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CATHODE-RAY BEAM DEFLECTION CIRCUIT

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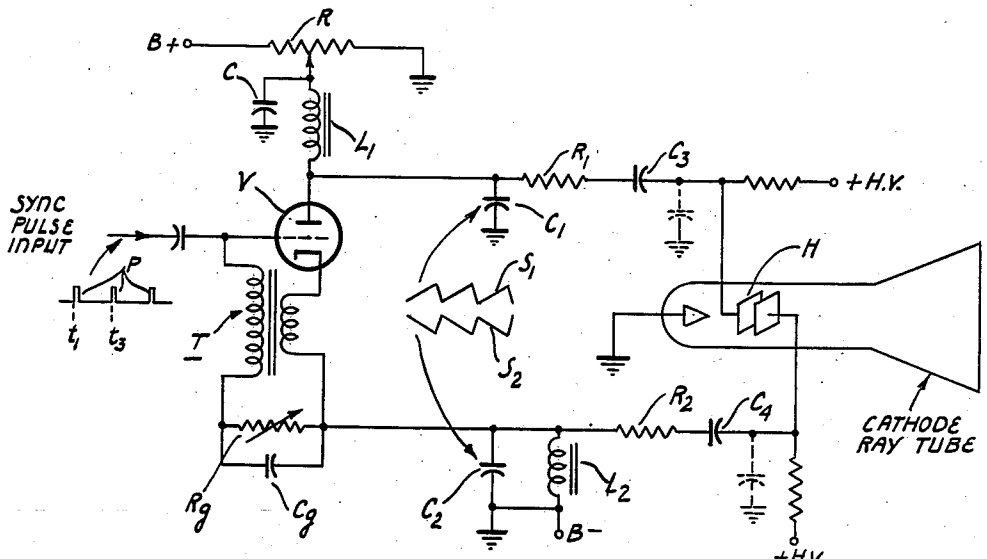


FIG. 1.

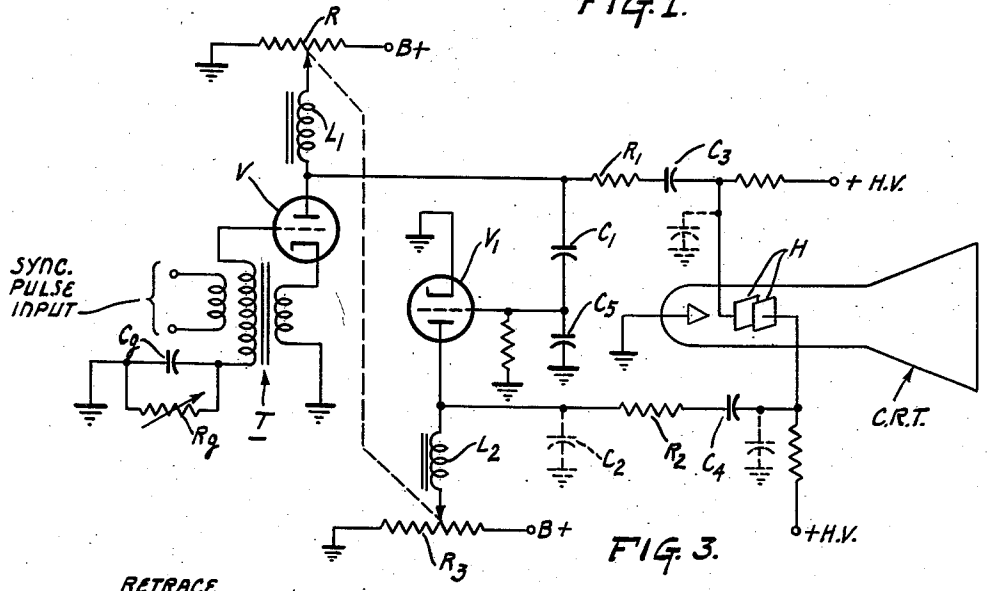


FIG. 3.

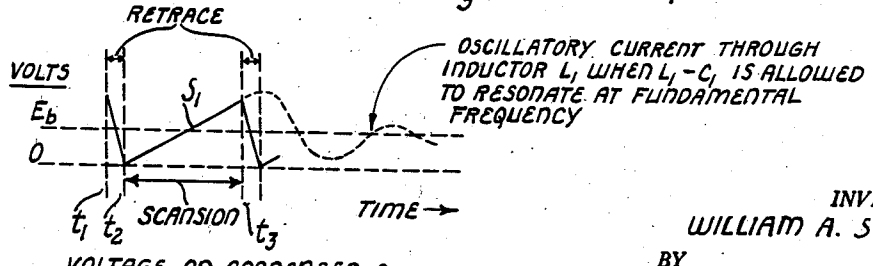


FIG. 2.

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CATHODE-RAY BEAM DEFLECTION CIRCUIT

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7 Claims. (Cl. 315—26)

1

The present invention relates to cathode ray beam deflection circuits, and more particularly relates to those circuits which are designed to form part of a television system wherein the electron scanning beam of a cathode ray tube is deflected in at least one of its mutually perpendicular directions by the action of an electrostatic field.

Television systems employing cathode ray tubes of the type having two pairs of electrostatic deflection plates commonly include means for generating two sawtooth voltage variations having different repetition frequencies. In certain known arrangements, these sawtooth voltages are respectively applied to one deflecting plate of each pair, while the remaining plates are maintained at ground or some other constant potential. In other known arrangements, however, two further sawtooth voltages are developed which are in phase opposition to the voltages initially generated. These additional voltages are also applied to the deflecting plates in a manner such that the cyclically varying potentials on the two plates of each pair are symmetrical, or balanced, with respect to a predetermined voltage level. The provision of such balanced voltages is usually desirable, inasmuch as it increases the angle through which the cathode ray beam may be deflected and hence the size of the image raster area scanned by the beam. In addition, by causing the balanced voltages to have a reference level which coincides substantially with the second anode potential of the cathode ray tube, any defocusing of the cathode ray scanning beam (which frequently results when a so-called "single-ended" deflecting circuit is used) is largely overcome.

In one form of electrostatic deflecting arrangement particularly adapted for use in television receivers, an electron discharge tube is provided with a time constant circuit connected to its anode and a further time constant circuit connected to its cathode. Each of these time constant circuits customarily includes a condenser, or other energy-storage device, which is discharged by conduction of the tube and charged during the time that the tube is cut off. By selecting proper values of resistance in the charging path of each condenser, the voltage developed in the anode circuit of the tube during scansion will be a linearly rising sawtooth, while the voltage appearing in the cathode circuit will be a linearly falling sawtooth. Furthermore, these

2

voltages will be balanced with respect to one another. A system operating in accordance with the above principles is described in a United States patent to C. E. Hallmark, No. 2,345,668, issued April 4, 1944.

One disadvantage in such an arrangement, however, resides in the fact that the charges which are developed on the condensers in the respective time constant circuits have peak-to-peak values which are lower than the voltage of the operating potential source itself. In fact, the peak-to-peak value of these developed charges must be considerably below the voltage supplied to the anode of the discharge tube during scansion if approximate linearity of deflection is desired. Thus the angle through which the cathode ray beam is deflected may be limited to such a degree that the circuit is rendered unsuitable for use in many types of television systems. In order to overcome this disadvantage, it has been the procedure in certain cases to "step up" the voltage of the operating potential source, but, since this usually requires additional components, it may serve to increase the overall cost of the television apparatus.

Another type of presently employed deflection circuit is one in which the sawtooth-voltage-generating network is arranged as a separate unit so that it merely provides the control, or driving, voltage for a power tube. The latter element in this case forms part of the circuit which actually supplies sawtooth energy to the deflecting plates. As a consequence, a relatively high scanning voltage output may be obtained relative to the amplitude of the voltage which appears on the control electrode of the power tube. It is obvious, however, that this arrangement is considerably more complex than one in which the output of the sawtooth generator is applied directly to the plates of the cathode ray tube itself, inasmuch as the latter circuit provides a deflecting voltage which is utilized directly for beam deflection without the presence of an intervening amplifier stage.

According to one feature of the present invention, a single-tube cathode ray beam deflection circuit of the electrostatic type is provided in which a pair of parallel-tuned, or parallel-resonant, inductance-capacitance networks are respectively connected in the anode and cathode circuits of an electron discharge tube. By properly determining the natural period of oscillation of these resonant networks, it has been found that the energy developed across the inductive

portion of each network during the retrace periods of the cathode ray beam (when the discharge tube is conductive) may be utilized for the purpose of increasing the charge which appears on the capacitive portion of each network during scansion. The peak-to-peak value of this charge may accordingly be raised to a point considerably in excess of that which would normally be reached as a result of charging the capacitor from the operating potential source alone. Furthermore, by a particular connection of these parallel-resonant networks, both with respect to each other and with respect to the electron discharge tube, it has been found that the waveforms of the voltages respectively appearing on the capacitive portions of the networks may be made substantially symmetrical about a fixed reference level.

In accordance with a further feature of the present invention, a plurality of wave-shaping units are provided by means of which any dissimilarity between the voltages respectively developed across the two resonant networks may be corrected. Furthermore, this is accomplished without increasing the distributed capacity in the circuit to an objectionable degree, and without appreciably increasing that portion of each deflection cycle which is allotted for the retrace action of the cathode ray scanning beam.

In accordance with an additional feature of the invention, the balanced deflecting voltages which are developed in the manner above set forth are capacitively coupled to the deflecting plates of the cathode ray tube. This eliminates any possibility that the waveform of these voltages will be undesirably deformed in the coupling circuit, such as frequently occurs when the cathode ray tube is coupled to the sawtooth generating circuit by some inductive member such as a transformer. In the latter case, high-frequency oscillations, or transients, often result in vertical bars being visible on one side of the image raster due to "ringing" of the transformer following each retrace interval. Furthermore, transformer coupling requires very critical adjustment in order to obtain fidelity of image reproduction.

One object of the present invention, therefore, is to provide an improved form of cathode ray deflection circuit of the electrostatic type.

Another object of the present invention is to provide an electrostatic cathode ray beam deflection circuit adapted to produce deflecting potentials which are balanced with respect to a predetermined voltage level, and which at the same time have peak-to-peak amplitudes which are greater than the maximum value of the supply voltage source.

An additional object of the invention is to provide a single-tube cathode ray beam deflection circuit of the electrostatic type, and further to provide a pair of parallel resonant networks which are respectively connected in the anode and cathode circuits of the tube in such a manner that the energy developed across each such resonant network during the retrace period of the cathode ray beam is made available during the succeeding scanning interval to reinforce, or "boost," the potential which would otherwise be developed for deflecting purposes as a result of the charging of the network capacitance from the operating potential source.

A still further object of the invention is to provide an electrostatic cathode ray beam deflection circuit including a single discharge tube having a pair of parallel resonant circuits respectively

associated with its anode and its cathode, the natural period of oscillation of these resonant circuits being so chosen that the energy developed thereacross during the time that the discharge tube is conductive is utilized during the time that the discharge tube is non-conductive to increase the angle through which the scanning beam of the cathode ray tube is deflected with respect to the angle through which it would normally be deflected as a result of utilizing only the voltage supplied by the source of operating potential.

Other objects and advantages will be apparent from the following description of preferred forms of the invention and from the drawing, in which:

Fig. 1 is a circuit diagram of a preferred form of cathode ray beam deflection circuit in accordance with the present invention;

Fig. 2 shows the waveform of the sawtooth voltage present on one of the deflecting plates of the cathode ray tube of Fig. 1; and

Fig. 3 is a circuit diagram of a modification of the arrangement shown in Fig. 1.

Referring first to Fig. 1, there is shown a cathode ray beam deflection circuit including an electron discharge tube V which is provided with an anode, a cathode and at least one control electrode. This tube V is adapted to control the generation of scanning potentials in a manner now to be set forth, these potentials being respectively applied to a pair of horizontal, or line, deflecting plates H forming part of the deflecting assembly of an image-reproducing cathode ray tube. The latter also includes the usual means for developing a beam of scanning electrons, which are then deflected by the plates H so as to form a trace on the screen of the tube. It will be further understood that the cathode ray tube is provided with an additional pair of deflecting plates or other means for producing a movement of the scanning beam in a direction perpendicular to that produced by the plates H. However, this second deflection means forms no part of the present invention, and hence an illustration thereof has been omitted from the drawing for the sake of simplicity.

Tube V is designed to control the production of two cyclically varying voltages of sawtooth waveform and opposite phase. Consequently, the tube must be rendered alternately conductive and non-conductive at a rate of 15,750 cycles per second if the developed voltages are to be suitable for a horizontal, or line, deflection of the scanning beam under present television standards. In order to permit the tube to operate in this manner, certain of the components of Fig. 1 are arranged in the form of a blocking oscillator.

A transformer T is included in the anode-cathode circuit of tube V so that the current flowing in this circuit will also flow through one winding of the transformer. The remaining winding of the transformer T has one of its ends connected directly to the control electrode of tube V, as illustrated, and its other end connected to one plate of a capacitor C_g.

Accordingly, when tube V conducts, its grid, or control electrode, becomes initially strongly positive due to the voltage developed across the grid winding of transformer T by the flow of current in the anode-cathode circuit of the tube. This initially positive condition of the grid causes a heavy flow of grid current to charge the capacitor C_g with a negative charge. This is effective to bias the tube V beyond cut-off. It remains non-conductive until the negative charge on capacitor C_g leaks off through the parallel

resistor R_g, and the cut-off level of the tube is again reached. The above operation may be termed a "squegging" action.

The precise instant at which tube V becomes conductive in each cycle of operation is controlled by the reception of one of a series of synchronizing pulses P on the control electrode of the tube. These pulses P may represent the horizontal synchronizing pulses which form part of a composite television signal. However, although the circuit of Fig. 1 is being described in connection with the horizontal deflecting portion of a television receiving system, nevertheless it will be apparent as the description proceeds that the disclosed circuit is also suitable for bringing about a vertical, or field, deflection of the electron scanning beam in television circuits, or even for uses other than in connection with television, such, for example, as in oscillographic work.

The anode of tube V is supplied with a positive operating potential from a suitable source (indicated in the drawing as B+) through the potentiometer R and an inductor L_1. A by-pass condenser C is connected between the movable element of potentiometer R and ground.

A further capacitor C_1 is connected between ground and the anode of tube V in a manner such that it is effectively in parallel relation with the inductor L_1, the impedance of the by-pass condenser C being small at the operating frequency of the system. Thus the capacitor C_1 forms with the inductor L_1 a parallel-tuned, or resonant, circuit. As will be brought out in detail below, the charge developed on this capacitor C_1 during operation of the system has a waveform which is of the substantially sawtooth nature indicated by the reference character S_1, with a long flank, or upstroke, of the sawtooth extending in a positive direction. This cyclically varying voltage S_1 is applied to one of the deflecting plates H of the cathode ray tube through a wave-shaping resistor R_1 and a blocking capacitor C_3.

The plate of the grid capacitor C_g which is opposite to that on which the negative charge is developed by the flow of grid current in tube V is connected to ground and also to the negative terminal of the operating potential source through the parallel combination of a further capacitor C_2 and a further inductor L_2, so that L_2C_2 forms a second parallel-resonant network which is effectively located in the cathode circuit of tube V. As will be later brought out, the charge developed on condenser C_2 during operation of the system is also of sawtooth configuration, but is opposite in phase to the sawtooth voltage S_1 developed on capacitor C_1. This charge on condenser C_2, which is identified by the reference character S_2, is symmetrical with respect to the voltage S_1, with its long flank extending in a negative direction. The cyclically varying voltage S_2 is applied to the remaining plate H of the cathode ray tube through a further wave-shaping resistor R_2 and a further blocking capacitor C_4.

In order that the deflecting plates H of the cathode ray tube be operated at a potential which precludes a defocusing of the scanning beam as it passes between the plates, the latter are connected to the same source of high voltage which serves as the second anode potential of the cathode ray tube. Due to the blocking capacitors C_3 and C_4, however, the high voltage is prevented from being applied directly to the electrodes of the oscillator tube V.

In describing the operation of the circuit illustrated in Fig. 1, let it first be assumed that tube V is rendered conductive by the reception of one of the synchronizing pulses P on the control electrode thereof. As previously brought out, the resulting flow of anode-cathode current results in a strongly positive charge being developed on the grid of the tube, which in turn results in a sudden surge of grid current to charge capacitor C_g negatively and cut off the tube.

The instant at which one of the synchronizing pulses P is received by tube V is identified as t_1 in Figs. 1 and 2. As soon as tube V conducts at this time t_1, it forms a low-impedance path between condenser C_1 and condenser C_2. Since there is a charge present on condenser C_1 at this time t_1 (as will later be shown), the conduction of tube V effectively results in substantially all of this charge being transferred to condenser C_2 due in part to the so-called "flywheel effect" of the resonant circuit L_1C_1. The potential on condenser C_2 is thus increased by an amount equal to that by which the potential on condenser C_1 is decreased. This charge transfer is completed before tube V is again cut off at time t_2 (Fig. 2), the interval t_1—t_2 corresponding to the retrace period of the cathode ray scanning beam.

At the end of the retrace interval (or in other words, at the time t_2) the shunting action of tube V is terminated, and capacitor C_1 begins to charge from the positive potential source B+ through the potentiometer R and the inductor L_1. Normally, the voltage to which condenser C_1 is charged will have a maximum value which is limited to that of the operating potential source B+. However, in accordance with applicant's invention, the resonant network L_1C_1 enters into oscillation at the instant t_2 when tube V is cut off, and current begins to flow through L_1 into C_1 under the influence of the voltage developed across the resonant circuit during the conduction interval of tube V. This current flow is maximum at some point near the voltage value of B+, but continues due to the resonance phenomenon until a peak value is reached at a time equivalent to approximately one-half cycle of the period of L_1C_1. Fig. 2 illustrates how oscillatory action of the resonant circuit L_1C_1 commences at time t_2, and results in the sawtooth voltage wave S_1 on capacitor C_1 rising to a level which is considerably in excess of the voltage E_b representing the voltage of the operating potential source B+.

In order for the above action to be effective, however, it is necessary that the resonant frequency of the tuned circuit L_1C_1 be properly chosen with respect to the frequency of the synchronizing pulses P. It has been found in practice that the described results will be achieved if the network L_1C_1 is tuned to a frequency such that the line-scanning period t_2—t_3 of each deflection cycle is equally approximately to between one-quarter and one-half the period of oscillation of L_1C_1.

At the instant t_2 when tube V is rendered nonconductive, the capacitor C_2 in its cathode circuit (which has acquired the energy present in capacitor C_1 at the end of the scanning interval) now begins to discharge to ground through the inductor L_2. However, due to the fact that the inductor L_2 and capacitor C_2 are tuned to a frequency of oscillation which is substantially identical to the resonant frequency of L_1C_1, the flow of current through inductor L_2 following cut off of tube V (or in other words, the discharge curve of C_2) has a waveform S_2 which is substantially the reverse of the waveform S_1 shown in Fig. 2.

It has been stated that the voltage developed on condenser C_1 is applied to one of the deflecting plates H through the resistor R_1 and the capacitor C_3. In a similar manner, the voltage developed on condenser C_2 is applied to the remaining one of the plates H through the resistor R_2 and the capacitor C_4.

It has been found that the resistors R_1 and R_2 may act respectively to linearize the deflecting voltages by acting as wave-shaping units in combination with the distributed capacitances to ground of the deflecting plates H (these capacitances being shown by broken lines in the drawing). In other words, the presence of the resistors R_1 and R_2 permits the phase of each deflecting voltage to be shifted within sufficiently broad limits so that the actual potentials as they appear on the deflecting plates H may be adjusted for substantially perfect balance and linearity.

The natural period of oscillation of the resonant circuits L_1C_1 and L_2C_2 would normally cause an oscillatory current to flow in each of these circuits, as indicated by the broken line in Fig. 2. However, it will be appreciated that at the end of the scanning period, or in other words at the time t_3, tube V is rendered conductive so as to place a very low resistance across each of the inductors L_1 and L_2 and thus effectively terminate the oscillations in the resonant networks. As a result of this mode of operation, each of the circuits L_1C_1 and L_2C_2 is effectively permitted to go into oscillation at the beginning of each line-scanning interval, but is only allowed to resonate until the beginning of retrace time, or in other words until tube V again becomes conductive. Accordingly, the low frequency of resonance of these tuned circuits does not undesirably lengthen the retrace time of the cathode ray scanning beam, since the damping action of tube V is so effective that it reduces the amplitude of the oscillations substantially to zero before the instant that a new scanning cycle is initiated.

In Fig. 3 is shown a modification of the deflection circuit of Fig. 1 in which an additional electron discharge tube is employed. Whereas in Fig. 1 the tube V included in its anode-cathode circuit the inductance-capacitance combination L_2C_2, the circuit of Fig. 3 is so arranged that the cathode of the tube V is connected directly to ground through one winding of the transformer T. Also, that plate of the grid capacitor C_g which is opposite to the one on which the negative charge is developed by the flow of grid current is likewise connected directly to ground instead of through the same inductance-capacitance combination L_2C_2. Accordingly, when the tube V conducts during the retrace interval t_1—t_2, the capacitor C_1 in the anode circuit of the tube V is discharged directly to ground instead of into the capacitor C_2 as is the case in the circuit of Fig. 1.

A sawtooth potential is developed on condenser C_1 in the circuit of Fig. 3 which is similar to that developed in the circuit previously set forth. However, in the circuit of Fig. 3, an additional capacitor C_5 is connected between capacitor C_1 and ground. The value of these two series-connected capacitors C_1 and C_5 is so chosen that their total capacitance is substantially equal to that of capacitor C_1 in Fig. 1. Hence these two elements merely serve as a voltage-dividing network for a purpose now to be described.

The voltage appearing on capacitor C_5, which has a waveform similar to that of the voltage wave S_1 in Fig. 2 but which is reduced in amplitude with respect thereto, is applied to the control electrode of a further electron discharge device V_1, which may, if desired, be similar to tube V. As shown in Fig 3, the cathode of this additional tube V_1 is grounded, while its anode is connected through inductor L_2 and a further potentiometer R_3 to the same source of positive operating potential (B+) as that to which the potentiometer R is connected.

It will now be seen that this additional tube V_1 acts to invert the phase of the voltage variation S_1 appearing on its control electrode so as to develop in its anode circuit a voltage variation which will be opposite in phase to the voltage variation S_1, and which accordingly will have substantially the configuration of the voltage wave S_2 illustrated in Fig. 1. In order that this voltage wave produced by tube V_1 be of an amplitude which is equal to that of the voltage wave produced by the tube V, the two potentiometers R and R_3 are ganged together so that they may be adjusted simultaneously.

It will be noted that, in the circuit of Fig. 3, the capacitor C_2 is shown in broken lines. This is due to the fact that in actual practice the inductor L_2 may be made to resonate with the distributed circuit capacitance, thus providing an output oscillation suitable for optimum deflection of the cathode ray beam. Hence, it may not be necessary to employ a physical capacitor in the resonant circuit L_2C_2 in Fig. 3, although such a capacitor may of course be used if it is found desirable. However, the circuit L_2C_2 should preferably have a frequency of resonance such that one-half cycle of oscillation of the circuit will occur within the retrace time interval t_1—t_2.

Inasmuch as the circuit of Fig. 3 employs an additional electron discharge tube, it develops a substantially increased power output over the maximum voltage which is obtainable with the circuit of Fig. 1. However, the latter circuit is especially suitable for providing electrostatic deflection of the cathode ray beam of an image-reproducing tube in television systems where voltages are required which do not exceed, for example, the values given in the following table. In this connection, it has been found advantageous to employ, for maximum efficiency of operation, a tube of a type having a high transconductance. One tube especially suitable is a 6J6 with its two halves connected in parallel.

It is also desirable that the inductors L_1 and L_2 be provided with iron cores to reduce the A.-C. resistance of the resonant circuits and raise their "Q." It has furthermore been found in many cases that, unless such iron cores are used, high-frequency oscillations may appear in the voltage waveforms S_1 and S_2. When iron cores are used, however, the coupling between turns of the inductors is so tight that the magnitude of any such oscillations which may be developed is not great enough to be objectionable.

The following table illustrates the manner in which the output voltages developed by a system constructed in accordance with the present invention compare with the output voltages obtainable from those deflection systems of the prior art which are limited to the maximum value of the operating potential source. It will be seen that the peak-to-peak voltage obtainable on each deflection plate of the cathode ray tube is increased by the use of applicant's circuit as shown in Fig. 1 up to approximately 30% over the potential of the B+ supply, and by the use of the

circuit of Fig. 3 up to approximately 70% over the B+ potential:

D.-C. supply	peak-to-peak voltage (one plate)	peak-to-peak voltage (both deflecting plates)
CIRCUIT OF FIG. 1 USING ½ 6J6		
	V.	V.
200 v.	200	400
300 v. (3 ma.)	375	750
400 v.	500	1,000
CIRCUIT OF FIG. 1 USING 6J6 WITH BOTH SECTIONS IN PARALLEL		
250 v.	325	650
CIRCUIT OF FIG. 3 USING ½ 6N7(V) AND 6C4(V_1)		
500 v.		1,250

Having thus described my invention, I claim:

1. In an electrostatic cathode ray beam deflection circuit of the blocking oscillator type, including an electron discharge tube having an anode, a cathode and at least one control electrode, a source of operating potential for said tube, a source of synchronizing pulses of predetermined frequency, and a circuit for applying said synchronizing pulses to the control electrode of said tube to cyclically initiate the conduction of the latter, the improvement which comprises a pair of parallel inductance-capacitance networks tuned to resonance at a frequency lower than that of the said synchronizing pulses, means for connecting one of the said resonant networks in the anode circuit of said tube and the other of the said networks in the cathode circuit thereof, whereby the potential cyclically developed across the capacitance in each of the said resonant networks is of substantially sawtooth waveform and has a peak-to-peak value which exceeds that of the said operating potential source, and means for applying the potentials thus developed in the two resonant networks to control one direction of deflection of the said cathode ray beam.

2. The combination of claim 1, in which each of the two said inductance-capacitance networks has a resonant frequency of between one-quarter and one-half the repetition frequency of the said synchronizing pulses.

3. The combination of claim 1, in which the means for applying the potentials developed in the two said resonant networks to control one direction of deflection of the cathode ray beam includes a pair of wave-shaping resistors respectively located between each resonant network and that particular deflecting plate of the cathode ray tube to which it is connected, said wave-shaping resistors acting, together with the distributed capacitance in the circuit, as phase-shifting units which are effective to compensate at least in part for nonlinearities in the long flank of each cycle of the substantially sawtooth voltages developed in the said resonant networks.

4. In a cathode ray beam deflection circuit of the type including an electrostatically deflected cathode ray tube, an oscillator tube having an anode, a cathode, and at least one control electrode, a source of operating potential for the said oscillator tube, a source of synchronizing pulses of predetermined frequency, and means for applying said synchronizing pulses to the control electrode of said oscillator tube to cyclically initiate the conduction of the latter, the improvement which consists in storing energy in the deflection circuit during periods when the said oscillator tube is conductive and utilizing this energy during the next time interval when the tube is non-conductive to increase the angle of deflection in one direction of the said cathode ray beam, said improvement including a pair of parallel-tuned inductance-capacitance networks, means for connecting one of the said networks in the anode circuit of said oscillator tube and the other of the said networks in the cathode circuit of said oscillator tube, whereby the potential cyclically developed across the capacitance in each of the said tuned networks is of substantially sawtooth waveform and has a peak-to-peak value which is greater than that of the said operating potential source, and means for respectively applying the potentials thus developed in the said tuned networks to one set of deflecting plates in the said cathode ray tube.

5. In combination, an electron discharge tube having an anode, a cathode and at least one control electrode, a source of operating potential for said tube, means for rendering said tube alternately conductive and non-conductive at regularly recurring intervals, a first resonant inductance-capacitance network, means for connecting said first inductance-capacitance network in the anode circuit of said tube so that the capacitance in said network is charged from said operating potential source through the network inductance when said tube is non-conductive, a second resonant inductance-capacitance network, and means for connecting said second inductance-capacitance network in the cathode circuit of said tube so that when the latter becomes conductive the charge developed on the capacitance of said first inductance-capacitance network during the preceding period when the said tube was non-conductive is transferred to the capacitance of said second network, from which it is gradually dissipated through its associated inductance concurrently with the charging of the capacitance of said first network, whereby cyclically varying voltages of substantially symmetrical waveform and opposite phase are produced on the respective capacitances of the two said networks.

6. The combination of claim 5, in which the frequency of resonance of the said first inductance-capacitance network is so chosen that the peak-to-peak charge developed on the capacitance thereof during each interval that the said electron discharge tube is non-conductive exceeds the maximum value of the said operating potential source.

7. In combination, an electrostatically-deflected cathode ray tube, an electron discharge tube including an anode and at least one control electrode, a source of operating potential for said electron discharge tube, a source of synchronizing pulses of predetermined frequency, a circuit for applying said synchronizing pulses to the control electrode of said electron discharge tube to cyclically initiate the conduction of the latter, a resonant network tuned to a frequency which is lower than the recurrence frequency of the said synchronizing pulses, means for connecting said resonant network in the anode circuit of said electron discharge tube so that the energy cyclically developed in said network is of substantially sawtooth waveform and has a peak-to-peak value which exceeds the voltage of the said operating

potential source, means for deriving from the energy thus developed in said network a further energy variation which is of symmetrical waveform with respect to the said first energy variation but substantially opposite in phase thereto, and means for respectively applying the two energy variations thus developed to one set of deflecting plates in said cathode ray tube.

WILLIAM A. STEWART.

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