TECHNICAL DESCRIPTION

MARCONI-E.M.I. SYSTEM OF TELEVISION

PART 4 THE CAMERA CHANNEL

CONTENTS

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THE FOCUS PANEL

The Focus Panel is a unit whose function is to supply and control all voltages and current associated with the gun in an emitron. Each camera therefore has one Focus Panel associated with it, and located on the vision racks.

The gun in the emitron camera contains four electrodes: the cathode, the grid, the first anode and the second anode. The cathode is indirectly heated from A.C. at 4 V, at 1.1, 1.2, or 1.3 amperes, depending upon the particular type of emitron which is being used. The grid is given a bias of about $-$ 25 V, with respect to the cathode, and in addition is supplied with what is known as a black-out pulse, the function of which is to suppress entirely the emission of the gun during the line and frame return times.

It is an essential condition for the correct operation of the emitron that no element of the mosaic should be bombarded by the beam from the gun between the time it is normally scanned and the time in which the scanning beam comes round to it once again. Naturally, in the ordinary course of scanning the beam returns from one side of the mosaic to the other between lines, and traces a zig-zag path up the mosaic during the frame return time. If the beam were not suppressed those elements which fall on the return path of the gun beam would be bombarded and discharged additionally to the normal bombardment applied during the normal scan, and their potentials would differ from those which had not been so bombarded. This would, of course, result in the paths of the line and frame return strokes being seen in the transmitted picture. The black-out pulse, therefore, is applied to the emitron grid in such a sense that it renders the latter strongly negative with respect to the cathode during the period of the line and frame return strokes, thus cutting off the beam. It is the function of the valve V in the circuit diagram (p. 5) to receive the black-out pulses, which have been separately generated in the black-out pulse generator, and pass them to the emitron grid.

The first and second anodes constitute a normal electrostatic focusing system, taking the form of a positive lens which focuses the gun beam to a small spot on the mosaic. The sharpness of focus depends upon the ratio of the first and second anode potentials, and in practice this ratio should be approximately 2 : 5, the first anode having a potential of approximately 600 V, positive to the cathode, and the second anode some 1,500 V positive to the cathode. In view of the fact that the second anode forms a screen around the greater part of the path of the beam it must be earthed, so that the actual pontentials of the electrodes are as follows: the second anode, zero; the first anode, $-$ 900 V; the cathode, $-$ 1,475 V, and the grid at FORWARD STROKES ~~black level~~, $-$ 1,500 V. The necessary adjustment of all these voltages and currents is performed from the Focus Panel.

101 We can now consider the detailed arrangement of this unit. In the first place, it is essential that should there be a failure of the scanning, the beam current should immediately be switched off, as the continued incidence of a stationary electron beam on the mosaic would damage the latter by "burning" it. A spot on the mosaic which has been burnt in this way appears as a black spot in the transmitted picture. To prevent this, the D.C. supplies to the valve in the Focus Panel are automatically cut when the scanning current flowing down the emitron cable is interrupted. The coil of the relay *C* (Fig. 2, page 5) is energised by the D.C. anode current of the valve V_7 in the Keystone Output Panel (Item 4.2, page 5). This anode current is entirely dependent upon scanning current and ceases when the latter is interrupted. Assuming, therefore, that sufficient scanning current is flowing, D.C. from the Keystone Output Panel enters the Focus Panel by the terminals *AB* and operates the relay *C*, closing the contacts *D* and *E*. The contacts *D* operate the green lamp mounted on the Focus Panel from 12 volts supplied by the transformer *TRI*, thus indicating that the scanning is in order. The contacts *E* supply 110 volts from the Control Room supply to the push-button contactor. This contactor is of a type standard throughout the system, and has an **On** button coloured black and an **Off** button coloured red. Depression of the **On** button energises the contactor coil, and an iron link attached to the button is simultaneously depressed on to the pole pieces, thus completing the magnetic circuit of the contactor, and the button accordingly remains depressed. The **Off** button simply breaks the energising circuit, thus causing the contactor to fall out and the **On** button to fly up under the influence of a spring. This type of contactor really does no more than a multi-contact switch, except that it falls out if the control supply is broken, and does not make again if the control circuit is reapplied. Thus, these contactors may be used to build up a system of interlocks.

Assuming, therefore, that the relay *C* has closed contacts *E*, the push-button contactor may now be made by hand, thus closing the contacts *F, G, H and I*. The circuit, $C_1 R_1$ forms a spark quencher for the contacts *E*. The circuit $C_2 R_2$ performs the same function for the operating buttons of the push-button contactor. The voltage developed across the contactor coil is also applied via the resistance R_3 to a relay in the H.T. STABILISING circuit of the appropriate Head Amplifier, which operates, and that amplifier is accordingly energised. The contacts *G*, *H* and *I* make the supplies to the first anode, cathode and grid respectively. It will be seen that should the scanning current fail due to any cause, including the uncoupling of a cable without having previously switched off, the relay *C* will open, thus allowing the push-button to fall out and disconnecting all the emitron electrodes except the second anode, which is earthed, and the heater which can safely remain on.

These electrode supplies are derived from a separate rectifier contained in the Camera H.T. Unit, the output of which arrives at the Focus Panel by the terminals JK, across which are connected the potentiometer formed by the resistances R_4, R_5, R_6, R_7, R_8, R_9 and R_{10}. The first anode potential of $-$ 900 V is found on the resistance R_6, which is made in the form of a potentiometer manually adjustable from the front of the panel. This adjustment varies the first anode pontential, and hence the ratio of the first and second anode potentials upon which the focal length of the equivalent positive lens depends. This potentiometer therefore enables the scanning spot to be finely focused upon the mosaic, and it is accordingly designated **Focus.**

As already stated, the second anode is earthed, but as will be seen from the diagram, the connection to earth is made via the mirror galvanometer M_1, which enables the beam current to be read. Each division on this instrument corresponds to 1/100th of a micro-ampere. In order to prevent possible damage to this delicate instrument, it is normally held short-circuited by the button N, which must be depressed in order to take a reading. In connection with this meter a control knob is provided designated **Zero ADJ.**, which sets the zero by effecting a mechanical adjustment of the mirror, that throws the spot of light from the galvanometer on to the screen.

A cathode potential of $-$ 1,475 V is found on the resistance R_9, and the grid potential of $-$ 1,500 V is found on the terminal K to which the grid is connected via the contact I of the push-button contactor and the anode circuit of the valve V. The grid bias, or the negative potential between the grid and the cathode must be variable, as by this means control of the beam current, which must be set to a certain figure, is obtained. Grid bias variation is obtained by means of the potentiometers R_9 and R_{10} of which the former gives coarse adjustment and is designated **Coarse Bias,** and the latter a fine control, and is correspondingly designated **Fine Bias.** The potentiometer R_9 operates by varying the positive potential of the cathode with respect to the relatively negative and fixed potential of the grid, and R_{10} makes a very slight adjustment to the current flowing through the complete potentiometer R_4 to R_{10}, and so exercises a fine control upon the grid to cathode pontential. The potentiometers R_9 and R_{10} obviously affect the relative potentials not only of the grid and cathode, but of the first and second anodes, but their influence on the potentials of the two latter electrodes is entirely negligible.

The condenser C_3 removes any ripple or vision frequency components from the first anode potential, and the condenser C_7 performs a similar function for the grid-cathode potential. It is convenient to be able to read the value of the first anode-cathode voltage, and this is done by means of the 0—250 micro-ammeter, M_2, which in combination with the series resistance R_{11} reads 0—1,000 V. It will be seen that in practice the meter is connected so as to read the first anode-grid voltage, which is approximately the same as the first anode-cathode voltage.

It will be seen from the circuit diagram that the connection from the terminal K to the grid of the emitron includes the anode circuit of the valve V. Any potentials which may be developed across this anode circuit will also be impressed on the emitron grid in series with the grid bias. It is arranged that the black-out pulses, the function of which has already been described, are developed in this anode circuit in the negative sense and of sufficient amplitude as to extinguish the beam current during the periods of their application. In order that the anode circuit may contain negative black-out

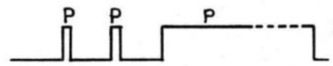


Figure 1. Line and Frame Black-out Pulses

pulses, positive black-out pulses which have been given an appropriate degree of delay in the Camera Delay Unit are applied to the grid of V. The waveform of these pulses is illustrated in Fig. 1, which shows as an example two line black-out pulses followed by a frame black-out pulse. The duration of these line and frame pulses is just sufficient to cover the line and frame return times of the emitron scanning beam. For the moment let us consider that the elements forming the anode circuit of V (Fig. 2), comprising R_{12} R_{13} R_{14} C_2 TR_4, are collectively equivalent to a pure resistance. Then during the peaks of the pulses, shown at P in Fig. 1, the valve V will pass anode current and there will be a drop of potential across the equivalent anode resistance of V, which will, for the duration of the pulse, greatly increase the grid bias applied to the emitron grid, and the beam will be extinguished.

The detailed action of the circuit associated with the valve V is as follows.

An H.T. supply at 250 V and derived from a separate rectifier, also located in the Camera H.T. Unit, is applied between the terminals K and L. The anode of V is connected via the external anode impedance R_{12} R_{13} R_{14} TR_2 C_4 to the positive side of this supply, terminal K, while the cathode of V is returned to the negative side, terminal L, via the decoupling circuit R_{16} and C_6. This decoupling circuit is quite standard except that it is included in the negative side of the supply instead of the positive side. Positive black-out pulses derived from the Camera Delay Unit are applied to the control grid of V via the input condenser C_5, and the grid leak R_{15} is returned to a point on the potentiometer R_{17} R_{18} connected across the 250 V H.T. supply, at which point there is a potential of approximately + 80 V. There is therefore no negative bias on V, but rather a positive bias of 80 V. Restoration of D.C. is therefore strongly encouraged, and the tips P of the pulses will coincide with a grid-cathode potential on V of approximately 0 V, but the troughs of the pulses will make the control grid of V sufficiently negative as to cut off the anode current. The principle of D.C. restoration is used here, as in many cases, because since we are dealing with a square 102 pulse there is no need to adopt straightforward linear methods of amplification to achieve the desired result. We desire the tips P of the pulses to make V draw a considerable anode current, and we also desire the troughs to extinguish the anode current; the location of the pulses on the operating characteristic of the control grid of V in order to bring about this state of affairs is automatically effected by allowing the valve to restore D.C. to the incoming pulses. The connection of R_{15} to a potential of $+80$ V is of no great significance, and the circuit would look more orthodox if it were returned, as it might well be, to the cathode of V; but since the restoration of D.C. demands that the grid shall attempt to draw grid current during the tips P of the pulses, such grid current will obviously be enhanced by returning the grid leak R_{15} to a source of positive bias. Since the impedance of any grid-cathode circuit always drops to a very low value when the grid is made positive with respect to the cathode, the impedance of the grid-cathode path of the valve V will be so low compared with the value of R_{15} during the tips P of the pulses, that the grid will only be positive with respect to its cathode by $+1$ V or so, and not by $+80$ V, the potential to which R_{15} is returned.

The valve V is accordingly shut off during normal scanning times and opened, so as to pass anode current, during the return times; hence its anode circuit contains negative black-out pulses of large amplitude.

We may now consider the function of the elements R_{12}, R_{13}, R_{14}, C_4 and TR_2, which constitute the complex anode circuit of the valve V. The black-out pulses must be transmitted to the emitron via the black-out line in the emitron cable, which may have a length of anything up to 1,000 feet. As usual, unless the transmission of these pulses is carried out under matched impedance conditions, they will not proceed smoothly from the Focus Panel to the emitron, but will be reflected backwards and forwards a number of times along the cable. The pulse will therefore not cease at the end of its prescribed duration, but will be followed by a series of further pulses each of successively reduced amplitude owing, of course, to loss of energy at each reflection. It has been found that the time over which this succession of subsidiary pulses can last will extend beyond the duration of the suppression pulses, particularly in the case of the line suppression pulse. Therefore, during the first part of the line scan, the scanning beam, which should be of constant intensity, will be modulated by the last few subsidiary pulses. In these circumstances there may be observed on the screen, as would be expected, a series of vertical black and white lines, which decrease in intensity from left to right and disappear altogether about a quarter of the way across the picture when the reflected subsidiary pulses have lost so much amplitude that they cease to be effective.

To avoid this, the black-out line must be operated under matched impedance conditions. It is not desirable to terminate it in its own characteristic impedance at the receiving, or emitron, end since this would halve the voltage of the pulses available, and it is found that the prolongation of the black-out pulses by reflection can be avoided if the sending, or Focus Panel, end is terminated with reasonable accuracy. The characteristic impedance of the cable is 165 ohms, and it might be thought that it would be sufficient to include a simple resistance of 165 ohms in the anode circuit of the valve V and connect the cable across this. Unfortunately, however, the impedance presented to the anode circuit of V, being only 165 ohms, is insufficient to develop an adequate amplitude of black-out pulses, and it is necessary to seek a means of increasing the voltage which can be applied to the cable, while still keeping the cable properly terminated. This function is carried out by the elements R_{12}, R_{13}, R_{14}, C_4 and TR_2. Instead of a pure resistance of 165 ohms, a resistance, R_{12}, of approximately 4 times this value, is placed in the anode circuit, and since the valve V_2 is a pentode, the black-out amplitude across R_{12} will be 4 times the amplitude which would be obtained were it only 165 ohms. Across R_{12} is connected the transformer TR_2, which has a turns ratio of $2:1$. The impedance transformation ratio of this transformer will be $2^2:1$, or $4:1$, and the impedance presented to the line will be $\frac{650}{4}$ ohms $= 162$ ohms which terminates the cable with reasonable accuracy. The voltage ratio of the transformer will be the same as its turns ratio, viz. $2:1$, so that although it transforms down the impedance of R_{12} by 4 times, it will transform down the voltage across R_{12} by only twice. Since the available voltage across R_{12} is 4 times that available were it given a value of 165 ohms, the arrangement will provide a net gain of twice the black-out amplitude, while keeping the cable terminated.

The transformer TR_2 is unfortunately not adequately efficient over the whole of the frequency range of the black-out pulses, which, including both frame and line components, extends from 50 to some 300,000 c/s, and in order to avoid self capacity, which would be detrimental to the upper frequencies, it cannot be given an inductance which will adequately preserve the lower frequencies. The inductance of the transformer therefore shunts R_{12} at the lower frequencies, and an inadequate output is obtained. This is corrected by the insertion of R_{13} which has a value approximately half of that of R_{12}; at low frequencies we may neglect the presence of R_{12} and of the transformer TR_2, and consider that the black-out line is connected to the lower end of R_{13}, at which there will exist an output equal to that normally supplied to the line at high frequencies by R_{12} and TR_2. The voltage output developed across R_{13} is, of course, half that developed across R_{12}, but since this output is not being divided by 2 by the action of the transformer TR_2, as in the case at the upper frequencies, the output actually supplied to the line will be unchanged. Clearly, R_{13} must be eliminated at the upper frequencies. This is effected by shunting it with C_4. In order that the transition between the transmission of the upper and lower frequencies may be correct, the value of C_4 is so chosen that the time constant

103

C_4 R_{13} is equal to the time constant of the inductance of the transformer in conjunction with R_{12}. A small resistance R_{14} is inserted to compensate for the effect of the resistance of the transformer winding. Obviously, at low frequencies the impedance in which the cable is terminated is 330 ohms, i.e., the value of the resistance R_{13}, but as usual the maintenance of an exact termination is not important at the low frequency end of the range.

The 4 V A.C. supply to the emitron heater is provided by the transformer TR_3, and the cathode is returned as usual to the electrical centre of the secondary by means of the potentiometer R_{17}, which is designated **Hum Adj.**

It is necessary to maintain at a constant value the heater current of the emitron, no matter what length of cable is being used between it and the Control Room. As A.C. is employed, it is not necessary to adjust the current by means of a rheostat, but this adjustment can be maintained automatically by the use of what is known as a *Boucherot* constant current network. This is formed essentially by the transformer TR_3 and one or other of the capacities C_8, C_9 or C_{10}. Without going into mathematical details, the principle is roughly as follows. If we imagine that the secondary of the transformer TR_3 is short-circuited, the effective inductance of the primary will be less than if the secondary is open circuited because current induced in the short-circuited secondary will create fields in opposition to those of the primary. The open and short circuit cases are extremes, and the effective inductance of the primary will in fact vary with the resistance placed across the secondary. The connection of the emitron heater via various lengths of cable across the secondary is, of course, in effect the connection of various values of resistance across the secondary, and the effective primary inductance consequently varies. As the length of emitron cable used increases, the current in the heater which must be maintained constant decreases, and the effective inductance of the primary increases. Accordingly a condenser (C_8, C_9 or C_{10}) is inserted of such a value that when the effective inductance of the primary increases, the series circuit formed by this effective inductance and the condenser tend to approach resonance with the frequency of the mains; thus more current flows from the mains into the transformer and in turn into the emitron heater. For short lengths of cable the resistance placed across the transformer secondary is reduced and the emitron current tends to rise, but the effective primary inductance is reduced and the resonant frequency of this and the condenser move away from 50 c/s, thus cutting down the current. In this way exact and automatic compensation can be secured. The three values of capacity provided enable the current to be fixed at 1.1, 1.2 or 1.3 amperes.

It may be required to use with the Focus Panel an alternative type of emitron which is provided with a magnetic focussing system additional to the electrostatic focussing system already considered. The current required by such a system is derived from the 110 V control voltage supply and is fed down a line in the emitron cable from terminal W in the Focus Panel. It is convenient to switch this supply by means of the remaining contacts QF on the push button contactor. The elements C_{11} and R_{18} form a spark quenching circuit for these contacts.

The emitron heater is switched on by the switch S.

Operation

The method of operation of the Focus Panel in conjunction with a long gun tube is as follows.

The Focus Panel controls are in general the last to be operated in the series of operations entailed in obtaining a picture on the system. The remainder of the system, therefore, is switched on first ; at the same time the emitron heater may be warmed up for a minute by closing the switch S on the Focus Panel.

In order to prevent possible underscan of the mosaic when the beam is switched on, the operator should at this stage assure himself that the **width** and **height** of the appropriate Keystone Output Unit are set to maximum. If everything is in order adequate scanning current will be delivered from the Keystone Output Unit and the relay C in the Focus Panel will operate. This will cause the green lamp to light up indicating that it is safe to apply beam current. At the same time the galvanometer lamp, which is fed in parallel with the green lamp, will light.

The main H.T. push button contactor on the fish plate having been closed, the push button contactor on the Focus Panel may also be closed. Assuming that the bias controls have not been touched since the previous transmission, and are therefore so set that they permit a normal beam current to flow, the mosaic will appear as an intense black patch of, in general, trapezioidal shape surrounded by an intense white area. This white area is the natural signal produced by the emitron when, owing to excessive scanning amplitude, the beam at the extremities of both scans shoots off the edge of the mosaic. This signal, being abnormally large, will overload certain parts of the vision chain, and at certain points an inadvertent restoration of D.C. with reference to the positive peaks of this signal occurs while all signals of lesser amplitude, such as those from the area of the mosaic itself, are forced down into the regions of black. This is the cause of the appearance of the mosaic as a black patch in these circumstances.

The Keystone Output amplitudes will now be restored to normal, whereupon the picture will appear normally.

The beam current should now be checked. For this purpose the **Coarse** and **Fine Bias** controls should be turned to a maximum, thus extinguishing the beam, and the button **N** should be depressed so as to allow the galvanometer M_1 to read. Although there is no beam current, the meter will give a small indication due to leakage in the cable. This reading 104 should be taken as zero. The **Coarse** and **Fine Bias** controls should now be adjusted until the reading increases by **approximately 8 divisions,** i.e. 0.08 microamperes. This figure will vary for different emitrons, but in general is correct. Next the **Focus** control R_6 should be varied until the beam is as finely focussed as possible, which may be seen by observing the sharpness of the picture on the picture monitor. In these circumstances the meter M_2 will read **between 500 and 600 V.**

The panel is now adjusted for use.

The adjustments provided on the Focus Panel are amongst those from which assistance may be sought at times when the conditions for the transmission of a good picture are somewhat difficult. In particular, the adjustment may be varied with the amount of light available on the scene.

When the scene is adequately lit the amount of correction which has to be introduced by the tilt and bend apparatus is small, the operation of the gear is generally satisfactory, and the normal beam current of 0.08 microampere may be employed. If the lighting is reduced, it will be found that the error in illumination distribution of the emitron, which is normally corrected by the tilt and bend apparatus, can no longer be completely compensated for in this way.

The tilt and bend apparatus provides a tilt waveform and a bend waveform in both the line and frame directions, because it is found that under normal circumstances the illumination error of the emitron has the form of a tilt or bend. With poor lighting, however, the waveform which has to be corrected is no longer purely a tilt (i.e., a saw-toothed waveform) or a bend, but is a peculiar waveform with a pronounced uplift at the edges of the picture. Since the principle of tilt and bend correction consists of injecting into the picture circuit a waveform precisely the inverse of that causing the error, it is clearly no longer possible for the tilt and bend apparatus to effect a remedy, and the picture is considerably spoilt by the flaws which occur at its edges. It is found that under these circumstances, if the beam current is reduced below 0.08 microampere by adjustment of the **Coarse** and **Fine Bias** controls, then even with the reduced lighting the waveform of the emitron illumination error is much nearer to that which can be properly compensated for by the tilt and bend apparatus, i.e. it has returned by a considerable extent to the saw-toothed and bend form.

Thus, the judicious adjustment of the beam current can be used to improve the picture when the lighting is poor. The rule is, *if the lighting is reduced, the beam current must be reduced*, and *vice versa*. Unfortunately, this process cannot be carried too far, as the sensitivity of the emitron falls with a decrease of beam current, and if the latter be reduced too far, then the gain of the 'A' Amplifier will have to be increased (in order to produce enough modulation) to an extent which will bring up the mush level in the picture to an undesirable extent.

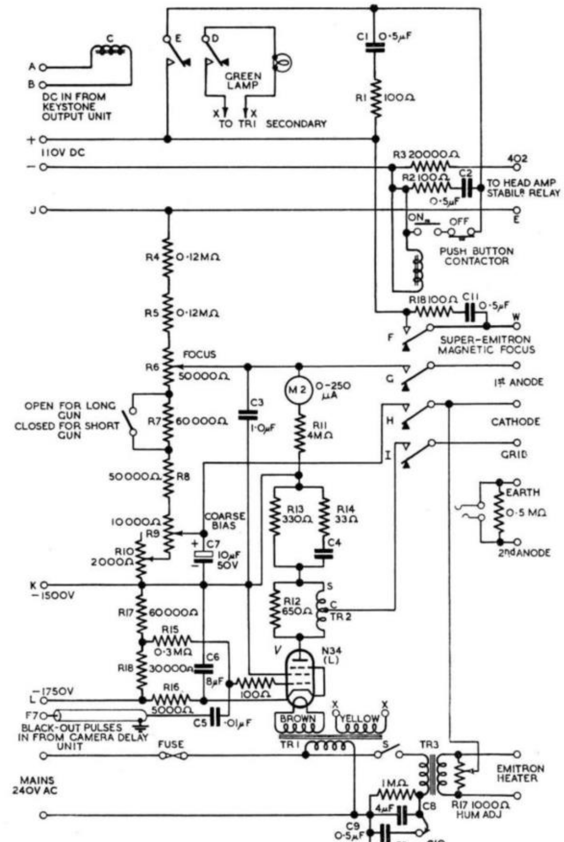


Figure 2. Circuit Diagram

THE KEYSTONE OUTPUT PANEL

The deflection of the emitron beam necessary to produce the scanning action is performed electromagnetically by means of two pairs of coils mounted in appropriate positions round the neck of the emitron tube. This method is preferred to the alternative of electrostatic scanning for a number of reasons, the chief of which is that in magnetic scanning a certain current amplitude is required at a comparatively low voltage, but in electrostatic scanning large deflecting voltages are needed, and it is in practice easier to develop the current required for magnetic scanning than the voltage necessary for the alternative method. The emitron coils are connected to two separate pairs of cables, forming the quad in the emitron cable, and it is the function of the keystone output panel, one of which is provided for each camera, to develop the required scanning currents and apply them to the emitron cable.

It will be remembered that scanning currents of a particular wave shape are required in order that the scanned patch on the emitron mosaic may be rectangular when viewed from the optical axis, although scanned at an angle by the gun. It is not the function of the Keystone Output Panel to generate this special waveform ; this has already been done in the Keystone Generator, which produces voltages of the required waveform. These voltages are applied to the Keystone Output Panel, which converts them into currents of similar waveform.

Owing to irregularities in the construction of the emitron, if no precautions are taken, the scanned patch may not be properly centralised on the mosaic but may be displaced horizontally or vertically. This may be corrected by passing through the emitron scanning coils a constant D.C. current, which will effect a permanent displacement of the scanning in the opposite directions, so as to centralise the scanning. These are known as the ***shift*** currents, and it is a further function of the Keystone Output Panel to apply and regulate these currents.

As will be seen from the circuit diagram (page 5), the panel contains seven valves, of which V_1, V_2, V_3 and V_4 are associated with the line scanning, and V_5, V_6 and V_7 with the frame scanning. V_2, V_3 and V_4 are paralleled and form the output stage which supplies the line scanning current to the camera. At first sight it would seem sufficient that the input from the Keystone Delay Unit should be applied directly to the three grids in parallel. If this were done, however, a serious state of affairs would develop if there were an accidental interruption of the H.T. supply to those three valves, or if the H.T. were off due to the associated camera not being required, for in the event of this happening the three control grids would immediately draw a large grid current which would place a heavy load on the Keystone Delay Unit. Since this has to supply scanning voltages to all the other Keystone Output Panels, the amplitude delivered to the other channels would be reduced and the amplitude scanned on the mosaic of their associated cameras would be reduced. Accordingly, it is considered advisable to isolate these three grids from the Keystone Generator by means of the cathode follower V_1.

The grid of V_1, therefore, receives line keystone input from the Keystone Generator, but not directly ; it is necessary to interpose a delay circuit. The general question of delays, as applied to pulses, is treated in a separate technical note, but it may be stated here that if a camera is being used at the end of a long length of cable, an appreciable period of time will occur before the line scanning impulses reach the camera from the sending end, and the scanning will be late with respect to the scanning of any monitor at the sending end or any receiver used normally on the transmission. Since it is impossible to advance the scanning, it is necessary to delay the scanning of all cameras to a standard figure corresponding to that delay which will be produced by the longest length of emitron cable which the system is designed to use. Hence, the grid of V_1 takes its input not from the Keystone Generator, but from a unit termed the Camera Delay Panel, which in turn receives the scanning impulses from the Keystone Generator.

It is found that, although the grids of V_2, V_3 and V_4 are isolated from the Keystone Generator by the cathode follower V_1, if the H.T. is not on, even the grid of V_1 will form an appreciable load on the Keystone Generator, and to offset this effect it is accordingly arranged that when the H.T. is off a negative potential is applied to the grid. To effect this, half the heater voltage, i.e. that existing between one side of the heater and earth, is applied to the Westinghouse rectifiers D_1, D_2 and the condensers C_1 and C_2, all of which form a voltage doubling circuit, and at the point A there appears an unsmoothed rectified potential of about 20 volts negative with respect to earth. This is smoothed by the resistance R_1, and the condenser C_3, and appears at the point B as a smooth voltage. The grid resistance R_2 of V_1 is returned not to earth, but to the point B and so picks up this negative voltage in parallel with the line keystone input, which is applied between the input terminal C and earth. The state of affairs, therefore, when the H.T. is off is that V_1 is biased well back by the negative voltage at B and it cannot load the Keystone Generator. When the H.T. is applied, a current passes via the high resistance R_3 and the further resistance R_4, and imposes a positive voltage at the point B which cancels that due to the rectifiers D_1, D_2, so that the valve V_1 is placed at its proper operating point, and the keystone input takes effect.

V_1, being a cathode follower, the anode circuit contains no impedance, but merely the decoupling components R_5 and C_3. The cathode resistance R_6 is, of course, unshunted, and takes the form of a potentiometer by means of which the amplitude delivered to the power amplifiers of V_2, V_3 and V_4

107

may be regulated. This potentiometer therefore constitutes a control of the width of the scanned patch on the mosaic. The cathodes of the valves V_2 V_3 and V_4 contain the unshunted small resistances R_7 and R_8, which, having a low value, do not cause the valves to function particularly as cathode followers, but provide a small amount of feed-back which lengthens the grid characteristic. The correct grid bias in each case is found by returning the grid resistance R_9 to the junction of R_7 and R_8 in each case.

The anode circuit of these valves is somewhat complicated. The power generated in the anodes must be fed to the appropriate pair in the emitron cable, whose characteristic impedance is 100 ohms. It should be noted here that in order to avoid any possibility of reflection down the cable, which would, of course, modify the frequency characteristic and consequently the velocity of the scanning, with the consequent introduction of bad positional distortion, the cable is terminated in its characteristic impedance at the camera end and so looks like an infinite line. Its impedance at the sending end must, of course, be transformed up in order to present a proper load impedance to the anode circuit of the output valves, and a fairly high ratio transformer is required. The range of frequencies with which this transformer must deal faithfully is from about 10,000 to 500,000 c/s for good scanning, and consequently such considerations as self-capacity and leakage inductance, which must both be kept small, will limit the maximum ratio obtainable. The particular transformer fitted, TR_1 in the diagram, has a ratio of 13 : 1. Its secondary feeds the line, and its primary presents an impedance of $13^2 \times 100$, or 17,000 ohms. This transformer has to have a mu-metal core and D.C. must therefore be held off from its primary. It is therefore parallel fed by means of the inductance L_1 and the condenser C_5. Unfortunately L_1 has a self-capacity, shown dotted in the diagram at C_6, having a value of 24 $\mu\mu$F. Further, the transformer, although as well designed as possible, has a leakage inductance of 40 μH all on the secondary side, and lastly the transformer primary and associated wiring has a self-capacity of 60 $\mu\mu$F., and these three facts detract from the frequency characteristic obtained. They are, however, eliminated by designing the circuit in the form of three constant resistance networks.

Referring to Fig. 1, it will be remembered that if the values of the four components are so chosen that $L = CR^2$, then the impedance measured across the ends of the circuit will be equal to R at all frequencies. The same applies in the circuit of Fig. 2. If, therefore, in designing a circuit for television an unwanted capacity is involved, it may be possible to annul its effect by adding two resistances and an inductance so that the capacity combines with these three additional elements to form the circuit of either Fig. 1 or Fig. 2, in which case its effect is annulled, as a circuit whose impedance is the same at all frequencies can have no effect on a frequency characteristic. This principle is applied three times in the anode circuit of the valves V_2, V_3 and V_4. C_6 is an unwanted capacity. By the addition

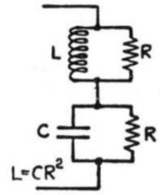


Figure 1

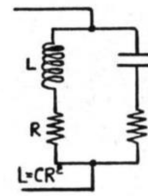


Figure 2

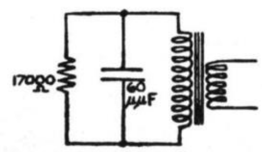


Figure 3

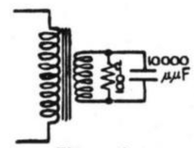


Figure 4

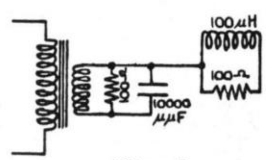


Figure 5

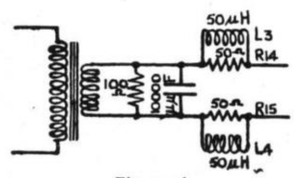


Figure 6

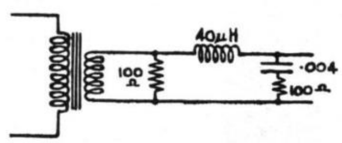


Figure 7

of the inductance L_2 and the resistances R_{12} and R_{13}, the capacity is made to form part of the circuit of Fig. 1, and the impedance across the primary of TR_1, instead of decreasing with frequency, as it would if C_6 were present alone, remains constant at a value of 17,000 ohms, and the frequency characteristic is unaffected. Since the transformer transforms up the line impedance of 100 ohms to a value of 17,000 ohms, this value is naturally chosen as the impedance of the constant resistance circuit which is designed around C_6 in order to secure impedance matched conditions.

The primary of TR_1 now has effectively across it a resistance of 17,000 ohms at all frequencies, but this is shunted by a capacity produced by the valve anodes and wiring and a certain amount of self-capacity in the primary of TR_1. The equivalent circuit is shown in Fig. 3. This capacity is again built out by inclusion in the constant resistance network in order that this effect may be eliminated. This is, however, done on the secondary side. By simple calculation the load resistance of 17,000 ohms and the capacity of 60 $\mu\mu$F. becomes on the secondary side 100 ohms and 10,000 $\mu\mu$F. approx. respectively, as shown in Fig. 4. By applying the rule $L = CR^2$ this may be built out to form a constant impedance by the addition, as shown in Fig. 5, of an inductance of 100 μH in parallel with a resistance of 100 ohms. In order to keep the circuit symmetrical these values are halved, and half inserted in each leg so that in practice two pairs of elements, each consisting of 50 ohms, in parallel with 50 μH are added, and are shown as L_3, L_4, R_{14} and R_{15} in the circuit diagram, and also in Fig. 6.

The elements in Fig. 6 then may be represented as a simple resistance of 100 ohms across the secondary of the transformer, but we have yet to correct for the effect of the secondary leakage inductance of 40 μH, shown in Fig. 7. By the addition of a condenser of 0.004 $\mu\mu$F in series with a resistance of 100 ohms the circuit is made similar to that of Fig. 2, and the effect of the leakage inductance is cancelled. In the circuit diagram, Fig. 8, p. 4, these additional elements are shown at C_7 and R_{16}. Thus, finally, the anode circuit of V_2, V_3 and V_4 shows a pure resistance of 100 ohms to the line.

The line shift voltage necessary for centralising the scanned patch on the mosaic as regards the horizontal plane is taken from a 6-volt supply, and injected across the potentiometer R_{17}, and may be varied at will by this potentiometer.

During the lining-up process it is considered advisable to expand the scanning amplitude both in the line and frame directions. In the line direction this expansion is achieved by the switch S_1, which in the **Normal** position sets up the circuit arrangements which have been described above, but which in the **Condition** position cuts out half of the secondary winding L_5, together with the shift voltage, leaving in operation only the other half, L_6. The ratio of the transformer is thus doubled and the scanning current is correspondingly increased. Since the impedance matching arrangements are upset by this arrangement, the scanning waveform and return time are both poor, but this, of course, does not matter.

We can now consider the operation of the valve circuits involving V_5, V_6 and V_7, which are solely concerned with the frame scanning. For reasons of design based on securing the correct amplitude, the keystone generator delivers the frame scanning waveform in push pull and this is applied to the grids of V_5 and V_6 which act in push pull. It will be noted that no delay network is included, as the time of propagation down the cable is so short compared with the frame scanning period that no appreciable defect is produced by the delay, and no delay network is necessary.

In the cathode circuits of V_5 and V_6 are included unshunted resistances, R_{18}, R_{19}, R_{20} and R_{21}, which are sufficiently high that we may regard the valves as acting really as cathode followers, but they are not there for that purpose. They are there to give these valves very lengthy grid characteristics and produce considerable negative grid bias. The grid resistances are returned not to earth, but to the point D on the potentiometer R_3, R_4, R_1, which, as has been described, is provided to generate positive grid bias for the operation of the complex grid current of V_1. Thus, in a similar manner, the point D provides positive bias which, in conjunction with the automatic bias of V_5 and V_6, sets their grids at the proper working point when the H.T. is on, but allows them to become more negative when the H.T. is off, so that similarly loading of the keystone generator is obviated. The gain of the valves V_5 and V_6 is controlled by a somewhat novel method of volume control consisting of the variable resistance R_{22} in series with the limiting resistance R_{23}. As the valves are operating in push pull, the potentials existing at any moment on the cathodes of V_5 and V_6 are in phase opposition, and as the valves are working as cathode followers, there is considerable feed-back to their grids, which is reducing their gain. If the cathodes were short-circuited their potentials would mutually cancel out, and there would be no feed-back to their grids. The gain would therefore rise. The connection of the resistances R_{22} and R_{23} provides a means of varying the mutual cancellation of the potentials on the cathodes and so varies the feed-back to the grids and therefore the gain of these valves. Clearly, as R_{22} is reduced the gain will increase. The resistance R_{22} therefore constitutes the control for the height of the scanned area on the mosaic.

The anode circuit feeds the transformer TR_2, which in turn feeds the transformer TR_3, from which the output proceeds to the frame scanning line in the quad. As the range of frequencies involved in this circuit is very much less and extends only between 50 and less than 2000 c/s., no special precautions are required as regards building out of the circuit to constant impedance. The frame shift voltage is similarly injected from a 6-volt D.C. supply across the potentiometer R_{24}, variation of which consequently enables the scanned patch to be centralised on the mosaic in the vertical plane. As in the case of the line scanning, the **Normal-Condition** switch S_2 in the **Normal** position places in circuit both sections L_7 and L_8, of the secondary of the transformer TR_2, but in the **Condition** position removes L_8, leaving only L_7, thus doubling the scanning current. S_1 and S_2 are, of course, ganged.

It remains to describe the function of the valve V_7. It is essential that no beam current should be applied to the emitron mosaic until an adequate supply of scanning current is flowing, for if this were not so, the beam would be stationary, and the continuous bombardment of one spot on the mosaic would photoelectrically burn it, and the burnt place would appear in subsequent pictures as a dark spot. It is considered sufficient that an adequate supply of frame scanning current only must exist, and it is accordingly arranged that in the absence of the latter it is impossible to turn on the beam. This has the additional advantage that if the cable be uncoupled at any point without having previously turned off the apparatus, the cessation of frame scanning current so produced will remove the beam current, and with it the dangerously high potentials supplied to the emitron cable. It will be remembered from my technical note on the Focus Panel that in the latter a relay is provided which permits the application of the emitron gun potentials only when it is operated by a supply of D.C. It is the function of the valve V_7 to provide this supply of D.C. when there is sufficient frame scanning current.

The voltage between one side of the heater A.C. supplied at 13 volts and earth (which is, of course, half the heater A.C. supply since the latter is centre tapped) is applied via the resistance R_{25} to the Westinghouse rectifier D_3, and a voltage of nearly 10 volts is developed across the load resistance R_{26}. This voltage is smoothed by a condenser C_8. Since the grid resistance R_{27} of V_7 is returned to the point E, this voltage biases the grid negatively and cuts off the anode current. If sufficient scanning current is passing, a voltage will be induced in the winding L_9 of the transformer TR_3, which is applied across the load resistance R_{28}, and is rectified by the further rectifier D_4, and smoothed by the condenser C_9, and the rectifier is so connected as to provide a positive voltage at the point F in opposition to the negative voltage received from the point E. This cancels the negative grid bias and permits V_7 to draw anode current, which is sent to the **Focus Panel** where it operates the relay and permits the application of the emitron gun potentials. Clearly, if the cable is broken or if from any cause the frame scanning current ceases, the positive voltage at F is withdrawn and V_7 is biased back, the anode current fails and the relay in the Focus Panel drops out, thus cutting off the emitron beam.

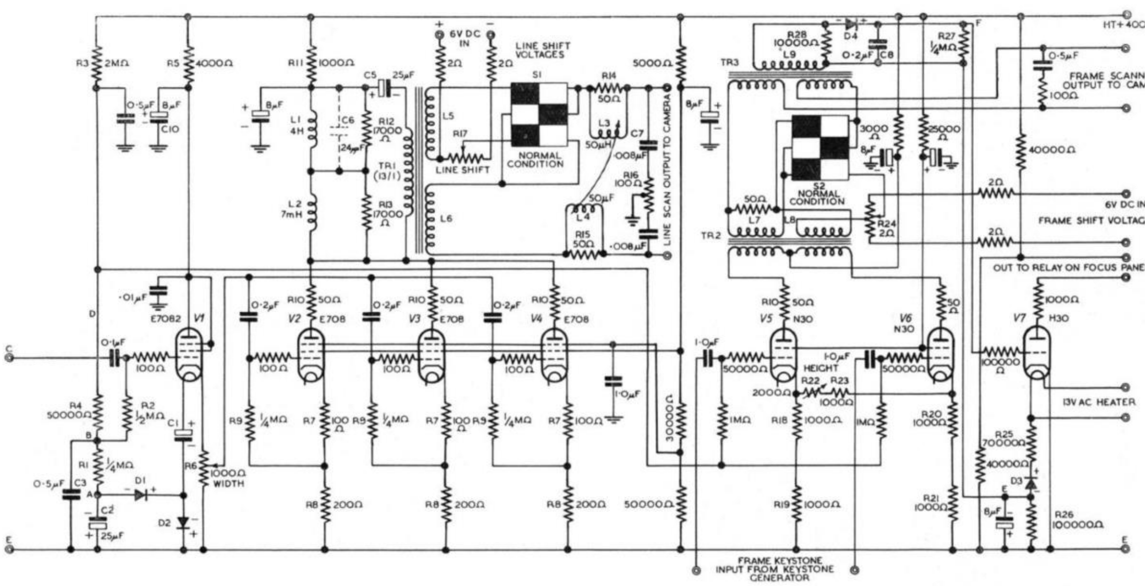


Figure 8. Circuit Diagram.

THE CAMERA

The Emitron

This note describes the camera, which incorporates the emitron tube and its associated head amplifier, all of which are enclosed in an aluminium casing mounted on a suitable stand.

As the complete theory of the operation of the emitron is very complex, the explanation of its action which follows has been intentionally simplified in the interests of brevity.

The emitron consists of an evacuated tube containing a mica plate, upon one side of which has been deposited a large number of photoelectric nodules, each of which is individually insulated from its neighbour. The nodules are exceedingly small, there being in fact a very large number of individual nodules in the small area occupied by one picture element. This surface of photoelectric nodules is called the mosaic. Subsequent processes involving treatment with oxygen and the distillation of caesium into the tube activate the nodules with caesium. On the back of the mica plate there is deposited a homogeneous silver deposit (i.e. not gathered up into nodules) known as the signal plate. The assembly is made in such a way that the scene to be transmitted can be optically focused on the mosaic.

The tube is also fitted with an electron gun, the function of which will appear later, but the final anode of this gun is situated so that it can collect any electrons which may be emitted from the photoelectric mosaic. When an image is focused on the mosaic, photoelectric emission occurs, and those nodules situated in the bright parts of the image emit a proportionately greater photoelectric current than do those in the darker parts. This current is collected by the final anode of the gun. As there is no direct electrical connection to the back of each nodule, the electrons lost cannot be replaced from any source of potential, and the mosaic exhibits over its area a deficiency of electrons, i.e. its potential has become positive. The greater the light falling upon a given part of the mosaic, the more positive after a given time will be the potential of that area. Expressing this in another way, each nodule forms with the common signal plate a condenser, the dielectric of which is the mica plate, and, under the influence of light and the fact that one of the condenser plates is capable of photoelectric emission, each condenser loses electrons, and is therefore charged positively. After a time, therefore, the various areas of the mosaic are charged to the various positive potentials, dependent upon the amount of light that has been falling upon them.

If, now, we can provide some means, as it were, of measuring the various positive potentials which have been taken up, we shall have a measure of the light which is falling on each element, and this is the function of the electron gun, the beam from which does not perform the same function as
113 the electron beam in a cathode ray tube, but which in this case is acting like a weightless brush moving rapidly in the proper order of scanning over the mosaic. As it touches each element of the mosaic in turn, it restores it to its original potential by supplying it with electrons to make good the deficiency due to emission. Again, expressing this differently, we may say that each little elemental condenser is in turn discharged, its positive charge being annulled, and the charging current must, of course, flow in any circuit connected to the signal plate. Since the capacities of all the elemental condensers are the same, the potential they have taken up electronically will be proportional to the charge on them, and since the velocity of the beam is constant, the time of discharge is also constant, and consequently the current in the backplate will be proportional to the voltage of the element, which is at that moment being discharged by the beam. There is, of course, simultaneously flowing in the backplate circuit, but in the opposite direction, the photoelectric current drawn off by the second anode simultaneously from all parts of the mosaic, which is, of course, proportional to the overall brightness of the complete picture. The resultant current flowing in the signal plate circuit is the difference between these two currents, one the individual instantaneous discharge current of an element, and the other the perpetual current representing the overall brightness. This second current merely acts, therefore, as a type of bias and does not prevent the resultant current from representing at any moment the brightness of the scanned element. By placing an impedance in the signal plate circuit, we shall therefore obtain across it voltages at any time representing the brightness of the element then being scanned. This is, of course, the emitron load impedance.

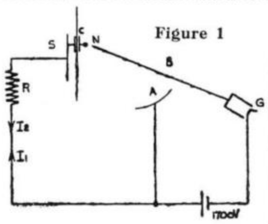


Figure 1

The action may be made clear by reference to Figure 1, in which C represents any elemental condenser in the mosaic, S is the signal plate, N is any nodule, R is the emitron load impedance, A is the second anode, B is the cathode beam, and G is the gun. I_1 is the instantaneous discharge current of the element, and I_2 is the photoelectric emission from the whole mosaic proportional to the overall brightness. The current flowing through R, therefore, is the difference between I_1 and I_2. It is, of course, the current I_1 which, though unidirectional, is composed of frequencies lying anywhere between zero and some 3 Mc/s. I_2 is of a different character, its undulations representing any change in the relative totals of white and black in the picture.

It has been found that the irregularities of illumination which are inherent in the signal emerging from the emitron and which are counteracted, as will be seen later, by the introduction of tilt and bend waveforms, are materially reduced if a small amount of standing illumination is allowed to irradiate the mosaic. Furthermore, the sensitivity of the emitron is thereby somewhat enhanced.

Accordingly a small lamp, fed from the head amplifier heater supply, is placed inside the camera in such a position that it causes a permanent but slight illumination of the mosaic. The strength of the illumination is controlled by means of a series resistance. If the lamp is insufficiently bright the improvement will be small, but if the brightness is excessive the picture will exhibit characteristics similar to those produced by low-frequency phase distortion. In practice the brightness is adjusted to a degree which effects the greatest reduction of the illumination distribution errors and increase of sensitivity compatible with the avoidance of an amount of apparent phase distortion that would be detrimental to the picture.

The Head Amplifier

The head amplifier associated with the emitron is located in the same casing in order to give a preliminary gain to the signals before they are liable to be mixed with interference. It is a 4-valve amplifier, the circuit of which is shown in Fig. 2. The initial voltage, as has been mentioned, is developed across the emitron load impedance, which consists of the resistance R_{179}. The internal impedance of the emitron signal plate circuit is very high, like a screened grid valve. Therefore, the voltage developed across the emitron load impedance is, to all intents and purposes, proportional to the value of that impedance, and it is consequently desirable to make this as high as possible. Since, however, the output of the emitron contains very high frequencies, there is a limit to the value of the load impedance, as it must inevitably be shunted by capacities which will reduce its value at high frequencies. It is therefore imperative to reduce these capacities to a minimum. With this end in view, the first valve V_1 is designed to be a cathode follower, which is here used not so much for its virtue in presenting a low output impedance as for its other and equally important virtue of presenting a minimum capacity at its input. (It will be remembered that in a cathode follower there is no Miller effect; there is scarcely any grid to cathode capacity, as the cathode is executing nearly the same voltage excursions as is the grid, and there is only the grid to anode capacity.) It is found that the load impedance at high frequencies may be made as high as 300,000 ohms, the value of R_{179}, but even so the frequency characteristic drops, and it is subsequently corrected in the cathode circuit of the first valve of the 'A' amplifier.

An additional scheme is incorporated to keep to a minimum the capacity placed across the emitron load resistance. Normally there would be a capacity between the signal plate and earth as represented by the camera cover. Round the emitron tube, however, is placed a screen, which is connected to the cathode of V_1. A capacity now exists between the signal plate and the screen, but since the screen, being connected to the cathode of V_1, is approximately executing the same potential excursions as the signal plate, the effective capacity between signal plate and screen is very small. There is now, of course, a considerable capacity between the screen and the camera cover, but this now occurs across the cathode circuit of V_1, which, due to its cathode following action, is presenting a very low impedance, so that this capacity has little effect.

The cathode load resistance of V_1 is R_{172}, which gives too much negative bias for the correct operation of V_1. This bias is therefore offset by a suitable degree of positive bias introduced by passing H.T. current through R_{176}, which is shunted completely by C_{118}. $R_{164, 165}$ and $C_{117, 137}$ decouple V_1, and no anode impedance is provided.

The output of V_1 is applied to V_2 by the R.F. filter F_7. C_{125} and R_{180} are the normal coupling resistance and condenser, and L_1 is added for a purpose which is standard in the design of most television amplifiers. The frequencies to be reproduced in a television amplifier are so high that unless measures are taken to offset the effect of intervalve capacities, linear amplification will be impossible. One excellent method of doing this, which is largely standard in the M-E.M.I. system, is to design the intervalve couplings as low-pass filters in the form of π-sections, in which case the output capacity of the valve preceding the coupling and the input capacity of the valve succeeding the coupling constitute the end condenser of such a π-section, and the inductance constitutes the series element. If such sections are designed with a cut-off frequency of not less than twice the frequency it is desired to produce, then the coupling will be satisfactory both from amplitude and phase consideration. An approximate termination only is possible by resistance, and so long as this is properly chosen it is found to be satisfactory. Such sections may be terminated, of course, at either end so long as they are terminated at one end, and it is usual in the M-E.M.I. chain to terminate at the initial end. In this case the termination consists of the output impedance shown by the cathode follower V_1.

The second valve, V_2, is followed by a somewhat more complex coupling circuit. The inductance L_3 gives the coupling the configuration of a low-pass filter as before and its phase linearity in the upper frequency range is improved by R_{187}. The filter is terminated by the anode resistance R_{200} and the anode inductance L_2 acting jointly. The characteristic impedance of a low-pass filter set up in the form of a π-section increases in value in the upper-frequency range, rising to infinity at the cut-off frequency, and the termination should have a similar characteristic. While this is not readily possible with the simplest circuits, the addition of an inductance such as L_2, in series with the terminating resistance, gives the termination a rising impedance with frequency. The anode decoupling circuit is formed by R_{166} and C_{117}, but between that and the anode resistance R_{200} is interposed a further circuit 114 comprising R_{167}, C_{138} and C_{150}. This circuit gives an increase of gain at the lower frequencies as compared with the middle and upper frequency band and its object is to lift the gain at these frequencies in advance so that they may be cut down later in the 'B' amplifier where such attenuation will also act upon mains and other interference which is picked up in the camera and earlier amplifier circuits.

V_3 and its associated circuit constitute the third stage of amplification and its operation should now be clear. The final stage, V_4, is a cathode follower used here in order to provide a low impedance to match the line back to the Control Room. The impedance of this line is 165 ohms, and the output impedance of V_4 about 115 ohms. This is made up to 165 ohms by the insertion of the resistance R_{195}.

It should be noted that the filter F_7 consists of series elements, self-tuned to the vision carrier frequency, with a shunt series circuit also tuned to this frequency, and the windings carrying the signal currents are small coils tightly coupled to the self-tuned series elements, which are left floating. This is because the inductances of the filter coils themselves are too great to be allowed in the signal circuit.

The Gun

The gun, which provides the scanning beam to discharge the mosaic, consists of a heater, a cathode, a grid, and first and second anodes. Ideally, the optical axis and the gun should both be perpendicular to the mosaic, but this is clearly not possible, and the optical axis is given preference, and is perpendicular. The gun, therefore, is mounted at an angle to the mosaic, and as has been explained in my note on the keystone generator, has to be provided with scanning potentials which are specially modulated. These scanning potentials are applied to two coils mounted at right angles round the neck of the emitron. The heater consumes 1.2 amperes at 4 volts A.C. The grid is given a bias of about 8 volts and in addition is supplied with what is known as black-out pulse. It would be obvious that the return path of the cathode beam must not be allowed to influence the mosaic, otherwise certain elements would be discharged before their correct time, and the return path would be transmitted as a signal. This is achieved by turning off the beam during the return time by heavily biasing back the grid of the gun for an appropriate period by means of the black-out pulse. This pulse is generated in the black-out generator described in another note. Since the frequencies involved in the black-out pulse will be very high, it is necessary to supply them to the camera down a concentric line, and there are therefore two concentric lines in the emitron cable, one conveying the black-out pulse to the grid of the emitron and the second taking the picture output from the emitron to the Control Room. The first anode has a potential of approximately — 1000 volts to earth, and the cathode — 1500 volts to earth.
115

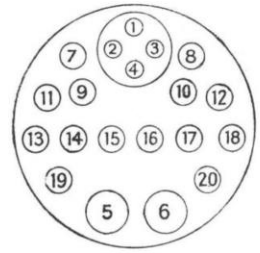


Figure 3. Plug

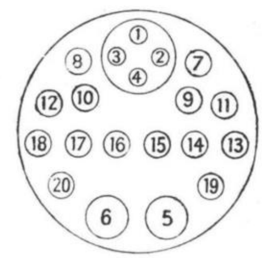


Figure 4. Socket

CAMERA CABLE CONDUCTORS

Description		*Connection*	*Purpose*
H.F. (Red binding)		5	Picture.
H.F. (Green binding)		6	Black-out.
Quad	Red	1	Scanning : Vertical.
	Black	4	,, ,,
	White	2	Scanning : Horizontal.
	Green	3	,, ,,
Thick cab tyre	Red	16	Emitron Heater.
	Black	17	,, ,,
Thin cab tyre	Red	15	Emitron : 1st Anode.
	Black	14	,, Cathode.
Thick maroon flex	Red	9	Amplifier Heaters LT +, & HT−
	Black	11	,, ,, LT−
Black flex	Red	20	Amplifier HT +
	Black	18	Electro-Magnetic Focusing
Green flex	Red	7	Beam Current Meter : Earthy
	Black	8	,, ,, ,, 2nd Anode
Tin shielded pair	Red	10	Telephone.
	Black	12	,,
Blue flex	Red	13	Mosaic Irradiation Lamp.
	Black	19	Cue Light.
Yellow flex		None	Spare line.

The electron beam is focused electrostatically by adjustment of the ratio of first and second anode potentials.

The Cable

The camera cable, which connects each camera with the Control Room, is of a composite type. In addition to the circuits by means of which the various supplies necessary for the operation of the Camera are transmitted from the Control Room, and the picture output conveyed to it, lines are provided for certain other purposes.

Each camera is provided with a pair of red cue lights operated from the programme control position, which may be used either to inform the studio that the camera is energised, or to give normal programme cues, These lights are fed via a circuit in the cable from a 12 volt D.C. supply. The camera operator must also be in a position to receive instructions from the programme control position which shall not be audible in the studio. He therefore wears a pair of telephones, which are fed from a talk-back system via a circuit in the camera cable. Of the remaining circuits, one enables the galvanometer in the Focus Panel to read the beam current in the emitron, and another supplies the mosaic irradiation lamp. One circuit is reserved for providing a supply at 110 volts for the magnetic electron lens system employed in an alternative type of camera of which the design is different from that of the emitron described in this section. Finally there is a spare pair which may be brought into service should any of the other circuits, with the exception of the picture, black-out, and scanning lines, fail.

It is desirable that the intensity of the mosaic irradiation lamp in the case of the ordinary emitron, and the intensity of the magnetic focusing current in the case of the alternative type, should both be capable of manual adjustment from the Control Room, and accordingly the mosaic irradiation lamp line and the electro-magnetic focus line both terminate in the Control Room on a panel at which such manual control is obtained.

The cables are connected together by specially designed couplings incorporating concentric plugs and sockets for the two concentric lines, special 4-pin plugs and sockets for the scanning lines, and individual pins and sockets for the fourteen other lines. The plugs and sockets are illustrated respectively in Figs. 3 and 4. Details of the various circuits together with the arrangement of the connections of the plugs and sockets are given in the table.

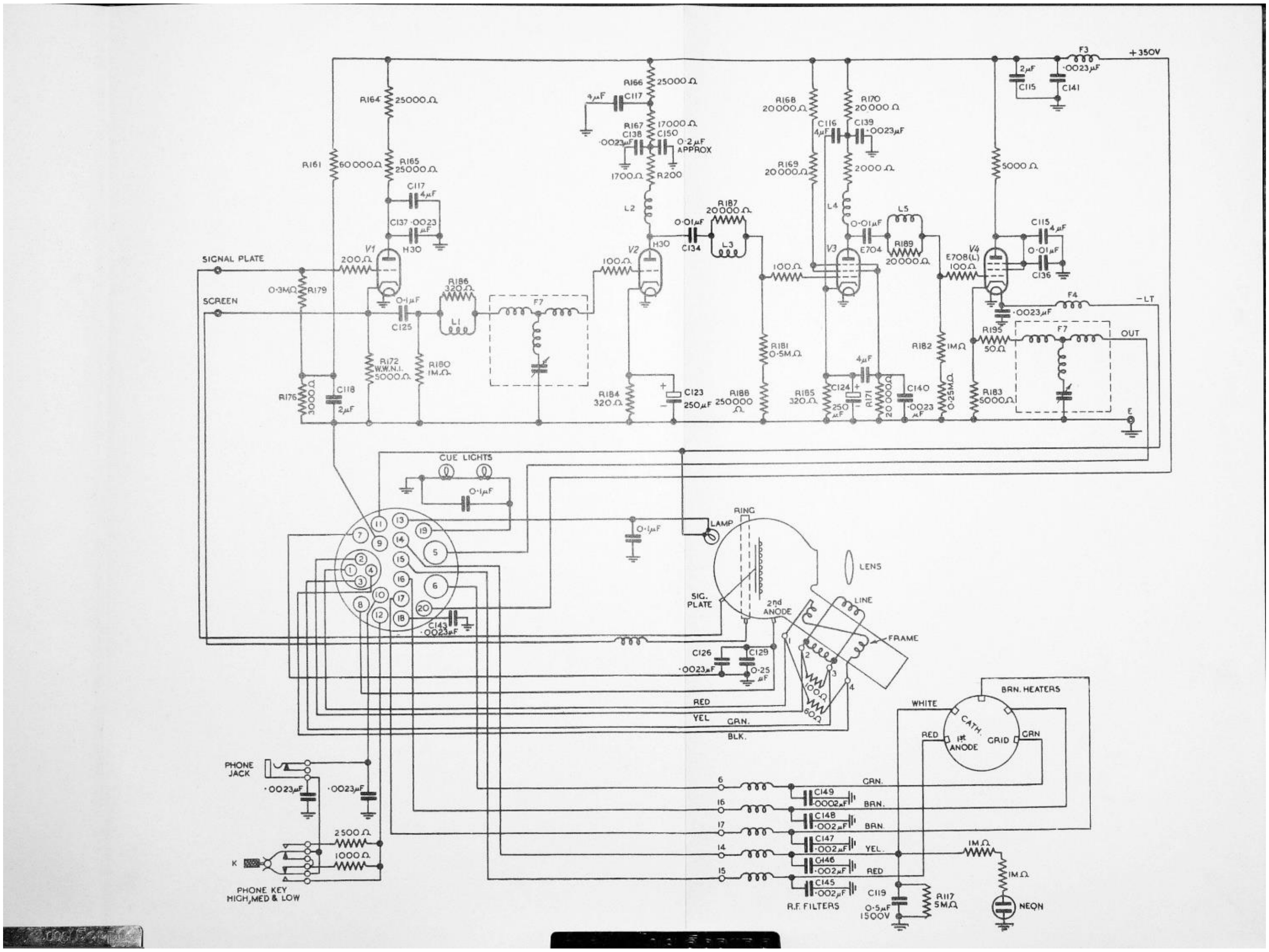
The socket is also shown in Fig. 4 with all its connections to the emitron and camera circuits ; the gun connections of the emitron are brought out to a set of sockets on the end of the emitron gun envelope into which flexible leads in the camera may be plugged. This socket is also shown in Fig. 2 slightly separated from the emitron.

Each emitron is fitted with its own scanning coils, flexible leads for which are plugged into sockets in the camera.

The neon lamp N indicates when the gun voltages are on.

The phone jack is provided for operators' talk-back, the level of which may be adjusted by means of the key K. The cathode is rendered earthy by the condenser C_{119} and the resistance R_{117} serves to render this condenser safe when the gun voltages are removed.

116


+350V
F3
·0023μF
2μF
C115
C141
R164
25000Ω
R161
60000Ω
R165
25000Ω
C117
4μF
C137 ·0023 μF
H30
V1
SIGNAL PLATE
200Ω
0·3MΩ
R179
SCREEN
0·1μF
C125
R186
320Ω
L1
F7
R172
W.W.N.I.
5000Ω
R180
1MΩ
R176
3000Ω
C118
2μF
R166
25000Ω
C117
4μF
R167
17000Ω
C138
·0023μF
C150
0·2μF
APPROX
1700Ω
R200
L2
V2
H30
100Ω
0·01μF
C134
R187
20000Ω
L3
R184
320Ω
C123
250μF
R188
250000Ω
R181
0·5MΩ
100Ω
R168
20000Ω
R169
20000Ω
C116
4μF
R170
20000Ω
C139
·0023μF
2000Ω
L4
0·01μF
E704
V3
L5
R189
20000Ω
R185
320Ω
C124
250μF
4μF
R171
20000Ω
C140
·0023μF
R182
1MΩ
0·25MΩ
5000Ω
V4
E708(L)
100Ω
C115
4μF
0·01μF
C136
F4
-LT
·0023μF
R195
50Ω
F7
OUT
R183
5000Ω
E
CUE LIGHTS
0·1μF
LAMP
0·1μF
RING
LENS
SIG. PLATE
2nd ANODE
LINE
FRAME
C143
·0023μF
C126
·0023μF
C129
0·25μF
100Ω
60Ω
RED
YEL
GRN.
BLK.
WHITE
BRN. HEATERS
CATH.
RED
1st ANODE
GRID
GRN
PHONE JACK
·0023μF
·0023μF
2500Ω
1000Ω
K
PHONE KEY
HIGH, MED & LOW
C149
·0002μF
GRN.
C148
·002μF
BRN.
C147
·002μF
BRN.
C146
·002μF
YEL.
C145
·002μF
RED
R.F. FILTERS
C119
0·5μF
1500V
R117
5MΩ
1MΩ
1MΩ
NEON

THE 'A' AMPLIFIER AND TILT MIXER

The picture signals delivered from the emitron via its cable are applied to the ' A ' Amplifier and Tilt Mixer in order that they may be raised in level, and also mixed with the line and frame tilt and bend waveforms, which, as has been explained in my note on the tilt and bend generators, are injected into the picture signals in order to correct for certain errors of illumination which are at the moment inherent in the emitron.

119

The incoming line from the emitron is terminated in its characteristic impedance by the resistance R_1, and the signals are applied to the grid of the first valve V_1 for amplification. If the input impedance facing the grid circuit of V_1 were high, it would be necessary to employ a pentode in order to avoid loss of upper frequencies by throwing back a sizable capacity on to the input impedance due to Miller effect. The grid, however, sees an impedance of 83 ohms, being the characteristic impedance of the line and of its terminating resistance in parallel. It is therefore possible to use a triode which we prefer to do here as the level of the signal is not high, and the triode, which is quieter than a pentode, will introduce less noise. V_1 receives automatic grid bias from R_2, and R_2, L_1 and C_1 form a cathode correction circuit which lifts the upper frequencies to compensate for the loss occurring in the coupling between the emitron and its head amplifier. The circuit L_1 C_1 is made to resonate at a high frequency, and thus short circuits the cathode impedance of V_1 gradually as that frequency is approached Consequently, at the upper frequencies there is no anti-phase feed-back from the grid to the cathode, and the amplification is high, but at low frequencies the impedance of the circuit L_1 and C_1 is very high, and the cathode impedance is therefore $R_2 + R_3$, which produces anti-phase feed-back from the cathode grid and the amplification is consequently reduced.

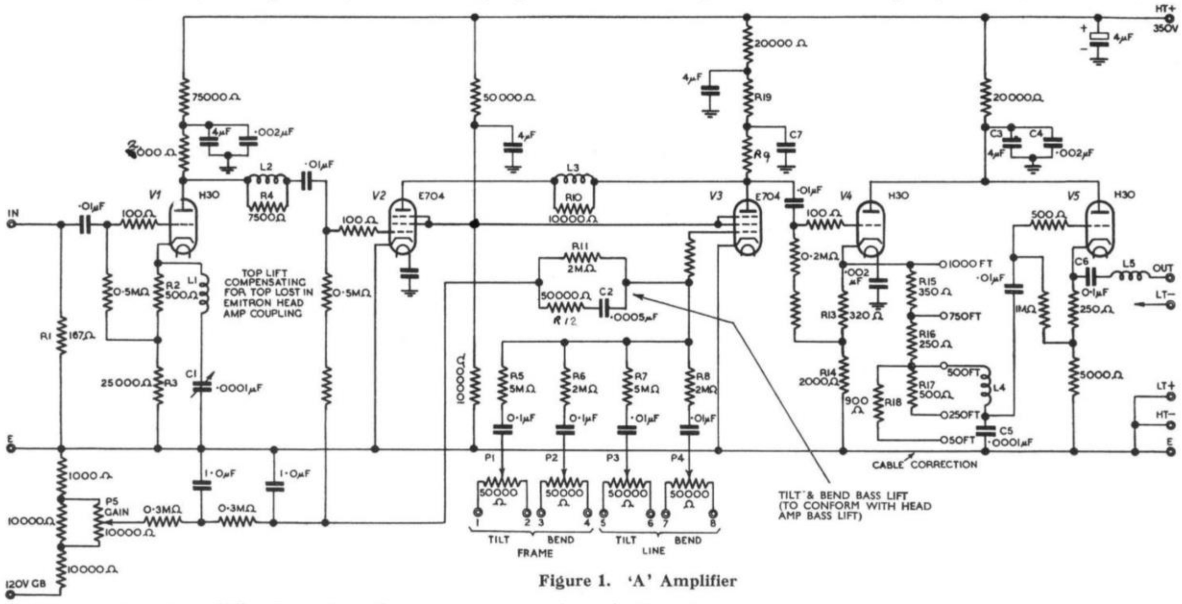


Figure 1. 'A' Amplifier

The valve V_1 is coupled to the second stage V_2 by a resistance capacity coupling, involving also the elements L_2 and R_4, the function of which was explained in my note on the emitron head amplifier. Briefly L_2 and R_4 cause the coupling to simulate a low-pass filter. It is now required to mix the illumination correction pulse with the vision signals, and it will be remembered that there are four of these pulses, the frame tilt, the frame bend, the line tilt and the line bend. These four sets of pulses are supplied to the

120

' A ' amplifier and tilt mixer at the terminals, 1, 2, 3, 4, 5, 6, 7 and 8, and are introduced in the right proportions by the potentiometers P_1, P_2, P_3 and P_4. They themselves are mixed at the grid of the valve V_3, the four circuits being kept separate by the resistances R_5, R_6, R_7 and R_8.

We supply, then, vision signals to the grid of V_2, and tilt signals to the grid of V_3. The anode circuit of these two valves is common, and a mixture of vision and tilt signals therefore appears in the anode circuit. The anode resistance is R_9, and the elements L_3 and R_{10} are included for the usual purpose of preserving amplification at the upper frequencies. They are placed between V_2 and V_3, rather than between V_3 and V_4, as it is only the vision signals which demand the services of L_3 and R_{10}. If these elements were between V_3 and V_4 the capacity on the input side would be too large. The anode circuit of V_3 also contains the elements R_{19} and C_7 whose values differ from unit to unit. These elements are inserted to compensate for the loss of gain and change of phase imposed on the vision signals by the blocking condensers of the various intervalve coupling circuits of the vision-frequency chain. Such an effect, if uncorrected, leads to streaking in the picture, that is to say, the presence of white horizontal streaks following a black picture detail, and vice versa. The elements R_{19} and C_7 together give the anode load a rising impedance as the frequency decreases and thus increases the gain in the lower frequency range while at the same time approximately compensating for the phase angle.

It will be remembered that a deliberate increase in the lower frequencies was given to the vision signals in the emitron to head amplifier coupling in order that these lower frequencies, together with any microphonic interference that might have been collected in the emitron and head amplifier, might be suppressed later. As this suppression will be performed after the tilt and bend signals have been added, clearly the lower frequency components of these signals must be raised also, or otherwise they will be eventually suppressed below normal. This is effected by the elements R_{11}, R_{12} and C_2, which form the complex grid leak of the valve V_3.

Control of gain is also effected at the grids of the valves V_2 and V_3. It is, of course, quite impossible to use potentiometers for this purpose, as the capacities thrown across that section of any potentiometer between grid and earth would, with the potentiometer, constitute a circuit for reducing top frequencies, and the amount of the upper frequencies present would vary with the gain setting. This is a consideration which applies generally in high definition television circuits, though with careful design it is possible to make potentiometers work up to an upper frequency limit of about 1 Mc/s. (The four tilt and bend potentiometers are possible, because the frequency range involved is not so large. If the tilt and bend impulse involved as high an upper frequency limit as the vision signals, even this simple mixing circuit would be impossible, as the isolating resistance would form with the shunt capacity a circuit for cutting upper frequencies.) Accordingly the variable-μ principle is employed, and by means of a potentiometer P_5, which is, of course, the main gain control, a variable degree of negative bias derived from a separate source is applied as well as the signals to the grids of V_2 and V_3.

The output from V_3 is applied to the valve V_4, which is arranged as a cathode correction stage, and its sole function is to correct for the attenuation of upper frequencies which occurs in increasing amount as the length of cable between the emitron and the Control Room is increased. Unlike the valve V_1, which is also a cathode correction stage, the output from V_4 is taken from the cathode circuit, and the anode circuit therefore has no impedance, being short-circuited at A.C. by the condensers C_3 and C_4. It has the appearance, therefore, of a cathode follower but is more correctly described as a cathode correction stage with cathode output. V_4 is a cathode follower which is followed by an acceptor circuit L_4C_5. This circuit is tuned to resistances at about 3.5 Mc/s. At and near this frequency it produces considerable voltage amplification dependent upon its effective Q. This is in turn effectively controlled by variation of total resistance by switching into circuit an appropriate number of the resistors R_{15}-R_{18}.

The output of V_4 is then applied to V_5, which is a pure cathode follower, presenting at its output terminals a low impedance suitable for connection to the output line. The condenser C_6 keeps D.C. off the line, and the inductance L_5 holds off the capacity of the output cable. From the ' A ' amplifier the output proceeds to the phase reverser.

THE PHASE REVERSER

It is desirable to have available the facility of being able to transmit negative or positive film at will as a positive picture. This may be done by inserting in the film picture channels phase reversers, whose function is to change the phase of the vision signals by 180°, so that a negative film will be reproduced as a positive picture. It was decided, for the sake of uniformity and to permit of special effects, to have this equipment available in the four studio channels as well.

Phase reversal of any of the six channels at will is effected by a unit which receives the outputs from the individual 'A' amplifiers, and delivers them reversed or not to the Fading and Monitoring Mixer. Phase reversal is effected in each case by means of a switch without alteration in gain. From the circuit it will be seen that the principle employed is to insert in the chain, a valve, the output of which may be taken either from the anode circuit if phase reversal is required, or from the cathode circuit if the phase is not required to be reversed. The gain is adjusted to be approximately unity in both cases. Since each of the six valves in this unit performs the same function for each vision channel, it will suffice to consider in detail the action of one valve only.

Consider the circuit of V_1, the output from the 'A' amplifier is applied to the grid circuit. With the double switch S_1 S_2 in position B, the output is taken from the anode circuit, which contains the very low anode resistance R_1. The cathode, for this condition of operation, contains the resistance R_2 unshunted, and so there is anti-phase feed-back to the grid. We may regard the behaviour of this valve stage from two points of view. Firstly, we may consider it to be acting as an ordinary resistance coupled amplifier with anti-phase feed-back to the grid to give a reduced gain with a straight characteristic. Alternatively, we may regard the stage as a cathode follower, which, unlike most cathode followers, has an anode impedance inserted so that we may take our output from the anode, and thus obtain phase reversal. Normally, we use the term cathode follower when the valve is employed with is inserted in the cathode circuit, and the output is removed from the anode circuit and joined across this resistor. The valve is now functioning as an ordinary cathode follower, and there is no phase reversal. The valve, of course, was functioning as a cathode follower before, when only the resistance R_2 was present in the cathode circuit, but the efficiency of cathode following was not high. (To get high efficiency cathode following, i.e. to make the

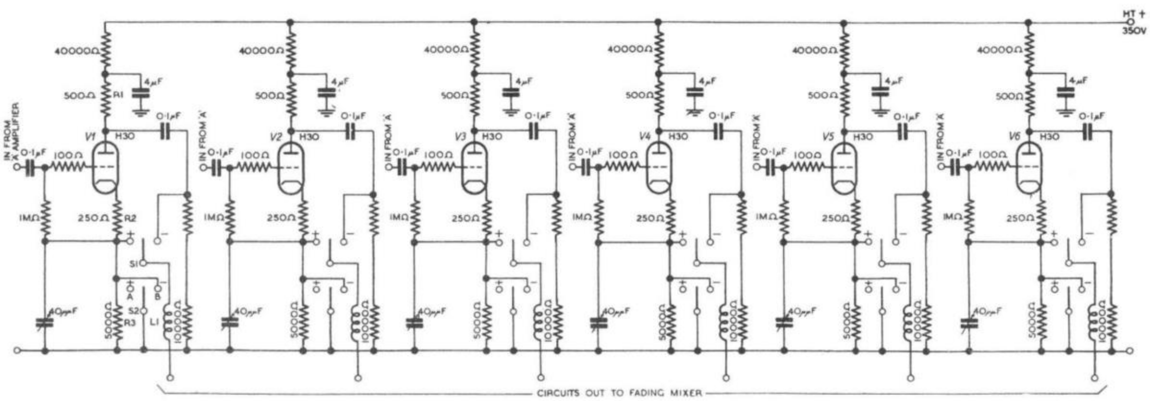


Figure 1. Phase Reverser

anti-phase feed-back to the grid either to generate a very low input capacity or a very low output impedance. In this case, we may truly describe the stage as a cathode follower because the excursions of cathode potential follow those of the grid, due to the unshunted cathode impedance, the object in this case not being a low cathode output impedance but a low stage gain, a low input capacity and a straight characteristic. It would be possible, of course, to shunt R_2 with a large condenser, in which case R_2 would merely provide automatic grid bias and the gain would be greater. To get a gain of unity R_1 would have to be reduced, under which circumstances the characteristic would be more curved and the circuit would be more expensive owing to the cost of the cathode condenser. The inductance L_1 holds off the capacity of the line.

When the double switch S_1 S_2 is thrown into position A, the resistor R_3 cathode potentials follow the grid very closely and to be approximately equal to them in value, the cathode impedance must be high.) The addition of R_3 gives high efficiency cathode following, so that the output voltage is very nearly equal to the input voltage, but the grid leak is returned to the junction of R_2 and R_3 so that the correct value of grid bias is obtained. The value of R_1 is, of course, so adjusted that the gain when the valve is operating as a phase reversing resistance amplifier is the same as when working as a high efficiency cathode follower.

The capacities present across the ~~out~~ in put when the circuit is adjusted for pure cathode following (non phase reversing) are somewhat less than they were in the anode output condition, and in order to maintain the same frequency characteristic in both cases, the output capacity is increased to the appropriate value by adjustment of the small 40 μμ condenser ~~C_3~~. 124