August, 1939

TECHNICAL DESCRIPTION

MARCONI-E.M.I. SYSTEM OF TELEVISION

PART 2. CONTROL PULSE GENERATORS

CONTENTS

SYNCHRONISING SIGNAL GENERATOR
Technical Description
M-E.M.I. System of Televisio
Item 2.1. October, 1937

THE SYNCHRONISING SIGNAL GENERATOR

The synchronising signal generator is a piece of apparatus forming part of the pulse generator and which produces the whole of the synchronising waveform which is required by the standards of the system to be radiated, i.e. the whole of the waveform below black level.

This synchronising waveform is fully described in my technical note on The Signal Waveform and it will be remembered that it consists of a series of line synchronising impulses having each a duration of 10 micro-seconds occurring at the end of each line, which are replaced for a space of four lines shortly after the end of each 50 cycle frame by a series of pulses at twice line frequency, and having a width of 40 micro-seconds, this series of 40 micro-second pulses being known as the frame synchronising signal. It is thus apparent that the synchronising waveform consists of two separate parts—the line synchronising signals and the frame synchronising signals. Accordingly, the synchronising signal generator is arranged to generate line synchronising signals and broad pulses continuously, and arrangements are made so that each of these types of pulse is supplied to the output during the appropriate periods as required by the standards laid down for the complete synchronising waveform.

It is necessary that certain precautions be taken to ensure that the above operations are properly performed and it will be as well to sum up the operations which must be performed by the synchronising signals generator. These are as follows :—

(1) Generate a line sync signal of proper shape
(2) Generate a frame sync signal of proper shape
(3) Introduce either of the above at the correct times
(4) Introduce the sync signal as a whole at the correct moment
(5) Ensure cleanness of waveform
(6) Ensure that the frame sync signal can only start at the exact centre of a line, as at the end of the primary raster, or at the exact end of a line, as at the end of the secondary raster. It must be emphasised that although the frame sync signal has a frequency of 50, it is this signal which determines when the spot shall commence to move up for the next raster, and if this does not take place exactly at the middle or end of a line as may be required, the primary and secondary rasters will not fit evenly and symmetrically in with each other, and there will be distortion. Thus, though the frame signal has a frequency of 50, this frequency must be steady to a very high order of accuracy. The frequency of 50 referred to is, of course, the overall frequency of repetition of the trains of pulses at a frequency of 20250 which constitute the frame synchronising signal.

We may now consider the circuit diagram, Figure 8.

Valves V_8 and V_9 form a multivibrator generating the line synchronising pulses of the correct duration. These are thus continuously available. Valves V_{10} and V_{11} form another multivibrator generating broad pulses of the correct duration which are similarly available continuously.

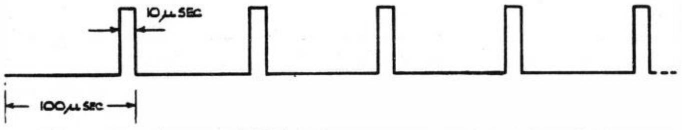

Figure 1. Output of Multivibrator V_8, V_9. (Line Sync Pulses)

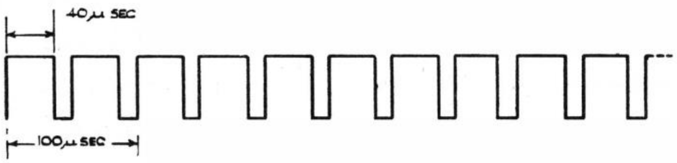

Figure 2. Output of Multivibrator V_{10}, V_{11}. (Broad Pulses)

The complete standard synchronising waveform requires that these two sets of pulses shall be mixed so that over a period of 198.5 lines line synchronising pulses are occurring alone, to be immediately followed for a period of four lines by a series of broad pulses alone. This cycle of introduction of pulses must be continuously repeated. This is achieved by an electronic switching operation which will now be described.

Two hexodes V_{12} and V_{13} are provided. The output of the broad pulse multivibrator V_{10}, V_{11} is applied to the third grid of the valve V_{12}. The output of the line sync multivibrator V_8, V_9 is similarly applied to the third grid of the valve V_{13}. The anode circuit of V_{12} and V_{13} is common and hence if both V_{12} and V_{13} were normally operative both line and broad pulses would be continuously mixed in the anode circuit. By applying to the first or control grid of V_{12}, for instance, a negative bias, this valve may be rendered inoperative and the broad pulses applied to its third grid will not reach its anode circuit. Similarly the application of bias to the first grid of V_{13} will prevent this valve supplying line sync pulses to the anode circuit. If bias is applied to the first grid of V_{12} only for a duration of 198.5 lines, then during this time the output will consist of pure line sync pulses delivered by V_{13}. If now the bias is removed from V_{12} and applied to V_{13} for a duration of four lines, i.e. 400 micro-seconds, then during this period the output will consist entirely of broad pulses supplied by V_{12}.

It is obvious that such bias may be supplied by providing a third multivibrator generating square pulses of a duration of 400 micro-seconds and having a frequency of 50 c.p.s., in which case the long period between each 400 micro-second pulse will have a duration of 198.5 lines. The multivibrator would be so connected to the valves V_{12} and V_{13} so that V_{13} received the 400 micro-second pulses in a negative sense, thus biassing this valve off for 400 micro-seconds and allowing V_{12} to be unbiassed for this period. The long periods between the pulses would then be in the negative sense from the point of view of the valve V_{12} and would bias this off for this period, i.e. a duration of 198.5 lines.

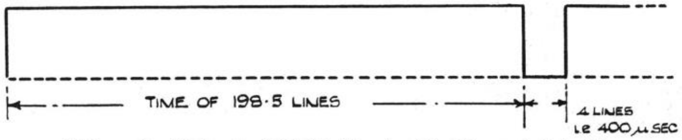

Figure 3. Output of Multivibrator V_6, V_7 as fed to V_{13}

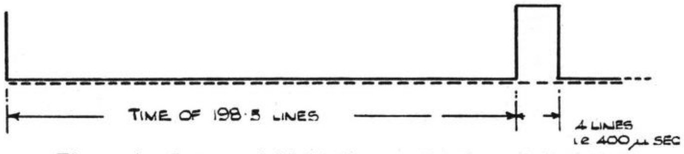

Figure 4. Output of Multivibrator V_6, V_7 as fed to V_{12}

This is actually what is done in practice. The additional multivibrator is known as the sync change-over multivibrator, and is formed by the valves V_6 and V_7, and as will be seen from the circuit diagram, a negative output is obtained from the anode of V_6 and is applied to the first grid of V_{13}. This output is illustrated in Fig. 3. The positive output is taken from the anode of V_7 for application to the first grid of V_{12} and is illustrated in Fig. 4. The valves V_{12} and V_{13} are consequently termed the frame sync admitter and the line sync admitter respectively.

The complete synchronising waveform will now appear therefore in the common anode circuit of V_{12} and V_{13}. Owing to the low value of the anode resistance $R_6 + R_7$ of V_{13} there will be undue amplification of the extreme lower frequencies due to the presence of the decoupling circuit R_8 C_1. Accordingly the coupling circuit between the anode of V_{13} and the grid of V_{14} contains the elements C_2, R_9 and R_{10}, which have the effect of counteracting this increase of amplification.

The grid resistance of the valve V_{14} is returned to cathode and this, in conjunction with the grid condenser, provides conditions suitable for D.C. restoration. The sync waveform applied at this point is in the negative sense, i.e. the peaks of the pulses are tending to drive the grid of V_{14} negative. The effect of the restoration of D.C. on this grid is to adjust the datum line from which the sync signals operate to coincide with zero grid potential at all times. In addition, their amplitude is in excess of that which can be accommodated by the characteristic of the valve V_{14}, so that the peaks of the signals are cut off by the bottom bend of the characteristic. This is deliberately done as it is found that owing to the natural operation of the multivibrator the synchronising pulses may be accompanied by spurious peaks which it is desirable to clean away, and this may be very conveniently done by the use of the bottom bend of a valve characteristic in the above manner.

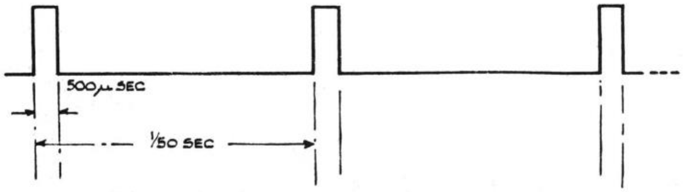

Figure 5. Output of Multivibrator V_1, V_2

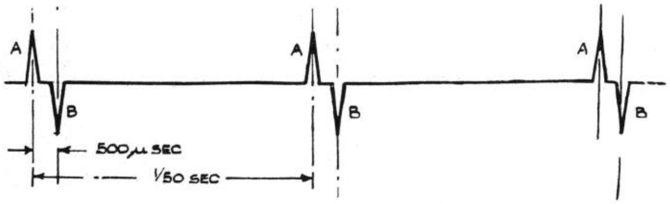

Figure 6. Output of Multivibrator V_1, V_2 after differentiation by C.R. i.e. as applied to R_2

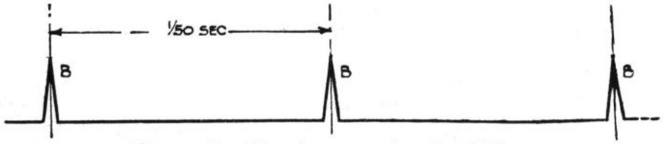

Figure 7. Waveform at Anode of V_3

The valve V_{14} can therefore be conveniently known as a cleaner. A similar cleaning action takes place at the grids of the valves V_{12} and V_{13}. The broad pulses applied to the third grid of V_{12} and the line sync pulses applied to the third grid of V_{13} are both in the positive sense. D.C. restoration is therefore effected about a datum line corresponding with their peaks, and their bases are squared off, in each case, by the bottom bend of the valve characteristic. Due therefore to adequate preservation of the upper frequencies, together with the cleaning process applied to both ends of the pulses, the synchronising waveform generated is very good, being almost devoid of curvature at any point.

In the anode circuit of the valve V_{14} the complete synchronising waveform appears in the positive sense. The output is required in this sense but at a low impedance, and therefore the signals are now applied to the grid of a further valve, V_{15}, connected to operate as a cathode follower and the final output is taken from the cathode circuit of this valve.

We have now to consider the action of valves V_1 to V_5. These are for the purpose of providing the frame sync delay which is required with the standard waveform and which is normally fixed at 500 micro-seconds, and also to provide a means of ensuring that the first broad pulse constituting the frame sync signal starts exactly half way along a line, or exactly at the end of a line, as required.

The delay is provided by the circuits associated with the valves V_1 to V_3. The valves V_1 and V_2 form a multivibrator energised at 50 cycles from the frame divider, and they generate a square topped waveform which is illustrated in Fig. 5.

It will be seen that the width of the pulse generated by this multivibrator is made equal to the desired frame sync delay, i.e. 500 micro-seconds. The output from the multivibrator is taken from the anode circuit of the valve V_1 and applied to the condenser C and the resistance R in series which are of such values that they form a differentiating circuit so that across R there appears the first differential of the waveform of Fig. 5. This is illustrated in Fig. 6 and is, of course, a waveform representing at all times the slope of the waveform of Fig. 5. It should be particularly noted that the peaks A of the differentiated waveform coincide with the leading edge of the 500 micro-second pulses of Fig. 5 and the peaks B correspond with the trailing edge of this pulse, so that between any peak A of Fig. 6 and its associated peak B, there is a time difference of 500 micro-seconds. The differentiated waveform is now applied to the grid of the valve V_3, via the resistance R_2 which has the unusually high value of 20,000 ohms. The peaks A of Fig. 6 tend to drive the grid of V_3 positive, under which conditions the grid-cathode impedance is low compared with the value of R_2, so that only a negligible part of the voltage corresponding to the peaks 'A' is applied between the grid and cathode of V_3. Consequently the peaks A scarcely influence the anode current of V_3. The peaks B, on the other hand, tend to drive the grid of V_3 negative, in which circumstances the grid-cathode impedance is high compared with R_2, so that almost the whole of the voltage corresponding to the peaks B is applied between grid and cathode of V_3 and, of course, influences the anode current. The arrangement constitutes therefore a means for suppressing the peaks A while not interfering with the peaks B, and in the anode circuit of V_3 there appear, therefore, the peaks B only, reversed as indicated in Fig. 7. The leading edge of the 500 micro-second pulses of Fig. 5, the pulse A of Fig. 6, and the frame timing pulse from the Frame Divider, all coincide in time, and it follows that the peaks B will be delayed with respect to the frame timing pulse by the amount of time occupied by the width of the pulse of Fig. 5. Consequently, by varying the width of this pulse, the delay of the peaks B can be varied within prescribed limits

Since the peaks B are ultimately used to fire the sync change-over multivibrator which determines the moment of admission of the broad pulses constituting the frame sync signal, it follows that the latter may be given any desired delay with respect to any other pulse timed from the master frame timing pulse, simply by adjusting the multivibrator V_1, V_2 to produce a pulse whose width occupies the time of the required delay. The width of the pulses produced by the multivibrator V_1, V_2 is adjustable by means of the potentiometer R_1 and this control is accordingly labelled Frame Sync Delay.

The valves V_4 and V_5 are concerned with ensuring that the frame sync signal will always start either half way along the line or at the end of a line as may be required. It will be appreciated that if the differentiated peaks B generated for timing the sync change-over multivibrator were used for this purpose without any further precautions, it would be possible to adjust the delay so that the moment of admission of the broad pulses did not necessarily occur half way along a line or at the end so as to give proper interlacing. In addition, the accuracy of firing of the multivibrator V_1, V_2 operating at 50 cycles per second is not such that it can be expected to maintain this frequency constant within the close limits which are naturally required to preserve proper interlacing. Clearly, its frequency must remain steady to within a small percentage of the time of a line for good interlacing. Since this is not practically possible the valves V_4 and V_5 are inserted to ensure perfection of interlacing and operate as follows.

The differentiated peaks B from the anode circuit of V_3 are applied, not directly to the multivibrator V_6 V_7, but via the hexode V_5. The circuits associated with this latter valve are arranged so that a pulse can only appear in its anode circuit if positive pulses are appearing simultaneously on both the first and third control grids. As will be seen from the circuit diagram, the differentiated peaks at a frequency of 50 are applied to the first control grid. In addition broad pulses derived from the frame sync multivibrator V_{10} V_{11} are applied in the positive sense to the valve V_4, which amplifies and reverses them, and they are then applied to the third control grid of V_5, and they are, of course, now in the negative sense. The anode circuit of V_5 will only receive a pulse when the first and third control grids are both simultaneously energised by their respective pulses. The first control grid of V_5 is energised positively by a differentiated peak and the third control grid is energised positively, not by a broad pulse, but by the interval between two broad pulses as it is this interval which is operating on this grid in the positive sense.

Let us suppose that the multivibrator V_6 V_7 is operating in the position which admits line synchronising signals to the main output via V_{13} and coincidently suppresses V_{12}, and that a differentiated peak has arrived on the first control grid. Although it is a short pulse, its frequency is 50 c.p.s. and its duration must be that of several broad pulses. Assuming that at the same time a broad pulse is energising the third control grid in a negative direction, there can be no pulse in the anode circuit. When the broad pulse ceases the third control grid will be energised positively by the interval, and this will result in a pulse occurring in the anode circuit. This will fire the multivibrator V_6 V_7 which will spill over, thus closing the valve V_{13} to line sync signals, and opening the valve V_{12} to broad pulses ready for the next broad pulse, for it must be remembered that this operation is taking place in the interval between two broad pulses. Accordingly the next broad pulse which arrives will be admitted into the sync output and the frame sync signal as a whole must therefore commence with a broad pulse.

Clearly it is impossible for the frame sync signal as a whole to start in the middle of a broad pulse, because at such an instant the differentiated peak cannot fire the multivibrator V_6 V_7 as the valve V_5 is held inoperative by the negative broad pulse at that moment applied to the third control grid. Owing to this provision it is impossible to radiate a waveform which will lead to bad interlacing.

It remains to cover a few circuit details. The width of the line sync pulses (illustrated in Fig. 1) is controllable by the potentiometer R_4 associated with the multivibrator V_8 V_9. The width of the broad pulses (illustrated in Fig. 2) is controllable by the potentiometer R_5 associated with the multivibrator V_{10} V_{11}. The width of the pulses generated by the multivibrator V_6 V_7, as shown in Figs. 3 and 4, is controllable by the potentiometer R_3 and, of course, determines the time during which broad pulses are admitted into the synchronising output, i.e. the duration of the frame synchronising signal. It is accordingly labelled **No. of Broad Pulses.** All the four potentiometers R_1, R_3, R_4 and R_5 operate by determining the potential to which their associated grids must leak, which in turn controls the time taken to leak to the value necessary to cause the multivibrator to spill over. They therefore constitute very simple controls of frequency.

It will be noticed that the three hexodes V_5, V_{12} and V_{13} have small additional diodes connected to their upper control grids. This is because in accordance with usual technique it is unnecessary to provide conditions for ' class A ' amplification of the pulses ; it is simpler to locate one end of the pulses at zero grid potential by the use of D.C. restoration. This process, although applicable to the lower control grids which are adjacent to the cathodes, does not operate so well with the upper grids and accordingly the additional diodes are provided to render these upper grids equivalent to the lower grids in this respect.

Adjustment

1. The line sync width should be set to 10 micro-seconds by means of the potentiometer R_4.

2. The broad pulses width should be set to 40 micro-seconds by means of the potentiometer R_5.

3. The number of broad pulses should be set to a total of 8 (a duration of 400 micro-seconds) by means of the potentiometer R_3.

4. The frame sync delay should be set to 500 micro-seconds by means of the potentiometer R_1.

5. The broad pulse waveform is available for examination at the jack J.2 (Panel 2), and should have an amplitude of 6 volts.

6. The line sync pulses may be examined at the jack J.1 (Panel 2), and should have an amplitude of 10 volts.

7. The complete synchronising waveform can be examined at jack J.3 (Panel 2) and should have an amplitude of 7 volts.

8. The pulses determining the frame sync duration (multivibrator V_6, V_7) may be examined at the jack J.2 (Panel 1), and should have an amplitude of 9 volts.

9. The pulses determining the frame sync delay (multivibrator V_1, V_2) may be examined at the jack J.1 (Panel 1) and should have an amplitude of 10 volts.

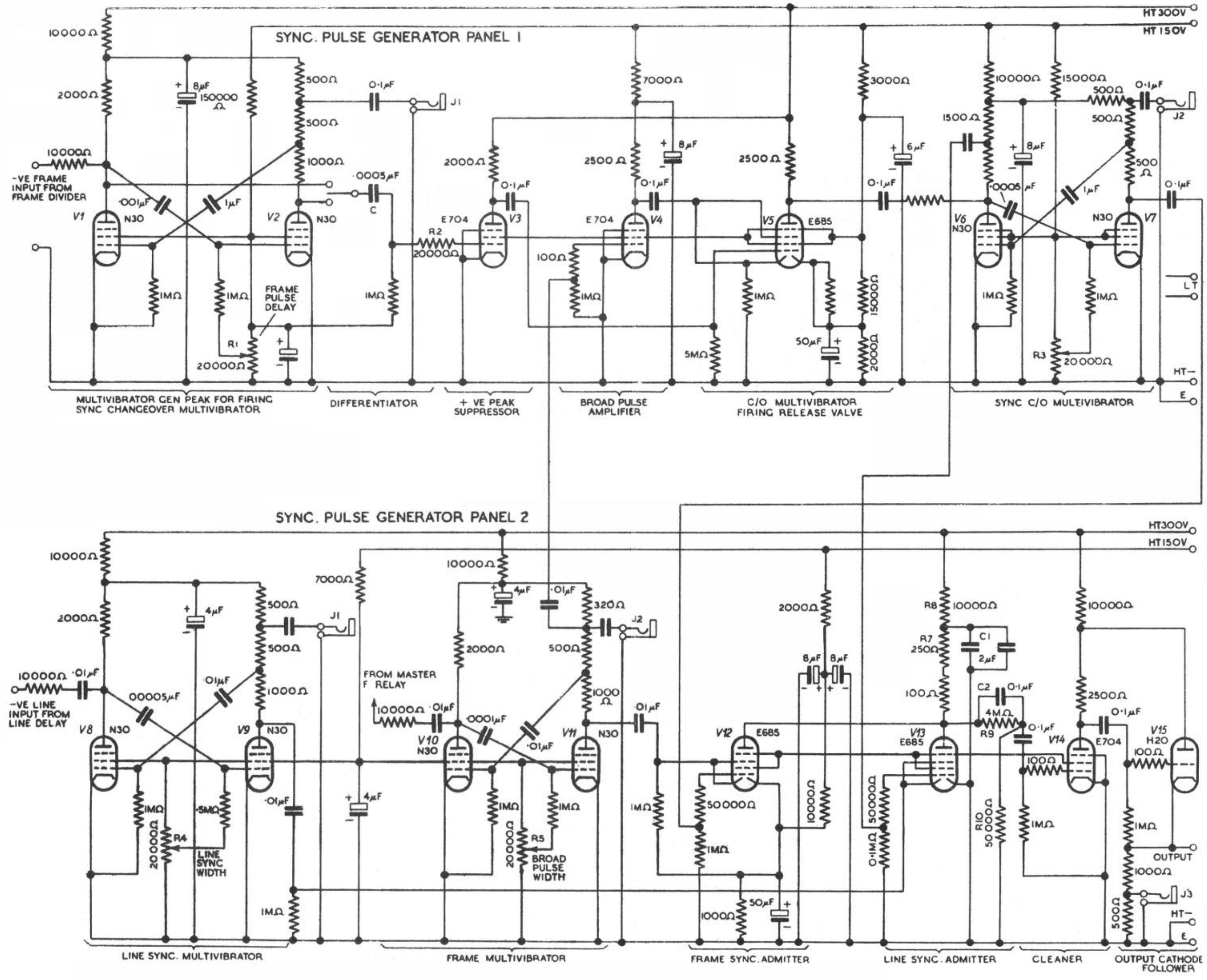

Figure 8. Circuit Diagram

KEYSTONE GENERATOR
Technical Description
M-E.M.I. System of Television
Item 2.2. October, 1937

THE KEYSTONE GENERATOR

The function of the Keystone Generator is to generate the fundamental scanning waveforms which, after amplification in power amplifiers, will be supplied to the scanning coils of the emitrons.

Since it is impossible to allow the optical axis of the emitron and the electrical axis of the emitron gun both to be perpendicular to the mosaic, one or other has to make an angle with the mosaic, and it is considered preferable for the optical axis to be perpendicular and the gun axis to be at an angle. Thus, the mosaic, as seen from the gun, has the shape of a keystone, that is to say, it appears wider at the bottom than at the top.

If scanning is to be accomplished generally from the top to the bottom of the picture, the mosaic must be scanned from bottom to top as the image will be upside down. The horizontal scanning therefore must be wider, that is to say, of greater electrical amplitude, at the bottom and must decrease as it is moved upwards by the frame scan. The horizontal scanning coils must therefore be supplied with current of a saw-toothed waveform whose amplitude decreases uniformly and symmetrically during the progress of the frame scan. This is known as the *line keystone waveform.*

The frame scanning, moving from bottom to top, will also have to be specially treated since it must move over equal distances along the mosaic in equal times. Due, however, to the angles which the gun makes with the mosaic, the angular deflection of the frame scan with time will have to decrease as the scan moves from the bottom to the top of the mosaic. The vertical or frame scanning coils of the emitron will therefore have to be supplied with a current whose waveform is not saw-toothed, but which has the form of a wave increasing in amplitude after the manner of a saw-toothed wave but flattening out more and more as the amplitude increases. This is known as the *frame keystone waveform.*

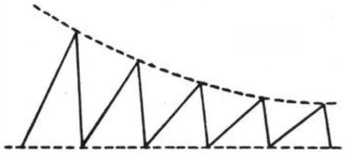

Figure 1. Five Successive Line Keystone Waveforms in which the Line Amplitude Successively Decreases this Emerges from V_5
(Fig. 5)

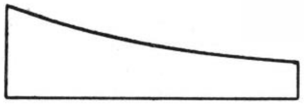

Figure 3. The Asymmetrical Envelope of the Line Keystone Emerging from V_5

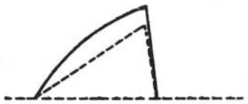

Figure 2. A Frame Keystone Waveform in which the Velocity Decreases during a Frame. This Emerges from V_2

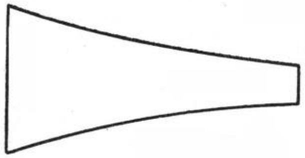

Figure 4. Symmetrical Envelope of the Line Keystone Waveform after the 'Put-Back' Operation

The frame keystone waveform is generated in the keystone generator by the valves V_1 and V_2. (Fig 5) The valve V_1, in co-operation with the resistance R_2 and the resistance R_1 if required, and also the condenser C_1 C_2, is a relaxation oscillator in which the condenser $C_1 C_2$ is being charged slowly through the resistance $R_1 R_2$ as in a saw-toothed generator. At the appropriate moment the condenser $C_1 C_2$ is discharged as the valve V_1 is energised via its control grid by frame input from the Frame Divider. Whereas in a true saw-toothed generator care is taken that R and C are so chosen that C is operating upon the linear part of its charging characteristic, in this case deliberate use is made of the non-linear portion of the charging characteristic so particularly avoided in the true saw-toothed generator, and $R_1 R_2$ and $C_1 C_2$ are so chosen that the amplitude on $C_1 C_2$ is not linear but flattens at the top in the manner required by the frame keystone waveform. The condenser $C_1 C_2$ further forms a condenser potentiometer and the output across C_2 is applied to the valve V_2, and the keystone frame waveform is taken out in push pull from the anode and cathode.

Valves V_3 to V_8 are employed in generating the line keystone waveform. The valve V_5, in co-operation with the resistance R_3 and R_4 if required, and also with the condenser C_3, forms a pure saw-toothed generator of line frequency. In order that the valve V_5 may discharge the condenser C_3, line input from the line delay is applied to the valve V_4 to be amplified and reversed, and the output from V_4 is applied to the control grid of V_5 which at the correct moment discharges the condenser C_3. If the supply to V_5 were a steady D.C. the output would be a pure saw-toothed waveform, constant in amplitude, but it is required that the amplitude should be modulated proportionately to the frame scanning amplitude. The supply to V_5 is therefore not taken from the H.T., but from the anode of V_3, the control grid of which is supplied with frame waveform via the potentiometer P_1. Therefore the line waveform appearing across C_3 is modulated in amplitude by the frame waveform delivered from P_1 and V_3 but it is modulated asymmetrically, that is to say, the amplitude of each successive line saw-tooth ~~in~~decreases regularly but from a standard lower level of zero. What is required, however, is a symmetrical waveform in which the amplitude of the line saw-tooth is modulated symmetrically about a central datum line. This may clearly be brought about by mixing with the asymmetrical waveform a frame waveform reversed in sense with respect to that fed to V_5. Valves V_6 and V_7 therefore form a mixer. To V_6 is fed the asymmetrical waveform, and to the control grid of V_7 is fed the frame waveform also derived from the potentiometer P_1. This is reversed by V_7 and mixed with the output of V_6 in the common anode circuit of $V_6 V_7$. The correct proportion of mixing is adjusted by the put-back potentiometer P_2. Thus the correct line keystone waveform appears at the output of $V_6 V_7$ and is applied to V_8 which is an output stage.

The output is taken from the anode circuit of V_8 and proceeds via The Keystone Delay circuits and The Keystone Output panels to the cameras. As will be seen from my technical note on the Pulse Delay Units, it is necessary that the line keystone output should be subjected to various degrees of delay proportionate to the length of cable which is being used with any individual camera. This necessitates a very accurate delay network, which is installed in the Camera Delay panel, and for certain reasons given in the above note it is necessary to put certain elements which properly belong to the keystone delay network in the Keystone Generator panel and not in the Camera Delay panel. These include the elements L_2, L_3 and C_4, which collectively constitute an M-derived terminating section in which $M = 0.707$, also a half section in which $M = 1$, in order correctly to terminate the delay network. The final resistive termination required by the delay network is formed by the anode resistance of V_8 of 2500 ohms. It is found that the stray capacities existing across this resistance slightly affect the keystone waveform and the series inductance L_1 is added to compensate for this.

It is necessary to take a further special precaution in order to preserve the linearity of the keystone waveform. The line feeding the output of V_8 to the Camera Delay Panel is split half way and a loading coil of 680μH is inserted. The capacity of each half of the line is made up to a total of 109 $\mu\mu$fds. This is done as regards the half of the line on the Keystone Generator side by a condenser in the box holding the loading coil, and in the other half of the line by a condenser in the Camera Delay Panel.

The line keystone waveform, as generated by the valve circuits associated with V_5, is not quite perfect and suffers slightly from the non-linearity which must always exist in any relaxation oscillator formed by a resistance and condenser. In terms of frequency this amounts to a bass loss. This effect is corrected by the insertion in the cathode circuit of V_8 of the inductance L_4 and the correct value to employ would be 0.11 H. A further bass loss is sustained, however, when the line keystone waveform passes through the Keystone Output Panel output transformer and in one or two other places. The value of L_4 is therefore modified so as to include correction for these additional reasons and its value is 0.075 H.

It will be noticed that the particular frame waveform which is used to modulate the amplitude of the horizontal scanning is not pure saw-toothed waveform, but the particular flattened saw toothed waveform which has been specially prepared for application to the vertical scanning coils. It might at first be thought that as the keystone waveform is required to have straight sides the horizontal waveform should be modulated by a pure saw-toothed waveform. It would, however, be useless to modulate the horizontal scanning with a linear frame saw tooth as its upward movement is not linear with time. Such an arrangement would give us a keystone whose sloping sides were convex outwards. Having arranged to move the horizontal scanning upwards in a manner which is non-linear with time, the modulation must clearly possess the same non-linearity.

Adjustment and Testing

The adjustment of the Keystone Generator is a delicate operation, which takes time to carry out properly, but when set usually requires adjustment only at very long intervals. It is important, however, that the adjustment be carried out with care, since on it depends the degree of geometrical accuracy with which the picture is reproduced.

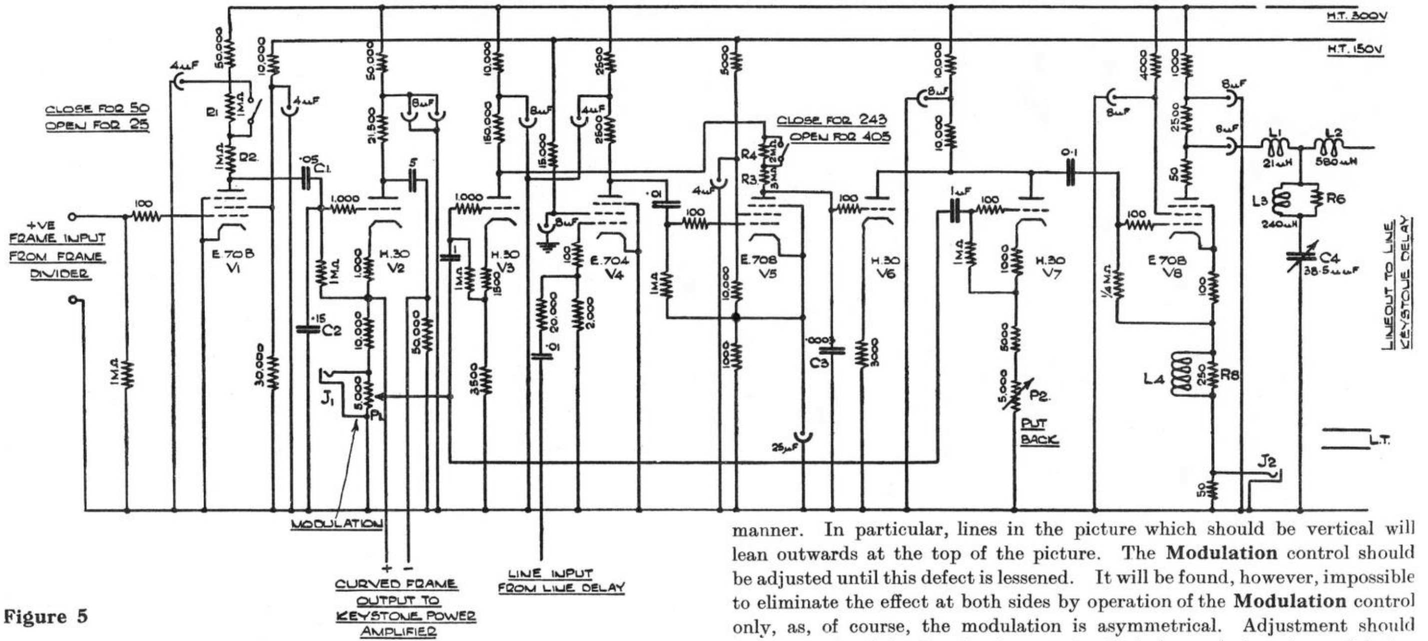

Figure 5

It is in the first place necessary to obtain a picture from a camera of some scene having well defined horizontal and vertical lines in various parts of the area. It is preferable to use some form of test card. This should be set up in front of the camera and tested with a plumb line and level so that it is truly level and perpendicular to the ground. Next the emitron must be carefully set up in the camera so that the mosaic is truly vertical, which may be established with the aid of a plumb line, and horizontal, which can usually be established with sufficient accuracy by eye. Further the camera will, of course, have been so positioned that the plane of the lens is vertical and that its axis passes through the centre of the picture. The point of all these precautions is to ensure that the most complete symmetry exists between the test card, the camera and the emitron so that no geometrical distortion is introduced at the start by the camera, lens or view point.

If the **Modulation** and **Put-Back** controls on the Keystone Generator are now set to a minimum value, the picture will be reproduced in a distorted manner. In particular, lines in the picture which should be vertical will lean outwards at the top of the picture. The **Modulation** control should be adjusted until this defect is lessened. It will be found, however, impossible to eliminate the effect at both sides by operation of the **Modulation** control only, as, of course, the modulation is asymmetrical. Adjustment should now be made of the **Put-back** control, which, by rendering the modulation symmetrical, will render the verticals straight on both sides. The optimum adjustment will be found by making a series of minute alterations in succession to the **Modulation** ~~of~~ and the **Put-back** controls until the best combination is secured.

The frame keystone waveform (frame saw-tooth velocity modulated) is available at the jack J_1 for examination on the waveform monitor, and should have an amplitude of 11 volts. The line keystone waveform (line saw-tooth amplitude modulated frame frequency) is available at the jack J with an amplitude of 16 to 20 volts.

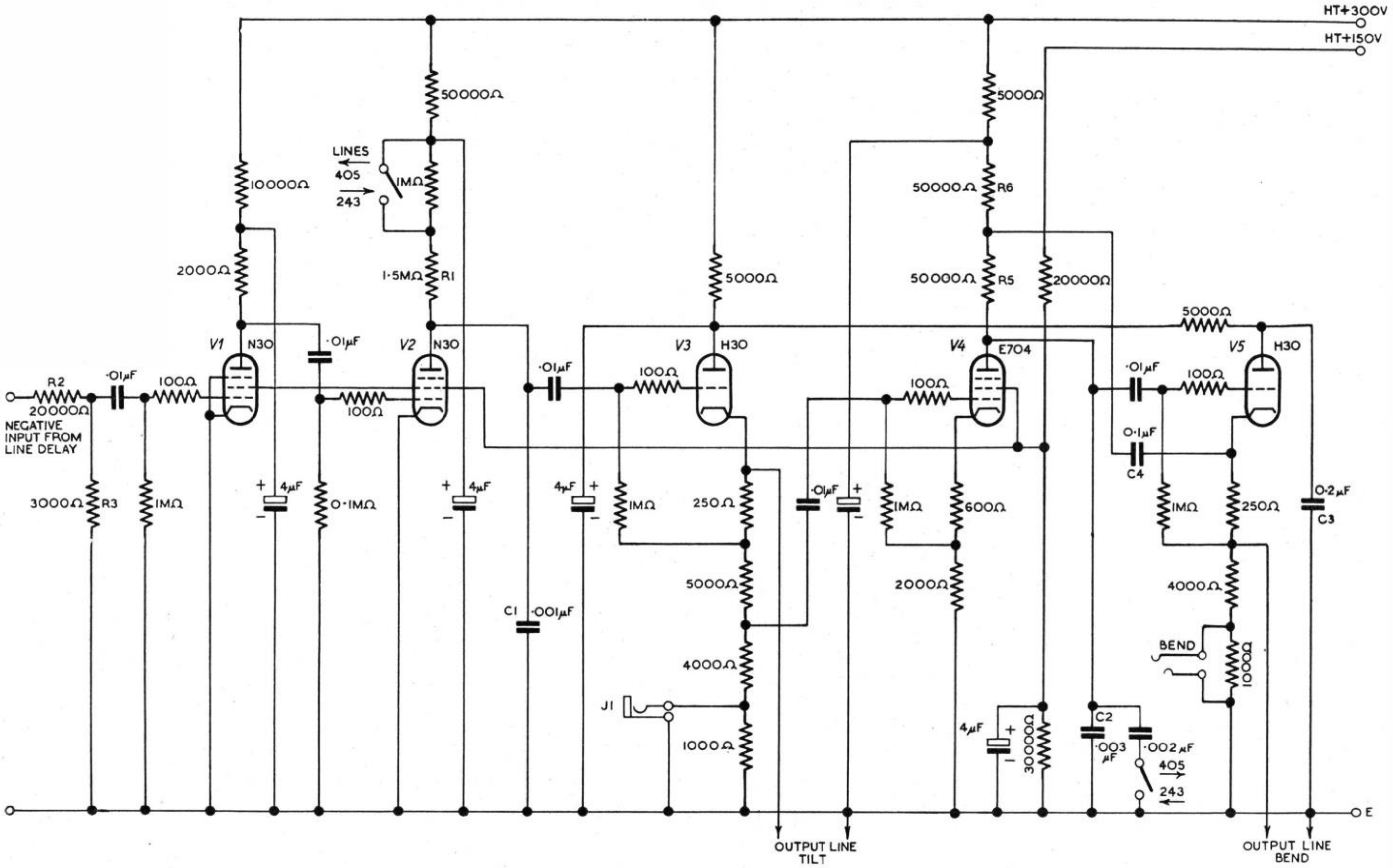

Fig. 5. Circuit Diagram Line Tilt and Bend Generator

THE LINE & FRAME TILT & BEND GENERATORS

When an emitron is set up in a normal and straightforward manner to scan a scene, it is found that the distribution of illumination of the resulting televised picture is not that which is present in the original scene. If, for instance, the emitron were set to scan a scene consisting entirely of a pure white area uniformly lighted, the transmitted picture would in general not consist of such a uniformly illuminated white area, but the illumination would be accentuated in one corner and relatively dark in the opposite corner. This is an unfortunate effect, the cause of which is attributed to the interaction of certain fields within the emitron, and since it cannot as yet be eliminated by emitron design, means must be sought for eliminating it by compensation.

The error of distribution of illumination is found to be composed to a close approximation of four components. In the first place, the total error may be regarded as being produced by two separate components, one acting in the horizontal direction and the other acting in the vertical direction, i.e. a line component and a frame component. Clearly, if a plain white area is reproduced on the receiving screen as an area which is unduly dark in the top left-hand corner and excessively bright in the bottom right-hand corner, then this must be produced by the presence of a progressive increase of illumination from the left-hand side of the picture to the right, together with an additional progressive increase from the top of the picture to the bottom.

Considering first of all the illumination error in the horizontal direction i.e. the line direction, if the change of brightness from one side of the picture to the other, i.e. over a line, is linear with time then it follows that this effect is that which would be produced if we had deliberately injected into the picture circuit of an emitron, possessing no natural illumination errors, a saw-toothed waveform at line frequency. In these circumstances, therefore, we may hope to be able to remove the effect by injecting into the picture circuits a saw-toothed waveform at line frequency but in reversed phase. Actually it is found that a considerable improvement is effected by such an injection, and this correction is accordingly made. The injected waveform is known as the *line tilt* waveform, and is illustrated in Fig. 1.

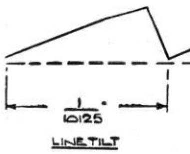

Figure 1

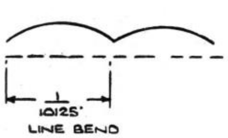

Figure 2

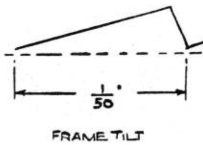

Figure 3

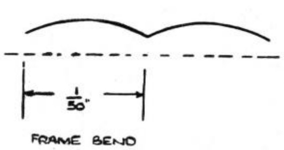

Figure 4

It is found, however, that after this correction has been made there is still a residual error which shows therefore that the complete error in the line direction is not linear. This remaining error takes the form of an increase of illumination at the sides of the picture and a corresponding decrease in the centre, or vice versa. The waveform of this component corresponds closely to a parabola, and it is found that this component also may be removed by the injection of the parabolic waveform at line frequency in anti-phase. This is known as the *line bend* waveform, and is illustrated in Fig. 2.

It is further found that the error in the frame direction may be corrected by the injection of similar components at frame frequency. These are known as the *frame tilt* and *frame bend* waveforms, and are illustrated in Figs. 3 and 4.

Apparatus is required therefore to generate these four correction components, and accordingly a unit known as the **Line Tilt and Bend Generator** is provided to generate the line tilt and bend waveforms, and a similar unit termed the **Frame Tilt and Bend Generator** provides the frame waveforms.

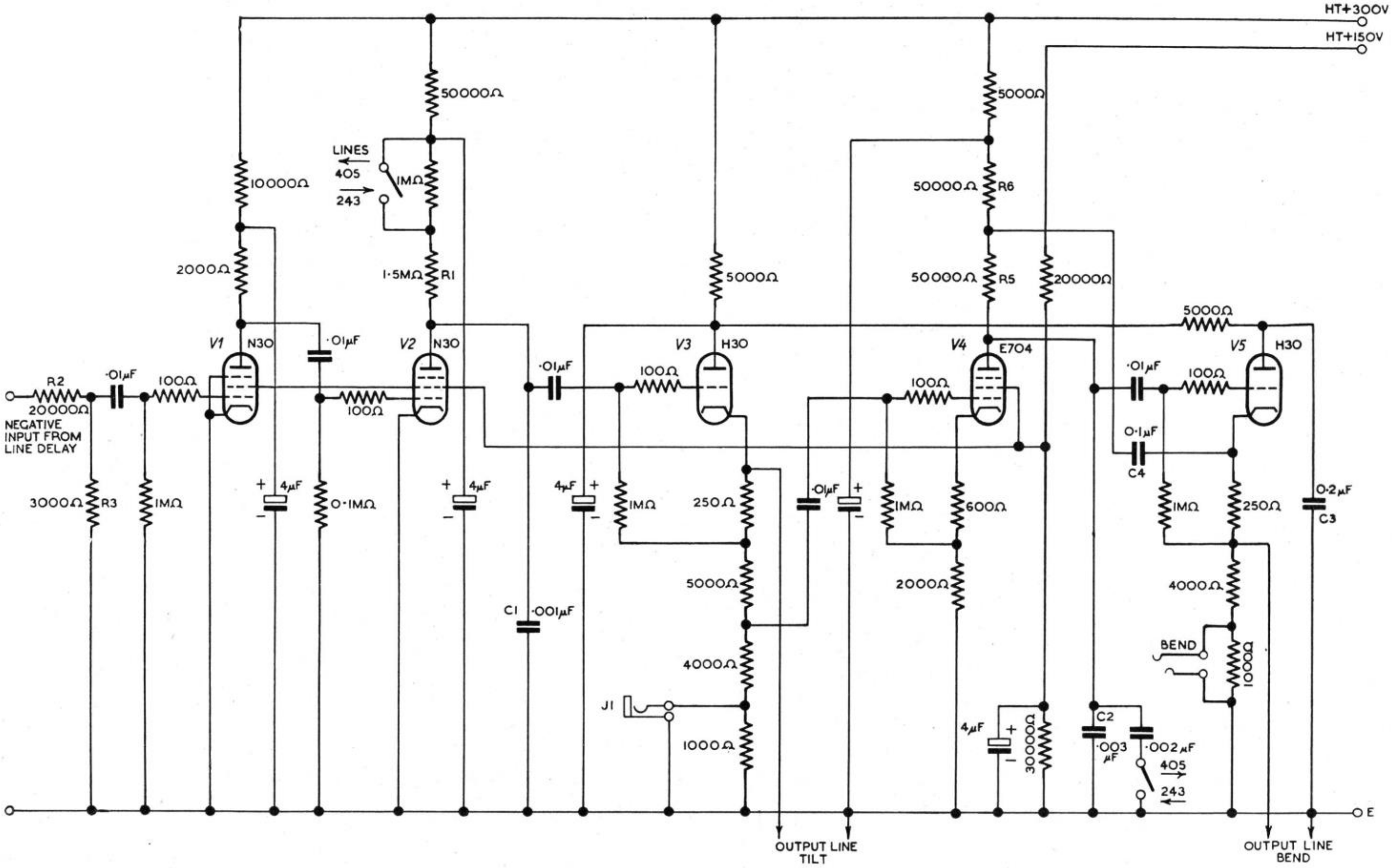

Fig. 5. Circuit Diagram Line Tilt and Bend Generator

The Line Tilt and Bend Generator

Generation of line tilt waveform : The valve V_2, in co-operation with the resistance R_1 and the condenser C_1, constitutes a saw-toothed generator operating at line frequency. The condenser C_1 is slowly charged through the very high resistance R_1, and at the appropriate moment is discharged by V_2. To effect the discharge, input from the Line Divider via the Line Delay is applied via the potentiometer R_2 R_3 to the valve V_1, where it is amplified and reversed, appearing as a positive pulse on the control grid of V_2, which thus on the arrival of the pulse discharges the condenser C_1. The voltage across C_1 is applied to the cathode follower V_3, whose output constitutes the source of line tilt voltage.

Generation of line bend waveform : This is carried out by the circuits associated with V_4. The condenser C_2 is connected to the high tension supply via the resistance R_5 and R_6, and it is also connected to the anode of V_4. It is therefore possible for the condenser C_2 to be receiving charge via R_5 and R_6 and simultaneously losing it via the anode impedance of V_4. If the impedance of V_4 is high then the rate of charge via R_5 and R_6 will be greater than the rate of discharge via V_4, and the potential across C_2 will rise. If now the impedance of V_4 is made low, the condenser C_2 will lose charge via V_4 more rapidly than it can acquire it via R_5 and R_6, and the potential across C_2 will fall. It will be seen therefore that if the impedance of V_4 be alternately raised and lowered, then the potential across C_2 will rise and fall sluggishly, and the waveform of the voltage across C_2 will execute a smooth ripple somewhat resembling the bend waveform of Fig. 2. It is required, however, that there should be a sharp discontinuity or reversal of slope at the end of each individual bend, as illustrated in Fig. 2, and this may be produced by controlling the impedance of V_4 so that its variations in time have a saw-toothed configuration. This is done as follows : A tapping on the cathode follower V_3 applies line tilt (saw-toothed) voltage to the grid of the valve V_4, and the application of this waveform causes the potential of the control grid of V_4 to rise steadily during the time of a line and then fall sharply to zero. At the beginning of this waveform the impedance of V_4, which will vary with its grid potential, is high, C_2 is receiving charge and the voltage across it is rising. As the saw tooth gradually develops on the control grid, the impedance of V_4 steadily falls and the discharge of C_2 becomes greater until a point is reached where the charge entering C_2 via R_5 and R_6 balances the discharge occurring via V_4. At this point the potential across C_2 reaches its maximum value, indicated by A in Fig. 6. The impedance of V_4 continues to become lower. The discharge of C_2 exceeds the charge, and its potential falls. Eventually the fly-back of the saw tooth occurs, and the control grid of V_4 is driven strongly negative, the anode impedance becoming correspondingly high. The discharging effect of V_4 therefore suddenly becomes negligible and the voltage across C_2 abruptly starts to rise. This is the point B of Fig. 6. It follows therefore that the voltage across C_2 executes an excursion which is the required line bend waveform of Fig. 2. This voltage is now applied to the cathode follower V_5, whose output constitutes a source of line bend voltage.

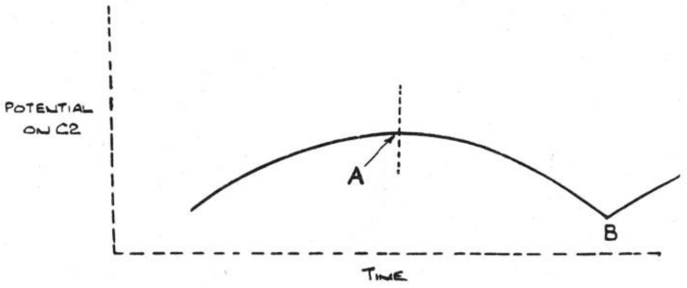

Figure 6

The correct operation of V_4 requires that its external anode impedance should be fairly low to D.C. in order that the excursions of C_2 shall be of reasonable magnitude, and so that V_4 may operate upon the correct part of its characteristic. At the same time this external anode path constitutes the impedance through which C_2 is charged, and the requirement in this connection is that the impedance should be high. It would be possible to secure this by making R_5 and R_6 very high resistances, in which case an unusually high value of high tension would be required. It is, however, possible to get over this difficulty by a special artifice involving the valve V_5. Since this is a cathode follower the potentials on the cathode would be closely following those on the grid, which are, of course, identical with those at the anode of V_4. By back-coupling the cathode of V_5 via the condenser C_4 to the junction of R_5 and R_6, this junction is made to execute variations of potential similar in waveform to, but slightly less in amplitude than, those executed by the anode of V_4, so that the resistance R_5 becomes in effect very high as regards the line bend waveform, but retains its ohmic value to D.C. (R_6 is, of course, necessary, as otherwise the cathode circuit of V_4 would be short-circuited at A.C. by the anode decoupling condenser of V_4.) This may be readily understood if it is realised that if the excursions of potential at one end of any resistance are equal to those at the other end, then there will be no current through the resistance, and an external measurement of the value of this resistance at A.C. would not detect the presence of any resistance at all, that is to say its value would appear to be infinitely high. The practical approximation to this state of affairs used in the Line Bend Generator is that the excursions at one end of the resistance are nearly equal in amplitude to those at the other, and the resistance appears therefore not to be infinite, but nevertheless very high.

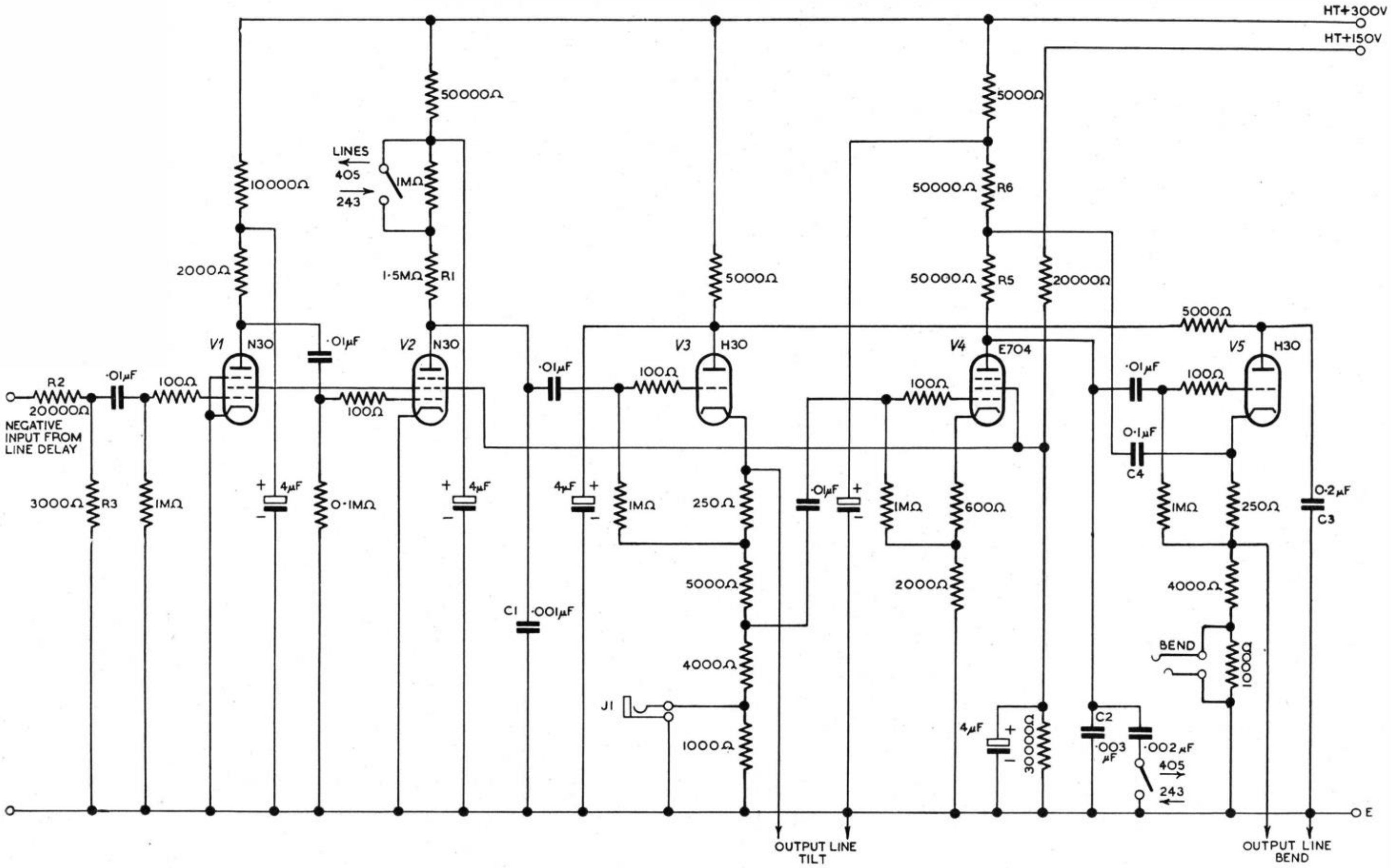

Fig. 5. Circuit Diagram Line Tilt and Bend Generator

The Frame Tilt and Bend Generator

This generator is in principle entirely, and in detail nearly, the same as the Line Tilt and Bend Generator, the main difference being that an initial stage for reversing the frame timing pulses is not included, as a positive input may be obtained from the Frame Divider. The valves V_1 to V_4 of the Frame Generator perform in succession the same functions as the valves V_2 to V_5 of the Line Generator, that is to say, R_1, R_2 and C_1 form a relaxation oscillator discharged by V_1, generating the frame tilt waveform, which is taken off from the cathode follower output stage V_2. V_3 is the variable conductivity valve which, in co-operation with C_2, generates the frame bend waveform, this being applied to the cathode follower output stage V_4. The feed-back to make the external anode impedance of V_3 high to $A.C.$ waveforms is similarly supplied via C_3.

The four waveforms are applied in another panel to four output transformers, each of which feeds the appropriate controlling potentiometer in The ' A ' Amplifier and Tilt Mixer panels. The object of inserting these transformers is so that centre tappings can be provided, with the result that the tilt and bend waveforms can be applied in either phase by their controlling potentiometers. When the potentiometers are set so that the waveforms are injected in the phase shown in Figs. 1 to 4, they are said to be tilt and bend waveforms. By rotation of the potentiometers the amplitudes of these waveforms can be reduced to zero or injected in the opposite phase, in which case they are referred to as *anti* tilt and bend waveforms.

Adjustment and Testing

The Line and Frame Tilt and Bend Generators require no adjustment.

The line tilt output on load is 8 volts. The line bend output on load is 8 volts. The frame tilt output on load is 10 volts. The frame bend output on load is 10 volts. In all the above cases the load consists of the appropriate tilt transformer shunted by all the corresponding tilt mixer potentiometers.

The line tilt output appears at the jack **J$_1$** of the line tilt and bend generator and should have an amplitude of 1.8 volts. The line bend output appears at the jack **J$_2$** of this unit, and should have an amplitude of 1.3 volts. The frame tilt output appears at the jack **J$_1$** of the Frame Tilt and Bend Generator and should have an amplitude of 1.5 volts. The frame bend output appears at the jack **J$_2$** of this unit, and should have an amplitude of 1.2 volts.

51

SUPPRESSION PULSE GENERATOR
Technical Description
M-E.M.I. System of Television
Item 2.4. October, 1937
(page re-issued January, 1950)

THE SUPPRESSION PULSE GENERATOR

In my technical note on The Signal Waveform, reference is made to certain pulses termed *Suppression Pulses* which are injected into the picture channel between lines and between frames. These pulses are provided for the following several reasons :—

(1) to suppress certain spurious signals of considerable amplitude which emanate from the emitron between lines and between frames ;

(2) to create the correct black level datum line from which the synchronising signals can hang ;

(3) to maintain the level of the radiated signal and consequently the intensity of the receiver spot at black for such a time as will allow the receiver fly-back to take place without showing a trace on the screen ;

(4) to provide a period of black subsequent to the synchronising, chiefly to the line synchronising signal, as this is required by the particular method of D.C. restoration adopted in the transmitter modulator ;

(5) to allow an adequate period of black between frames for the benefit in particular of the telecine apparatus, as it is during the frame return periods that the image of the film frame is projected on to the telecine emitron.

The various considerations detailed above require suppression pulses between lines of a duration of 16.5 micro-seconds and between frames of a duration of 1,400 micro-seconds. The line suppression pulses are illustrated in Fig. 1, and the frame pulses in Fig. 2. These pulses are, of course, mixed and delivered as one input to the Suppression Mixer, and this input will consequently appear as in Fig. 3, and it is the function of the Suppression Pulse Generator to produce this waveform.

Considering the circuit diagram, V_1 and V_2 constitute a multivibrator generating a continuous supply of line suppression pulses having the waveform roughly as indicated in Fig. 1. The multivibrator is timed from the line timing pulse which is supplied to the anode of V_2 via the condenser C_1 and the resistance R_1 from the Line Divider via the Line Delay Network. The grid resistance R_2 of V_1 is returned not to cathode but to the potentiometer P_1 upon which it finds a positive voltage. The time taken by negative charges to leak from the grid of V_1 will be dependent upon the potential which the grid is endeavouring to take up and which is determined by the setting of P_1, so that the duration of these negative charges, and consequently of the line suppression pulse, is controllable by P_1, which is consequently labelled **Line Width.** The frequency of these pulses is, of course, 10,125 c.p.s.

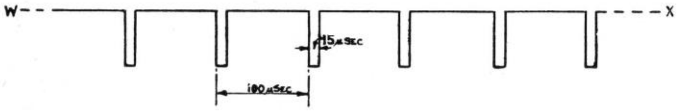

Figure 1. Line Suppression Pulses

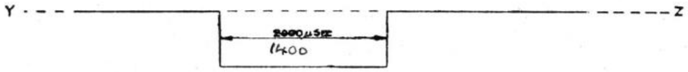

Figure 2. Frame Suppression Pulses

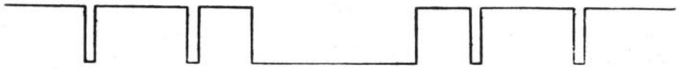

Figure 3. Mixed Line and Frame Suppression Pulses

The valves V_3 and V_4 form a multivibrator supplying continuously frame suppression pulses of the general form shown in Fig. 2, and in general this circuit operates precisely in the same manner as that involving V_1 and V_2. The width of the frame pulses is controllable by the potentiometer P_2, and the anode of V_4 is timed from the frame timing pulse received from the Frame Divider.

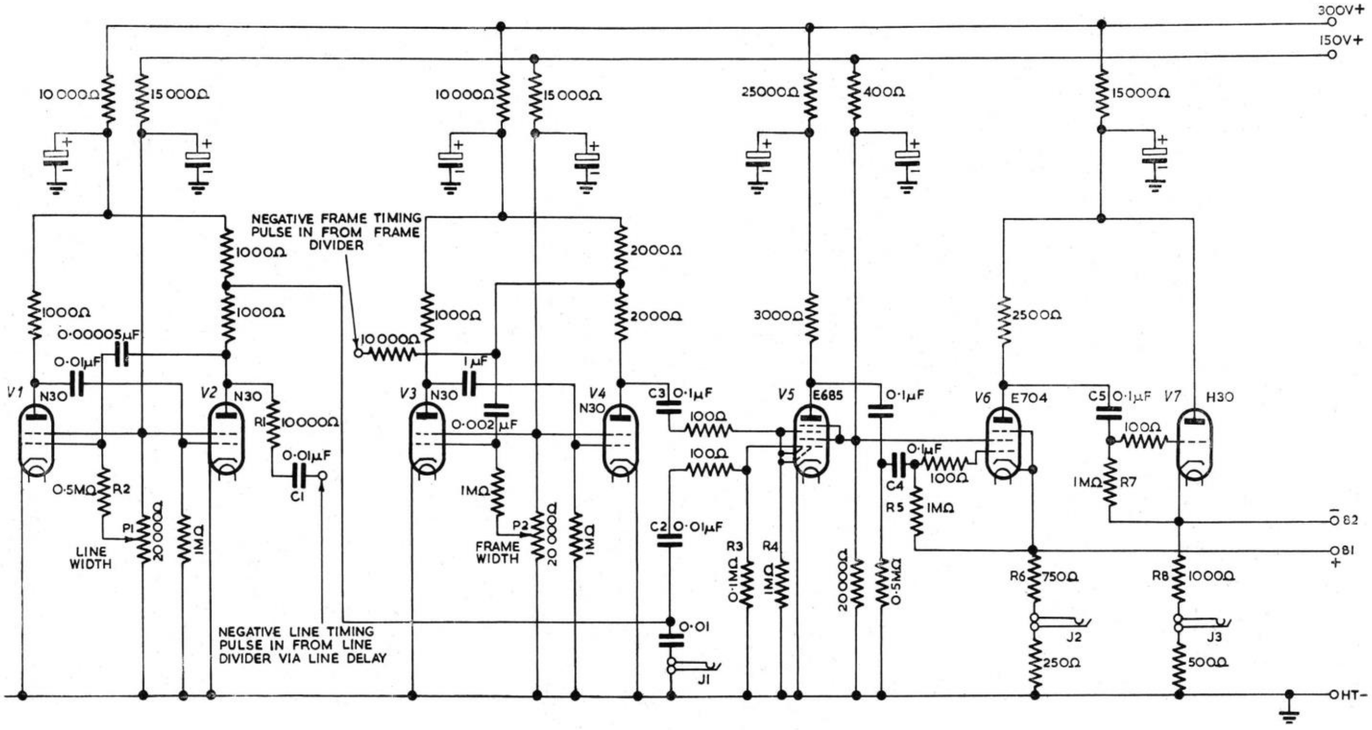

Figure 4. Circuit Diagram

The pulses are mixed in the valve V_5. An output from the multivibrator V_1 V_2 is taken from the anode of V_2 to the first grid of V_5. Similarly an output from the multivibrator V_3 V_4 is taken from the anode of V_4 to the third grid of V_5, and since the resultant anode current of V_5 is dependent upon the control voltages applied to these grids, mixed impulses of the general form of Fig. 3 will appear in the anode circuit. In accordance with the usual technique, D.C. is restored to both sets of pulses. This is done in order to be sure that the pulses always operate the valve on the same part of its characteristic, and because in the amplification and mixing of pulses there is no *a priori* necessity to have strict Class A amplification with appropriate grid bias. The process of D.C. restoration will set the pulses upon the optimum working range of the valve characteristic.

D.C. restoration is brought about as follows. The cathode of V_5 is connected to earth so that there is no automatic grid bias, and grid current can be drawn. For the line suppression pulses the condenser C_2 is provided, the grid resistance R_3 being returned to cathode. A complication, however, ensues in that the frame pulses are supplied to the third grid of V_5 which, being not adjacent to the cathode, as in the case of the first grid, cannot satisfactorily draw grid current. The valve V_5 is, however, a triode hexode, and the triode anode and grid are connected together and to the third grid so that they form a diode, which supplies the necessary grid charges for D.C. restoration.

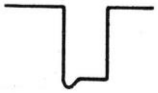

Figure 5. Diagram of Suppression Pulses

The valve V_5 performs a further function apart from the mixing of the line and frame suppression pulses. These pulses in their natural form straight from their appropriate multivibrators do not have the pure square topped form illustrated in Figs. 1 and 2, but have small peaks attached to them. This is illustrated in Fig. 5, which shows as an example a line suppression pulse. The small peak at the beginning of the pulses is really the timing pulse which is supplied to the multivibrator to keep it in step, and which also appears in the output superimposed on the multivibrator pulse. Since this peak represents a departure from the square topped form which is desired, it must be cleaned away. This is achieved by arranging that the amplitude of the line and frame pulses applied to the grids of V_5 are greater than the available grid bases belonging to the input control grids. In other words speaking more loosely, the valve is heavily overloaded, and consequently the troughs of the pulses, together with the superimposed peaks are lost around the bottom bends of the characteristics. Owing to D.C. restoration the pulses are always held in the same position on the operating characteristics of the input grids of V_5 since in the case of the line pulses D.C. restoration causes the line WX of Fig. 1, and in the case of the frame pulses the line YZ of Fig. 2, to coincide with zero grid potential.

The anode circuit of V_5 therefore contains the mixed line and frame pulses which have been cleaned and are in the final form as required by the Suppression Mixer. They appear at this point, of course, reversed, i.e. with the peaks of the pulses pointing upwards, and they are described as positive pulses. The valve V_6 constitutes a cathode following output stage for these positive pulses and its control grid is fed from the anode of V_5, the condenser C_4 and the resistance R_5 effecting the restoration of D.C. in accordance with the usual technique. The cathode following action is due to the unshunted cathode resistance R_6 across which the positive output is taken via terminal 81.

As will be seen from my note on The Suppression Mixer, this apparatus requires pulses in both senses, i.e. positive and negative, and it is necessary to derive therefore a negative output in addition to the above positive one. Accordingly, an output is also taken from the anode circuit of V_6 and applied to the grid of the further valve V_7, the condenser C_5 and the resistance R_7 as usual effecting the restoration of D.C. The pulses have, of course, been reversed once more by V_6, and appear as negative pulses at both the grid and cathode of V_7. This valve is, of course, a cathode follower, the appropriate feed-back being provided by the unshunted resistance R_8, and the unshunted output is consequently taken from the cathode via the terminal 82.

Adjustment

The line width should be set so that the line suppression pulses occupy a time of ~~15~~ 16.5 micro-seconds. (This is checked on the transmitter waveform monitor.) The frame width is set so that the frame suppression pulses occupy a period of 14 ~~20~~ lines. (This is checked on the transmitter picture monitor.) The amplitude of the line suppression pulses, as measured by plugging the waveform monitor into J_1, should be 16 volts. The amplitude of the positive output measured at J_2 should be $4\frac{1}{2}$ volts, and the amplitude of the negative output as measured at J_3 should be 6 volts.

BLACK-OUT PULSE GENERATOR
Technical Description
M-E.M.I. System of Television
Item 2.5. October, 1937
(*page re-issued October*, **1946**)

THE BLACK-OUT PULSE GENERATOR

The fundamental principle of operation of the emitron requires that its mosaic should be scanned by a beam of electrons which, passing over each photoelectric nodule in turn, restores it to its equilibrium potential. When the scanning of one complete frame is finished the beam must return to commence the next scan, and naturally it must not return in such a manner as to discharge any elements during the return stroke. It is an essential feature of the process that the time occurring between two successive impacts of the beam on a given element should be the same for all elements. This period is, of course, 1/25th of a second. and during this period each element is taking up a value of potential determined by the amount of light falling on it. If in addition certain elements were to be additionally scanned by the beam on its return stroke, their ultimate potentials would be changed, as a shorter time would have elapsed between successive impacts of the beam on them than that applying to the majority of the elements, and accordingly the path of the return stroke would be transmitted.

This difficulty may be avoided in two ways. The beam may either be deflected so that it does not pass over the mosaic during this return stroke, or it may be cut off at these times. In the system under consideration the second of these methods is adopted. The beam is cut off during the line and frame return periods by applying a strong negative potential to the grid of the emitron gun.

The line return strokes occur, of course, 10,125 times per second, and occupy a time of approximately 7% of the time of a line, i.e. 7 micro-seconds, and accordingly, to suppress the beam during the line return times, square pulses having a frequency of 10,125 c.p.s. and a width of 7 micro-seconds must be applied to the emitron grid. The frame return strokes occur, of course, 50 times per second, and occupy a time of approximately 6% of the time of a frame, i.e. 1,200 micro-seconds, and similarly square pulses having a frequency of 50 and a width of 1,200 micro-seconds must also be applied to the emitron grid to suppress the frame return strokes. These two sets of pulses are known as the *line black-out* and *frame black-out pulses*, and it is the function of the Camera Black-out Pulse Generator to generate them.

The generator is, of course, timed from the line and frame timing frequencies generated by the Line and Frame Dividers. The output of the generator passes to the Camera Delay Unit, which ensures that the pulses will arrive at the emitron grid at the right time, no matter what length of emitron cable may be in use. From there they pass to the emitron via the Focus Panel, which is convenient as the latter unit supplies all the other potentials to the various elements of the emitron gun.

Referring to the circuit diagram, the valves V_1 V_2 constitute a multivibrator generating a continuous supply of line black-out pulses having a waveform roughly as indicated in Fig. 2. The multivibrator is timed from the line timing pulse, which is supplied to the anode of V_2 via the condensers C_1 and the resistance R_1 from the Line Divider via the line delay network. The grid resistance R_2 of V_1 is returned not to cathode, but to the potentiometer P_1, upon which it finds a positive voltage. The time taken by negative charges to leak from the grid of V_1 will be dependent upon the potential which the grid is endeavouring to take up, and this is determined by the setting of P_1, so that the duration of these negative charges, and consequently of the line black-out pulse, is controllable by P_1, which is consequently labelled **Line width.**

The valves V_3 and V_4 form a multivibrator supplying continuously frame black-out pulses of the general form shown in Fig. 3, and in general this circuit operates in precisely the same manner as that involving V_1 and V_2. The width of the frame pulses is controllable by the potentiometer P_2, and the anode of V_4 is timed from the frame timing pulse received from the Frame Divider.

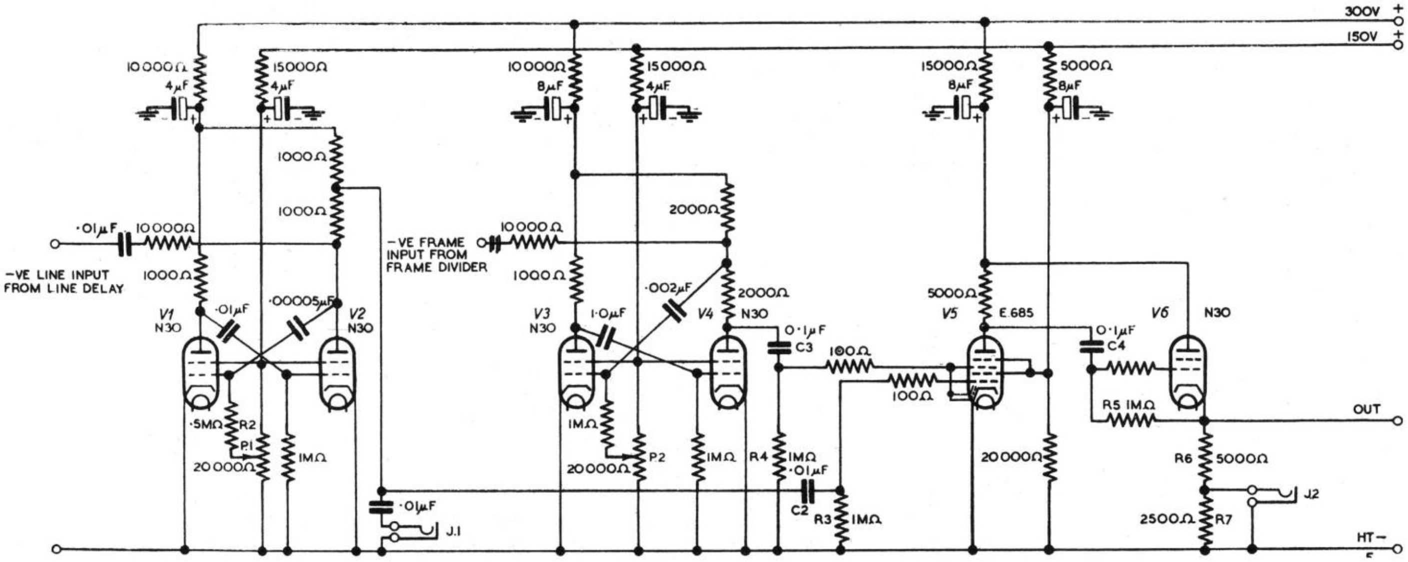

Figure 1. Circuit Diagram

The pulses are mixed in the valve V_5. An output from the multivibrator V_1 V_2 is taken from the anode of V_2 to the first grid of V_5. Similarly an output from the multivibrator V_3 V_4 is taken from the anode of V_4 to the third grid of V_5, and since the resultant anode current of V_5 is dependent upon the control voltage applied to these grids, mixed impulses of the general form of Fig. 4 will appear in the anode circuit. In accordance with the usual technique, D.C. is restored to both sets of pulses. This is done in order to be sure that the pulses always operate the valve on the same part of its characteristic, and because in the amplification and mixing of pulses there is no *a priori* necessity to have strict Class A amplification with appropriate grid bias. The process of D.C. restoration will set the pulses upon the optimum working range of the valve characteristic.

D.C. restoration is brought about as follows. The cathode of V_5 is connected to earth so that there is no automatic grid bias, and grid current can be drawn. For the line black-out pulses the condenser C_2 is provided, the grid resistance R_2 being returned to cathode. In the case of the frame black-out pulses the condenser C_3 is provided, the grid resistance R_4 being similarly returned to cathode. A complication, however, ensues in that

THE ARTIFICIAL BAR GENERATOR

It is desirable that there should be available some form of standard test signal in the form of an electrical waveform which can be injected into the picture channel so as to produce a standard geometrical design which can be used as a basis for measurements. Such a picture should enable the signal to be examined for high and low frequency performance, phase distortion and geometrical distortion. Thus, it should contain straight and sharp lines of demarcation between white and black, and also large areas of white and black. A satisfactory form of signal is a large black cross on a white background, which has the advantage that it is comparatively easy to generate electrically. It is the function of the Artificial Bar Generator to provide this test waveform, which is known by the abbreviated designation *Art Bars.*

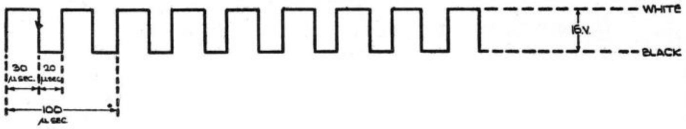

Figure 1. Line Component Generated by Multi vibrator V_1, V_2 (appearing at J_1)

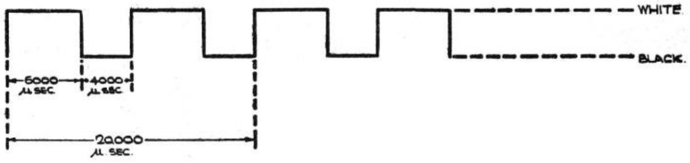

Figure 2. Frame Component Generated by Multi vibrator V_3, V_4.

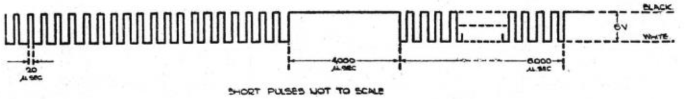

Figure 3. Complete Art Bar Waveform, i.e., Mixed Line and Frame Components (appearing at J_2)

From the nature of the waveform it is clear that it may be formed by mixing two square topped waveforms, one at twice line frequency and the other at twice frame frequency.

Considering the circuit diagram Fig. 4, the valves V_1 and V_2 constitute a multivibrator generating a square topped waveform at twice line frequency, i.e. 20250 c.p.s. The multivibrator is timed by the injection of master frequency timing pulses from the master frequency delay panel on to the screen[illegible] grid of V_1. The usual condenser and resistance C_1 R_1 are provided to isolate the multivibrator V_1 V_2 from the various other multivibrators which are simultaneously being timed by the master frequency. In accordance with the usual technique the potentiometer P_1 controls the width of

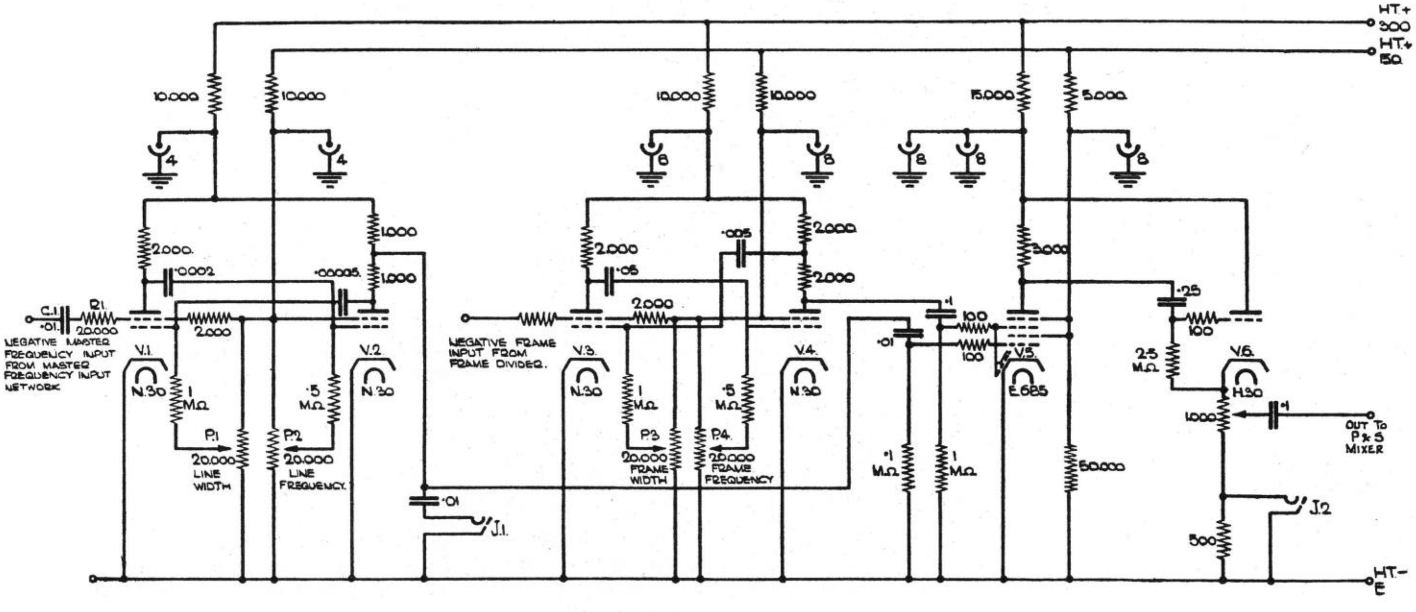

Figure 4. Circuit Diagram

the black pulses constituting the line component and the art bar waveform, i.e. the vertical bars. The grid of V_2 is returned to the potentiometer P_2, which controls the width of the white portion of the line component, and since this component is of much longer duration than the black component, the potentiometer P_2 effectively adjusts the frequency of the waveform produced by the multivibrator V_2. It is accordingly labelled **Line Frequency,** and enables the frequency to be brought into step with the master frequency.

The valves V_3 and V_4 constitute a multivibrator generating a square topped waveform at twice frame frequency, i.e. 100 c.p.s. The operation is similar to that of the line multivibrator, the potentiometer P_3 controlling the width of the black pulses constituting the frame component of the art bar waveform, i.e. the horizontal bars. No fundamental timing pulse is, of course, available with a frequency of 100 c.p.s. to time the frame multivibrators, but this may satisfactorily be timed from the frame timing pulses at 50 c.p.s. so long as only a loose hold is employed. This is achieved by feeding the timing pulses on to the screen~~ed~~ grid of the appropriate multivibrator valve instead of its anode. In this case therefore, negative frame timing pulses are applied from the Frame Divider to the screen~~ed~~ grid of the valve V_3. The potentiometer P_4 brings the frequency generated by the multivibrator V_3 V_4 into step with the frame timing pulses.

It should be particularly noted that when art bars are required, the waveform is injected into the Picture and Sync Mixer ; consequently the waveform replaces not only the picture signals, but also the suppression signals which are normally introduced a stage earlier, i.e. into the Suppression Mixer. It is essential therefore that the width of the black line and frame components of the art bar waveform should be adjusted by P_1 and P_3 so as to be not less than the widths of the normal suppression pulses, i.e. ~~15~~ 16.5 micro-seconds and ~~2000~~ 1400 micro-seconds respectively. In practice they are generally made much wider to form an agreeable signal.

The line output from V_1, V_2 is applied to the first grid of the mixing valve V_5. The frame output from V_3, V_4 is similarly applied to the third grid of V_5. At both these grids D.C. restoration takes place, but as is always the case with hexode mixers it is necessary to connect a diode between the third grid and the cathode if satisfactory D.C. restoration at this point is to be obtained. For this purpose a triode hexode is used with the grid and anode of the triode portion strapped together to provide the diode. As the amplitude of the pulses is greater than the available length of operating characteristic in the case of both the grids, the tips of the pulses are cut off and superfluous peaks thus eliminated. In the anode circuit of V_5 therefore, the mixed waveform appears, and it is fed to V_6 which is a cathode follower output stage feeding the output line at low impedance. Control of the amplitude of the art bar waveform is effected by the potentiometer P_5.

Adjustment

The jack $\mathbf{J}_1$ provides for examination on the waveform monitor of the art bar line components generated by V_1 V_2. At this point their amplitude should be 16 volts and their sense negative.

The jack $\mathbf{J}_2$ provides for examination of the complete art bar waveform. At this point the amplitude should be 6 volts and the sense positive. As stated above the frequency potentiometers P_2 and P_4 should be set so that a reliable hold from the timing pulses is obtained, and the potentiometers P_1 and P_3 so that any agreeable bar widths are obtained so long as they are not less wide than the standardised suppression pulses. A very satisfactory waveform may be obtained by arranging for the line width to be 20 micro-seconds and the frame width to be 4000 micro-seconds, as shown in Figure 3.