concerns the valves V_1, V_2 and V_3 together with V_4, the action of the latter being, of course, representative of that of all of the six individual stabiliser valves V_4 to V_9, the circuits of which are identical.

H.T. Stabiliser—Type 6c *(Contd)*

The control voltage from the Battery Panel at 120 V. is applied to the grid of V_1 via the elements R_1 and C_1, which smooth out any induction which may have been picked up by the wiring. The cathode circuit of V_1 contains the resistances R_2 and R_3, across which, since V_1 is a cathode follower, a steady positive voltage will be developed. The unstabilised H.T. supply enters via terminal A, and carries the fluctuations which it is desired to suppress. It is applied to the potentiometer R_5 R_6, and at the point D there will exist a fraction of the standing H.T. voltage together with fluctuations of proportionately reduced amplitude. To the point D is connected the potentiometer R_7, the other side of which is returned to the point E, which is a tapping on the cathode resistance R_2 R_3 such that the standing potentials of the points D and E are the same. Across the potentiometer R_7 are developed therefore the fluctuations but no D.C. potential.

The anode circuit of V_2 contains the anode resistance R_8, and therefore any fluctuations applied to the control grid appear magnified and reversed at the anode, whose steady potential apart from any fluctuations is proportional to the steady component of its grid voltage, and constitutes the actual control voltage which will be supplied via V_3 to the stabiliser valves V_4 to V_9. Clearly, by selecting the correct point on the potentiometer R_7, the amount of reversed fluctuations generated at the anode of V_2 may be so adjusted as exactly to cancel the fluctuations which would pass from the incoming H.T. through the stabiliser valves V_4 to V_9 to the output. The incoming fluctuations also appear at the anode of V_2 since it derives its H.T. from the common source, and these are also included in the cancellation. As in the case of stabilisers Types 4c and 5c, the form of circuit adopted gives a D.C. coupling between the incoming fluctuations and the grid of V_2, so that the fluctuations of the lowest periodicity are removed. The valve V_2 is a D.C. amplifier, and requires the usual grid bias in order that it may work upon the linear portion of its amplification characteristic. This grid bias is provided automatically by means of the drop of voltage across R_2. The standing potential at the anode of V_2, which is devoid of fluctuations when R_7 is properly set, is applied to the grid of V_3, which is a cathode follower. At its cathode is developed therefore a standing positive voltage which constitutes the actual control voltage for the grids of the valves V_4 to V_9. Should these valves take any grid current, the low output impedance of V_3 will enable this to be supplied without interference with the circuit conditions.

The action of V_4, which is representative of that of all six stabiliser valves V_4 to V_9, may now be described. The relay R is energised by means of the D.C. supply from the push button contactor on the appropriate Focus Panel. This relay is shown in the circuit diagram in the energised position, in which the stabilised H.T. supply to the Head Amplifier is switched on. In this condition the control voltage derived from the cathode circuit of V_3 is applied via the lower contact of the relay through the resistance R_9 to the grid of V_4, and the condenser C_2 is discharged, both sides of it being at the potential of the control voltage. When the relay R is ~~operated~~ de-energised so as to switch off the Head Amplifier supply, the centre contact moves so as to connect the grid of V_4, via R_9 and R_{10}, to a source of negative voltage at -130 V., and it will be seen that the condenser C_2 slowly discharges to a potential which is the sum of the control voltage and that of the negative supply, that is to say, approximately 500 V. The charging of this condenser is, however, controlled by the time constant given by C_2 $(R_9 + R_{10})$, which has a value of 1.5 seconds. When the relay R is operated, therefore, the grid of V_4 takes up an ultimate value of -130 V. at a rate determined by this time constant, and the H.T. to the appropriate Head Amplifier is gradually suppressed. The object of this is to avoid introducing into the H.T. supply a sharp transient which, despite the action of the stabilisers, might cause a pulse in the H.T. supply to any other Head Amplifiers which may be switched on. This precaution is desirable as the Head Amplifier is, of course, the earliest amplifier in the vision chain. Since the grid of V_4 is now receiving a strong negative bias from an independent supply, an accidental short circuit of the stabilised output which might be caused by the failure of cable cannot result in any flow of current.

When the relay R is energised so as to switch the supply on, the centre contact restores the circuit condition to that shown in the diagram. The grid of V_4 is connected to the control voltage via R_9, and this resistance is placed across the condenser C_2. The control voltage therefore builds up on the grid at a rate determined by the time constant $C_2 R_9$, which is 1 second, and similarly a transient when switching on is avoided. There is no significance in the difference of the value of the two time constants, which merely arises owing to circuit necessities. The normal output for each of the six stabiliser valves is 60 mA at 350 V.

The Battery Panel

The circuit of this is shown in Fig. 8, and is self explanatory. A main battery of 336 V. is provided which can be tapped in five places, so that five different values of output can be obtained. In series with each tapping is a small subsidiary battery for fine regulation of the voltage. The voltmeter may be connected to any of the five tappings in order to read the voltage. The earth connection is also made in the form of a tap, so that if necessary some or all of the tappings can be made to give negative voltages.

WAVEFORM MONITOR TYPE 3a

This type of Waveform Monitor has been designed so as to enable measurements of the amplitudes of waveforms to be made with a high degree of accuracy. It is therefore particularly useful for measuring the white, black and sync levels which are delivered by the Distribution Amplifiers in various parts of the system, it being important that these levels should be maintained with some precision.

The principle employed is as follows. The waveform to be examined is applied to the *Y* plates of a cathode ray oscillograph, to the *X* plates of which is applied the usual saw-toothed sweep voltage, which is held in synchronism with the predominant frequency of the applied waveform. The oscillograph is provided with a fixed cursor, the position of which coincides with the horizontal diameter or *X* axis of the fluorescent screen. The position of the waveform on the fluorescent screen can be adjusted with respect to the position of the fixed cursor by means of a vertical shift voltage, which is applied to the *Y* plates, and which can be accurately measured by means of a high grade voltmeter. It is arranged that when the applied shift voltage is at zero with respect to earth, the time base, that is to say, the line drawn by the sweep voltage in the absence of any applied waveform, is coincident with the cursor. It follows that upon a waveform being applied to the *Y* plates, if the various parts of it are in succession displaced so as to coincide with the cursor by the application of suitable shift voltages, then the value of shift voltage employed in each case will be the absolute value in volts of the corresponding part of the waveform which is coincident with the cursor. As an example, suppose that it is desired to measure a mixed picture and sync waveform having the following values : white level +10V, black level +3.5V, and sync level 0V. This will be recognised as the correct waveform which should be delivered by a Distribution Amplifier for application to a Picture Monitor. If the shift voltage is zero with respect to earth, and if the sync level is truly zero with respect to earth as it should be, then the waveform would appear upon the screen, as shown in Fig. 1. If now the shift voltage be readjusted so as to displace the whole waveform vertically, and bring the black level instead of the sync level in coincidence with the cursor, as shown in Fig. 2, it will be found, if the incoming black level is correct, that 3.5V of shift voltage have been required for this operation. If, for instance, 4V are necessary, it follows that the incoming black level has an absolute level of +4V, and is therefore too high. The same operation can be repeated for white level.

It will be evident that this method of measurement, being of the 'null' type, is capable of great accuracy, this being largely dependent upon the excellence of the voltmeter employed to measure the shift voltage.

The monitor provides other facilities which have been found desirable. Waveforms may be examined under D.C. conditions or with the D.C. component removed. Two waveforms may be observed simultaneously by

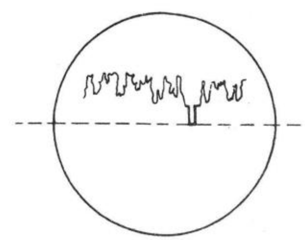


Figure 1.

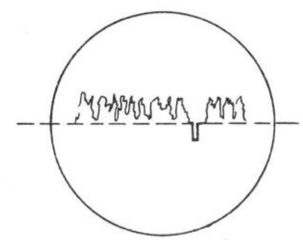


Figure 2.

superimposition, and therefore directly compared. The apparatus is also designed to provide efficient synchronism between the incoming waveform and the time base, whether the predominant recurrent frequency in the incoming waveform be in the positive or negative sense. To facilitate exact measurement, a number of ranges of shift voltage are available, these being 5, 10, 20, 50, 100, 200 and 500 volts, so that a range of input waveform amplitudes corresponding to these figures may therefore be measured.

Lastly, the apparatus is entirely self-contained, all the necessary electrode potentials being generated by a rectifier, an incoming supply at 230V A.C. being all that is required.

The Oscilloscope

The oscilloscope, which is illustrated in Fig. 3, is an electrostatically deflected cathode ray tube, the gun of which may be described as a tetrode.

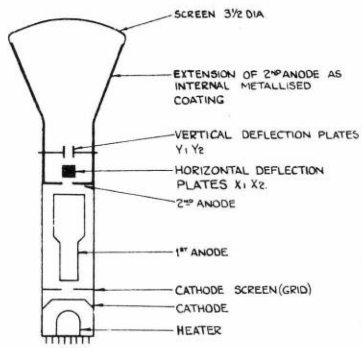


Figure 3.

It contains the following electrodes :

(1) A heater, rated to take 1.3A at 4V A.C.
(2) A cathode
(3) A cathode screen, which receives a negative bias of $-$ 9V with respect to the cathode
(4) A first anode, requiring a potential of $+$ 200V
(5) A second anode, requiring a potential of $+$ 1,000V
(6) A pair of horizontal deflection plates
(7) A pair of vertical deflection plates

All these electrodes, with the exception of the vertical deflection plates, are connected to a number of pins in the base of the cap. The relation between the various electrodes and these pins is illustrated in Fig. 4, which is a view looking down upon the base of the tube. The vertical deflection plates, which should have a minimum of capacity to earth, are brought out to a pair of studs located on the glass envelope itself.

The Amplifier and Shift Circuit

The circuit is illustrated in Fig. 9†.

An H.T. supply at 1,000V is generated by the power unit, comprising a transformer TR_1 the rectifiers V_7 and V_8, and the smoothing circuit C_1, L_1, C_2, L_2. It should be noted that neither the positive nor the negative of the H.T. supply is earthed, an important point the significance of which will appear later. The H.T. is applied to the potentiometer comprising the resistances R_1, R_2, R_3, R_4, R_5, R_6. The second anode receives its potential of approximately 1,000V from the junction of R_1, R_2 and R_3. The first anode receives its potential of approximately 200V from the resistance R_4, and since, as usual, the spot is focussed by the adjustment of this potential, this resistance takes the form of a potentiometer, which is brought out to a manual control designated **Focus.** The range of voltage variation provided

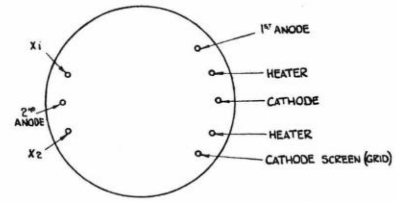


Figure 4.

by it extends between 140 and 420V. The cathode is supplied from the junction of R_5 and R_6, and the grid is connected to H.T. negative through the resistance R_7. The voltage drop across R_6 provides automatic grid bias of $-$ 9V for the grid. It will be seen later that in addition to the fixed bias of $-$ 9V, the grid receives a negative black-out pulse during the fly-back period to extinguish the return trace which would otherwise obscure clear observation of the waveform, and that this could not be applied to the grid if the latter were connected directly to H.T. negative in order to pick up its negative bias. The grid is therefore returned to H.T. negative via the resistance R_7. There is thus a direct D.C. connection to H.T. negative to provide the negative bias, while the black-out pulses are developed across this resistance. If the cathode resistance R_6 were not shunted by a condenser, it would apply anti-phase feed back to the black-out pulses which are applied to the grid, and their effective amplitude would be reduced. The resistance R_6 is therefore shunted by the condenser C_3 to remove this effect.

It is as usual necessary to apply the waveform which is to be examined to the Y plates of the oscilloscope in push-pull, in order to avoid defocussing the spot. The incoming waveform is usually asymmetrical and the valves V_1 and V_2 are accordingly provided to transform this input into one having push-pull characteristics, as well as to provide a necessary degree of amplification when waveforms of small amplitude are being examined. The latter may be applied to the monitor by any one of the four jacks designated DC_1, AC_1, DC_2 or AC_2. When applied to either of the jacks DC_1 or AC_1, the input appears upon the grid of the valve V_1, and the sense of this connection is such that a positive waveform will appear on the screen as an upward trace and a negative waveform as a downward trace. When the jacks DC_2 or AC_2 are used, this is reversed. It will be seen therefore that whatever the sense of the incoming waveform, it may be observed upon the screen the right way up. The two jacks labelled DC_1 and DC_2 enable waveforms having D.C. characteristics to be examined with their D.C. component retained,

† *Figure* 9 *attached to page* 9

The Amplifier and Shift Circuit *(Contd)*

but if the jacks AC_1 or AC_2 are used, then the D.C. component is eliminated.

Considering the circuit details associated with the control grid of V_1, the input, when applied to the jack DC_1, proceeds direct to the grid through the elements C_4, R_8 and R_9. The resistance R_8 is inserted to limit the flow of grid current which might occur if a high positive potential is associated with the incoming waveform, as such a potential might be damaging to the valve. This high resistance would, however, in conjunction with the input grid capacity of V_1, considerably reduce the upper frequencies present in the waveform, and the resulting trace on the tube screen would not be representative. It is therefore shunted by the condenser C_4, which by-passes such upper frequencies, and in fact the A.C. waveform as a whole. R_9 is the usual anti-parasitic resistance. When the jack DC_1 is not in use, the grid is earthed as regards static charges by the resistance R_{10}. When the input is applied to the jack AC_1, the D.C. component is eliminated by the condenser C_5, in conjunction with the resistance R_{10}. It may be that both jacks DC_1 and AC_1 are not in use (if the waveform is being examined on DC_2 or AC_2), and in this case it is desirable to eliminate stray potentials picked up by AC_1 and C_5. This is done by earthing the input spring of AC_1 to D.C. and A.C. respectively, by means of the elements C_6 and R_{11}. The jacks DC_1 and AC_1 are designed so that it should be possible to insert the plug carrying the input waveform no matter what may be the standing potential of that waveform, that is to say, it is unnecessary to remember to insert the input plug in the monitor jack first and into the source of the waveform to be examined last. Considering the jack DC_1, the outer is not earthed, but if the input cord is connected to a concentric cable, then the shank must be earthed when the jack is pushed home. This earth is provided by the spring S_1. This cannot, however, be earthed directly, as otherwise any standing potential on the inner of the plug would be momentarily short circuited during the insertion of the jack, with possible damage to the apparatus originating the waveform. The spring S_1 is therefore earthed to D.C. by R_{13} and to A.C. by C_8. C_7 and R_{12} perform the same function for the jack AC_1

Similar detailed circuit arrangements will be seen associated with the control grid of V_2, except that whereas the point A in the circuit associated with V_1 is directly earthed, the point B is not directly earthed for reasons which will appear later, but is effectively earthed by the condenser C_9.

The valves V_1 and V_2 transform the asymmetrical input into a push-pull output in the following manner. Let us assume that the input is being applied to the control grid of V_1, and that the grid of V_2, as we have seen, is earthed. When the input tends to drive the grid of V_1 positive, the cathode, which contains the unshunted resistances R_{13}, R_{14} and R_{15}, will follow the grid and similarly become more positive, but the increase of its potential is less than that of the control grid (in accordance with ordinary cathode follower theory), so that there is a net increase of potential between the control grid and the cathode of V_1. The increased cathode earth potential is communicated to the cathode of V_2 via the path comprising R_{13}, R_{16} and R_{17} (and by R_{18}, R_{19} and R_{20}, which latter resistances, however, are not there for this specific purpose), so that the cathode of V_2 also becomes more positive. The grid of V_2 is, however, held at a fixed potential to earth, so that there is a net decrease of potential between the grid and cathode of V_2. We might express this loosely by saying that whereas the grid of V_1 becomes more positive with respect to its cathode, the grid of V_2 becomes more negative with respect to its cathode. The potentials on the two control grids are therefore in push-pull. Magnified push-pull potentials are therefore developed at the two anodes by virtue of the inclusion of the anode resistances R_{21} and R_{22}, and the vertical deflection plates Y_1 and Y_2, being directly connected to these anodes, the vertical excursion appears upon the screen.

A convenient form of gain control is provided by the connection of the three resistances R_{18}, R_{19} and R_{20} between the two cathodes. Their junctions are brought out to the stud switch P_1, which enables the total resistance to be varied between zero and 2,950 ohms. If the total resistance between the two cathodes is zero, the cathodes are feeding each other with mutually reversed potentials. They cannot therefore follow the potentials of their corresponding grids so closely as they would if there were no such mutual interaction, and in each case the grid-cathode potential is comparatively great. The anode excursion is therefore correspondingly great and the gain of the stage high. On the other hand, when a resistance is inserted between the two cathodes, the magnitude of the reversed potentials which they mutually apply to each other is reduced, and they are now in a position to follow more closely their corresponding grid potentials. The grid-cathode potentials and the corresponding anode excursions, are now relatively less and the gain of the stage is reduced. The stud switch P_1 is brought out as a manual control designated **Gain,** and its several positions enable gains of 1, 2, 4 and 8 to be obtained.

Since V_1 V_2 is a push-pull D.C. amplifier, it follows that if no input is applied to either control grid, the two anode potentials should be equal. This is obviously desirable, since the cursor is situated on the central horizontal axis of the tube, and in the absence of any input the spot should be exactly central or underneath the cursor. Due to slight differences between the valves, however, this may not be the case, and there may be some slight standing difference of potential between the two anodes resulting in a vertical zero error of the spot. This is corrected by the provision of the variable resistance R_{16}, but an alternative method would be to replace R_{16} by two individual resistances connected in series with R_{13} and R_{17}. It will be seen that variation of R_{16} in one direction or the other will increase the amount of the cathode resistance which is effectively in series with the cathode of one valve, and correspondingly decrease the amount in the case of the other

175

The Amplifier and Shift Circuit (*Contd*)

valve. This changes the balance of the current through each valve, and by choosing a suitable position of R_{16} the two anode currents, and consequently the two anode potentials, may be made equal. The resistance R_{16} is brought out as a preset screw-adjusted control.

We may now consider the application of the shift voltage, which, as we have seen, is the basis of our method of measurement of the amplitude of the incoming waveform. The shift voltage must ultimately act upon the vertical deflection plates Y_1 and Y_2. A circuit could obviously be designed which would apply a shift voltage in push-pull to these two plates, but the design would be awkward and cumbersome, and it is clearly rational to apply the shift voltage to the control grid of either V_1 or V_2, when it will automatically act on the deflection plates in push-pull by virtue of the action of the amplifier V_1 V_2. An accompanying advantage will be that the absolute value of the shift voltage will be equal to the absolute value of the amplitude of the incoming signal, since they are both acting upon the grids of identical amplifiers. In practice the shift voltage is applied between the control grid of V_2 and earth. The action is then as follows.

Supposing an input waveform has a maximum amplitude of 10V with respect to earth, and it is applied to the control grid of V_1, then this grid potential will rise by 10V, and the potentials of the plates Y_2 and Y_1 will rise and fall respectively by a number of volts, depending upon the gain setting of the potentiometer P_1. The spot will therefore be deflected away from its initial position opposite the cursor to a new position in the upper hemisphere of the tube screen. If now a shift voltage having an amplitude of + 10V is applied to the control grid of V_2, the potential of this grid will rise by 10V, and the potentials of the plates Y_1 and Y_2 will rise and fall respectively by the same amount as occurred due to the action of the input waveform on the grid of V_1, but in the opposite sense. During the occasions when the incoming waveform is developing its maximum amplitude, there will be no relative difference in potential between the two deflection plates Y_1 and Y_2, as would be the case if the incoming waveform and the shift voltage were both removed from the control grids of V_1 and V_2. On these occasions therefore the spot will take up its original position coincident with the cursor and in other words there is no deflection. It can easily be seen therefore that by adjusting the shift voltage so that any part of the waveform is brought into alignment with the cursor, then the value of shift voltage obtaining at that time is the value of the amplitude of that part of the incoming waveform which is opposite the cursor. It will be appreciated that we are concerned here only with the relative potentials between Y_1 and Y_2. Clearly if a positive incoming waveform and a positive shift voltage are being applied to the respective control grids of V_1 and V_2, the standing potentials of Y_1 and Y_2 will both be lower than they were in the absence of any inputs to the control grids. This point is of no importance except as regards the linearity of V_1 and V_2, as we are purely concerned for the purposes of deflection with relative amplitudes.

We have now established the necessity of developing between the control grid of V_2 and earth a variable shift voltage. Since the incoming waveforms may be either positive or negative with respect to earth, the shift voltage must similarly be available in either sense. The principle adopted is illustrated in Figs. 5, 6, 7 and 8.

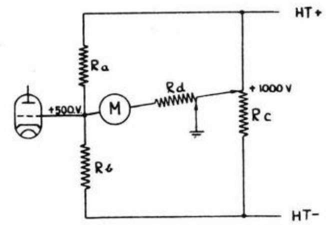


Figure 5

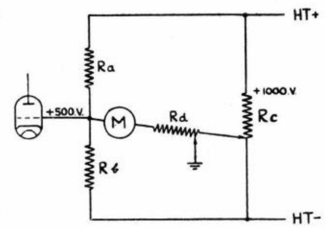


Figure 6

Referring to Fig. 5, the control grid of V_2 is fixed at a potential of approximately + 500V relative to H.T. – by means of the H.T. potentiometer R_a R_b. A second potentiometer R_c is also connected across the H.T. supply. The control grid is connected through the meter M to the slider of the potentiometer R_c through a further potentiometer R_d, the slider of which is joined to earth. Let us suppose that, as illustrated in Fig. 5, the potentiometer R_c is set at the extreme positive end of its range, and the potentiometer R_d is set at that end of its range which adjoins the slider of the potentiometer R_c. The following potential differences now apply :—

Between grid and H.T. negative	+500V
Between remote end of R_d and H.T. negative ..	+1,000V
Between grid and R_c slider	–500V
Between grid and earth	–500V

Referring now to Fig. 6, R_d is set as before, but R_c is set to the other, or most negative, end of its range. The following differences now apply :—

Between grid and H.T. negative	+500V
Between remote end of R_d and H.T. negative ..	0V
Between grid and R_c slider	+500V
Between grid and earth	+500V

It will be seen that by leaving R_d set as illustrated, and varying R_c over the whole of its range, a shift voltage between the grid and earth varying between + 500 and – 500V has been made available.

The Amplifier and Shift Circuit (*Contd*)

Referring now to Fig. 7, R_c has been reset to the most positive end of its range, and R_d has been adjusted to be at 1/10th of the range between the grid and the slider of R_c. The following differences now apply :—

Between grid and H.T. negative	+500V
Between remote end of R_d and H.T. negative ..	+1,000V
Between grid and R_d slider	−50V
Between grid and earth	−50V

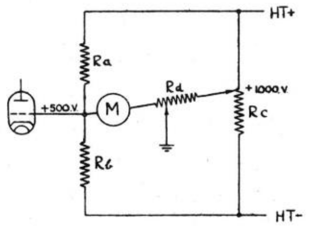


Figure 7

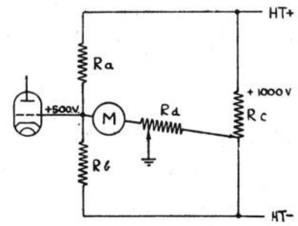


Figure 8

Turning now to Fig. 8, R_d is still 1/10th of the way between the control grid and the R_c slider, but the latter has been set to the most negative end of its range. The following differences now apply :

Between grid and H.T. negative	+500V
Between remote end of R_d and H.T. negative ..	0V
Between grid and R_d slider	+50V
Between grid and earth	+50V

It will be seen that maintaining R_d in the setting shown in Figs. 7 and 8, variation of R_c has enabled a variable shift voltage between grid and earth, ranging from +50V to −50V, to be obtained.

The significance of the fact mentioned earlier, that the H.T. negative is not earthed, will now be appreciated. The potentiometer R_c furnishes our control of the shift voltage over a range controlled by the setting of R_d. The scheme does not necessitate any arrangements to alter the range of the meter *M*, because the current flowing through it always varies over the same range. The virtue of the arrangement lies in the fact that by fixing the value of the standing voltage of the control grid with respect to H.T. negative, this does not change with respect to the standing voltages of the cathode, screen and anode, which are also fixed, so that the working conditions of the valve are not primarily affected by the adjustment of the circuit. It will be realised that in developing a variable shift voltage between the control grid and earth, it is fundamentally immaterial whether we fix the potential of earth and vary the potential of the grid, or vice versa, as is done in this case.

The potentiometer R_d is brought out as a manual control designated **Volt Range,** and in practice is tapped so as to give ranges of 5, 10, 20, 50, 100, 200 and 500V. The potentiometer R_c is also brought out to a manual control unlabelled.

Returning to Fig. 9, the equivalence between the simplified circuit diagrams of Figs. 5, 6, 7 and 8 and the actual apparatus may now be seen. The resistance R_a is formed by the resistances R_{23}, R_{24} and R_{25} of Fig. 9, and the resistance R_b by the resistances R_{26}, R_{27}, R_{28} and R_{29}. The potentiometer R_d is represented in Fig. 9 by the resistances R_{30} to R_{36} inclusive, while the potentiometer R_c is formed from the resistances R_{37} to R_{40} inclusive. The three potentiometers R_{38}, R_{39} and R_{40} are in effect only one simple potentiometer, but are actually constituted in the form shown for practical convenience. The condensers C_{10} and C_{11} provide further smoothing of the H.T. supply with respect to A.C. potentials developed between H.T. + and H.T. −, but smoothing of the supply with respect to earth, which is, of course, essential, is obtained by means of the elements R_{41}, C_9 and C_{12}. The shift voltage finally appears across C_9, the upper side of which is connected to the control grid of V_2 via the complex input circuit which has already been described.

The Sweep Circuit

This section of the circuit is formed by the valves V_3, V_4, V_5 and V_6 and their associated components. The forward stroke of the saw-toothed sweep voltage is generated by the charging of the condensers C_{13} to C_{19} inclusive through the high resistance R_{42} from the H.T. supply. During the forward stroke the anode-cathode path of the valve V_4 is non-conductive, but at an appropriate moment this path becomes conductive and rapidly discharges the condensers C_{13} to C_{19}. The spot therefore flies back, the valve V_4 then becomes non-conductive, and the cycle of operations repeats itself indefinitely. The means by which the valve V_4 becomes alternately non-conductive and conductive is as follows. At the beginning of the forward stroke the condensers C_{20} to C_{26} inclusive are holding a strong negative charge for reasons which will appear later, and the control grid of V_4 is biassed back well beyond the cut-off, so that the valve is non-conductive. During the forward stroke, that is to say, while the condensers C_{13} to C_{19} are being charged, the condensers C_{20} to C_{26} are being discharged through the high resistance R_{43} and the winding 3 - 4 of the transformer TR_2. Actually the condensers C_{20} to C_{26} and the resistance R_{43} are forming a second relaxation oscillator of precisely similar character to the other one formed from C_{13} to C_{19} and R_{42}, the only difference being that while C_{13} to C_{19} are being charged positively from a potential which was initially that of H.T. negative, the condensers C_{20} to C_{26} are also being charged in the positive sense but

177

The Sweep Circuit (*Contd*)

started from a potential which was much more negative than that of the H.T. negative line, and may therefore be rationally said to be discharging. This process proceeds until the grid-cathode potential to V_4 has become sufficiently less negative than originally as to permit the valve to conduct between screen and cathode. Current now starts to flow in the winding 2 - 1 of the transformer TR_2 and a voltage is induced in the winding 3 - 4 of such a sense as to accelerate the movement of the control grid potential in the positive direction. This in turn engenders more screen current and accordingly a greater positive control grid potential, and the cumulative action in practice drives the control grid strongly positive in a very few micro-seconds. Apart from the conductivity between screen and cathode, the valve is, of course, now conductive between anode and cathode, and this path discharges the condensers C_{13} to C_{19}.

The amplitude of the positive pulse delivered to the control grid from the secondary of the transformer TR_2 is sufficiently great as to attempt to drive the grid strongly positive, but restoration of D.C. occurs and the control grid does not succeed in becoming more positive than zero potential. Therefore at the moment during the return stroke when the maximum screen current is being drawn, and the maximum positive potential is being applied to the control grid, there co-exists on the control grid, due to D.C. restoration, a negative charge equal in value to the amplitude of the induced positive pulse. When the positive pulse has driven the grid as far positive as the restoration of D.C. will permit, the screen current can increase no further, and it is for the moment stationary. There is now no flux in the transformer, and the positive pulse is withdrawn, leaving a negative charge due to D.C. restoration on the grid, which accordingly cuts off screen and anode current. The screen current in falling will induce a flux in the opposite direction to the transformer TR_2, which will momentarily drive the grid more negative than the potential due only to D.C. restoration. But when the screen current finally ceases the flux in the transformer TR_2 will again be zero. The negative pulse will therefore cease, and the negative potential of the grid becomes that due to D.C. restoration alone. This last effect, involving a negative pulse on the control grid, however, has no bearing on the action of the circuit since the valve is already cut off by the potential due to D.C. restoration, and is a purely subsidiary effect which must result from the action of the transformer TR_2. The cycle of operations has now arrived at our original starting point, at which time the condensers C_{13} to C_{19} are discharged, but the condensers C_{20} to C_{26} are holding a strong negative charge and biassing V_4 well beyond the cut-off.

The frequency may be given a coarse variation by means of the ganged switches S_2 and S_3, which control respectively the capacity included in the grid and anode circuits of V_4. Fundamentally only the grid capacity need be changed, since it is the time constant of the grid circuit of V_4 which determines when this valve becomes alternately conductive and non-conductive, and consequently when the anode capacity is discharged. If the anode capacity were not varied as well, there would be considerable variation in the amplitude of the sweep as between different frequencies. If we imagine the condensers C_{13} to C_{19} to be replaced by a single condenser C, then a variation of S_2 alone would admittedly give a coarse adjustment of frequency, but when set to give a comparatively low frequency, the condenser C would have time to charge up to a greater amplitude before being discharged than if S_2 were set to give a higher frequency. To maintain the sweep amplitude constant with frequency, which is a desirable feature, the anode capacity must be reduced or increased at the same time as the grid capacity is reduced or increased. With this provision, when S_2 is set to give a comparatively low frequency, a certain amplitude will be generated across the comparatively large anode capacity. When S_2 is set to give a higher frequency, and the anode capacity is replaced by a smaller value, the latter will charge up more rapidly, and it can be arranged that the same amplitude is reached in the smaller charging period permitted by the higher sweep frequency. This is the reason for the presence of the several condensers C_{13} to C_{19} which are selected by the switch S_3, the latter being, of course, ganged with S_2.

A fine control of frequency is available from the potentiometer R_{44}. This firstly controls the potential applied to R_{43}, and therefore the rate of discharge of the condensers C_{20} to C_{26}. Again, without any further provision, this alone would result in some change in the sweep amplitude with variation of frequency, and to avoid this the potential applied to R_{42} is also taken from R_{44}. Thus, when the slider of R_{44} is brought nearer to the H.T.+ line to increase the frequency, the shorter charging period of C_{13} to C_{19} is compensated by the additional potential applied to them via R_{42}, and they therefore charge up more quickly.

The ganged switches S_2 S_3 and the potentiometer R_{44} are brought out as manual controls and are collectively designated **Frequency.**

The saw-toothed sweep voltage on the upper side of the condensers C_{13} to C_{19} must now be transformed into the push-pull form for application to the two horizontal deflecting plates X_1 X_2 of the oscillograph. It is therefore applied to the grid of the valve V_5, which, with the valve V_6, forms a push-pull amplifier operating on similar principles to the previously described amplifier V_1 V_2. A limited range of amplitude control is available by means of the potentiometer R_{45}, which is brought out as a manual control designated **Amplitude.**

It might be thought that the operation of this amplifier is different from the amplifier V_1 V_2, as there is apparently no common cathode resistance corresponding to R_{14} and R_{15} in the latter amplifier. In this case separate

The Sweep Circuit *(Contd)*

cathode resistances R_{46} R_{47} R_{48} and R_{49} R_{50} R_{51} are provided, but the operation of the amplifier is the same. The essential feature in procuring a push-pull output from two valves such as V_5 and V_6 when only one control grid is energised is the provision of a comparatively low resistance path between the cathodes. This is provided by R_{52} R_{45} R_{53}.

It will be noticed that the grid leak R_{54} of V_5 is returned to a point on the cathode resistance of V_6 instead of to its own cathode circuit, and similarly the grid leak R_{55} of V_6 is returned to the cathode circuit of V_5. This is a refinement which is added to minimise the difference in balance which might occur when a pair of valves which have not been specially chosen to have exactly similar characteristics are employed in these two positions. If the valves are dissimilar, there will be a permanent out of balance between the two standing anode potentials. This is not of great importance in the horizontal scanning direction, but it is minimised by the circuit design employed. If such an out of balance exists, there will be a difference between the two potentials at the two points C and D. By returning the grid leak of V_6 to C, and the grid leak of V_5 to D, these potentials are communicated to the grids of the opposite valves, where their action is such as to endeavour to restore the balance, which is in effect reduced to half the amount which would otherwise obtain. Clearly only the D.C. potentials at C and D are required, and it would interfere with the operation of the circuit if the A.C. potentials were also fed back. The feed back from D to the grid of V_5 is therefore decoupled by the insertion of the elements R_{56} and C_{27}, while that from C to the grid of V_6 is similarly smoothed by the elements R_{57} and C_{28}. The anode circuits are provided with the usual anode resistances R_{58} and R_{59}, and the anodes are directly connected to the oscilloscope X plates.

The valve V_3 is provided to enable synchronism to be maintained between the sweep voltage generated by V_4 and the predominant recurrent frequency in the waveform which is being examined. This predominant frequency, which may for example be the synchronising signal, may be in either sense, dependent upon the source of the incoming waveform, but it must always be applied to the valve V_4 in the positive sense, as will be seen later. It follows that some means must be provided for obtaining an input of the incoming waveform in which the sense of the predominant frequency is always positive. To effect this, the anode circuits of V_1 and V_2 are provided with two additional anode resistances, R_{60} and R_{61}, so that potentials corresponding to the incoming waveform will be developed at the points E and F. Since V_1 and V_2 are, however, in push-pull, the potentials at E and F will be mutually in opposite phase. A simple potentiometer connected between E and F will therefore provide at one extreme of its range
179 the incoming waveform in one sense, and at the other extreme in the other sense, while in the central position there will be no potential. Such a potentiometer is provided, and is shown as R_{62}. Its slider is connected to the grid of V_3 via the condenser C_{29}, which holds off the standing potential of the anode circuit of V_1 V_2. R_{62} is brought out as a manual control designated **Hold.**

A break jack designated **External Hold** is provided, which enables some extraneous frequency to be injected if it is not desired to hold the sweep voltage in synchronism with the incoming waveform. The incoming waveform appears amplified and reversed at the anode of V_3, and is developed across the parallel fed load resistance R_{64}. It will be seen that this resistance is included between the lower end of the condensers C_{20} to C_{26} and H.T. negative, so that the signal across R_{64} will be applied to the control grid of V_4. It is at this point that the signal must always be in the positive sense, as V_4 trips when its control grid has leaked sufficiently in the positive sense. The inclusion of R_{64}, however, in series with the condensers C_{20} to C_{26} has the unfortunate effect of slowing up the fly-back, since the speed of the latter depends upon the rapidity with which these condensers can discharge, and it is evident that they must discharge through R_{64} To improve this situation there is connected in parallel with R_{64} a condenser C_{31}, which by-passes R_{64} to a certain extent at the recurrent frequency. The value is, however, so chosen that it is not great enough to spoil unduly the sharpness of the wave-front of the potential of the predominant frequency by removal of the upper frequencies, as this would result in an indefinite hold. The potentials on the anode of V_3 are parallel fed to R_{64} by means of the high anode resistance R_{65} and the condenser C_{32}. The latter is specifically placed between R_{64} and H.T. negative instead of in the more usual position between the anode of V_3 and R_{64}, as by so doing it increases the impedance of the load at the frame frequency, and strengthens the hold, which is otherwise liable to be a little weak.

The D.C. potential of the screen grid of V_4 is provided from the H.T. potentiometer R_{44} R_{66} R_{67} R_{68} R_{69}. It will be noted that the resistances R_{67} and R_{68} are not shunted by condensers, as might be expected. This is specifically done for the following reason. During each fly-back period the screen grid-cathode path becomes highly conductive. Since R_{67} and R_{68} are not shunted by condensers, the pulses of current drawn from their junction during each fly-back period by the screen grid will considerably lower the potential of this junction (the point G in Fig. 9). Now it has already been stated that it is desirable to cut off the oscillograph beam current by biassing back the grid during the fly-back period so that the return trace will not obscure the waveform, and for this purpose we require strong negative pulses. It is evident that the omission of condensers between the point G and H.T.+ or H.T.− has resulted in such negative pulses being found at this point, and they are therefore communicated to the oscilloscope grid

The Sweep Circuit *(Contd)*

via the blocking condenser C_{33}, which holds off the standing D.C. potential.

As the valve V_3 is a straight amplifier, it is unnecessary for it to be provided with the exceedingly high H.T. value of 1,000V. The H.T. could be reduced by inserting a large dropping or decoupling resistance in series with the anode resistance together with the usual decoupling condenser. The cathode, however, would then be almost at the potential of H.T. negative, and since this is usually at approximately -500V to earth, unnecessary strain would be put on the heater-cathode insulation and on the insulation of the heater winding of V_3. It is desirable, therefore, in the interests of clean design, to set the cathode at a potential which will usually be near earth potential, that is to say, at about $+$ 500V with respect to H.T.$-$. A dropping resistance is therefore inserted in the cathode circuit, and is shown in Fig. 9 as R_{70}. It has the same value as the anode resistance R_{65}, so that the valve is at approximately $+500$V with respect to H.T.$-$. The decoupling condenser which prevents R_{70} from creating strong feed-back is connected between cathode and H.T.$+$, and is shown as C_{34}.

Operation

The apparatus is first switched on by means of the mains switch, and allowed to warm up for a few minutes. The **Focus** control should be adjusted until the trace is as fine as possible, and the **Amplitude** control is also set to give a convenient width of scan.

The next operation is to equalise the potentials of the Y plates under the conditions when the grid-earth potentials of V_1 and V_2 are both zero. Since no plug has as yet been inserted in any of the input jacks, the grid-earth potential of V_1 is zero by direct connection. The grid-earth potential of V_2 is controlled, however, by the shift voltage. The main shift potentiometer should therefore be set so that the shift voltmeter reads zero. The grid-earth potentials of V_1 and V_2 are now zero, but unless the two cathode potentials are equal there will be a difference in the anode potentials. If we were to vary the gain of this amplifying stage, the difference in anode potential would correspondingly vary, and the horizontal trace would move up and down. The next operation is therefore to rotate the **Gain** control forwards and backwards, when in all probability the horizontal trace will move up and down. The preset potentiometer R_{16}, which appears on the front panel, should be adjusted until rotation of the gain control backwards and forwards makes no difference in the vertical position of the horizontal trace.

Having fixed the position of the horizontal trace when the grid-earth potentials are zero, it is necessary to bring the cursor, which is capable of mechanical adjustment in the vertical plane by means of a screw into line, with the trace. The apparatus is now ready for the measurement of a waveform. The latter should be connected in general to either the jack AC_1 or DC_1, and usually DC_1 will be preferred. The use of DC_1 is, of course, essential when a D.C. waveform, such as the output of a Distribution Amplifier is to be measured. Having applied the waveform, the coarse and fine frequency controls and the **Hold** control should be adjusted until the wave-form is synchronised. It must be borne in mind that, as explained in the preceding text, the zero position on the whole potentiometer is in the centre, the maximum hold in either sense being obtained in the fully anti-clockwise and fully clockwise positions respectively. It follows that to hold a given waveform, the **Hold** control should be tried in either of the extreme positions, and whereas in the incorrect position an indistinct trace will be obtained due to lack of synchronism, in the correct position a clear bold reproduction of the waveform will be secured. The **Gain** control should be set to give a convenient vertical amplitude, and the **Voltage Range** control to give a convenient range on the main shift potentiometer. The latter may now be adjusted to bring white level, black level and sync level in turn into line with the cursor, when in each case the precise voltage of these levels with respect to earth may be read off on the voltmeter.

No attempt should be made to measure A.C. potentials whose amplitudes exceed 100V double amplitude peak, as otherwise the amplifier V_1 V_2 will be overloaded. In the case of D.C. waveforms, this limitation does not apply, the limit being now set by the maximum shift voltage available, which is $\pm$ 500V.

One *important* point in the operation of these monitors requires to be stressed for the benefit of operators accustomed to working with other designs. It is unnecessary to make any allowance for the setting of the **Gain** control of the monitor in computing the amplitude of a waveform which is being examined. Supposing that a waveform is applied to one of the input jacks, and its vertical amplitude is too small to be clearly seen, so that in consequence the **Gain** control is set to give a gain of 8, for example. Let us further suppose that the difference in the two shift voltages which are required to bring first one side and then the other side of the waveform to the cursor is, for example, 16 V. It might now be thought that the actual amplitude of the incoming waveform is $16/8 = 2$V, because it has been magnified 8 times in the monitor. This is not so, however, since the monitor amplifier also amplifies the shift voltage. Accordingly, the setting of the **Gain** control may be ignored, and in the example quoted the actual amplitude of the incoming waveform will be 16V, i.e. the actual shift voltage difference used in its measurement.

Maintenance

With the monitor set up in accordance with the above procedure, so that the shift voltmeter is reading zero, and the apparatus is ready for the neasurement of the waveform, the **Coarse Frequency** and **Fine Frequency** controls should be set to a minimum. In these circumstances the following readings should be obtained on external instruments connected to various parts of the circuit.

Valve	*Cathode Current*	*Screen Grid Voltage*	*Cathode Voltage*	*Control Grid Voltage*
V_1	18.6mA	800V	604V	599V
V_2	18.6mA	800V	604V	599V
V_3	4.4mA	—	440V	440V
V_4	—	90V	0V	—
V_5	2.7mA	—	677V	674V
V_6	2.7mA	—	677V	674V

All the above voltages are measured with respect to H.T.—.

Total H.T. feed 60mA

H.T. voltage 1,000V

The input capacity at DC_1 or DC_2 is $50\mu\mu F$, and at AC_1 or AC_2, $60\mu\mu F$.

181

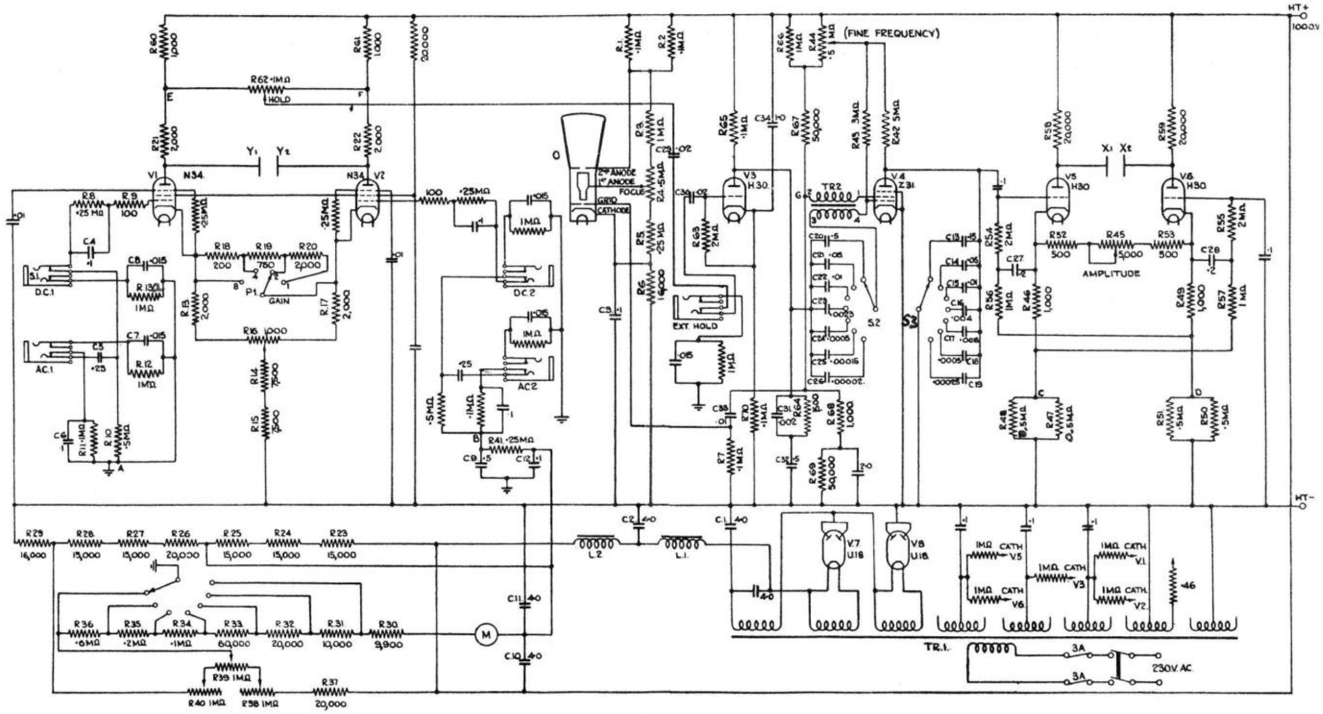


Figure 9. Circuit of Waveform Monitor, Type 3a.