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2,460,601

CATHODE-RAY TUBE DEFLECTING SYSTEM

Filed Jan. 18, 1945

2 Sheets-Sheet 1

Fig. 3.

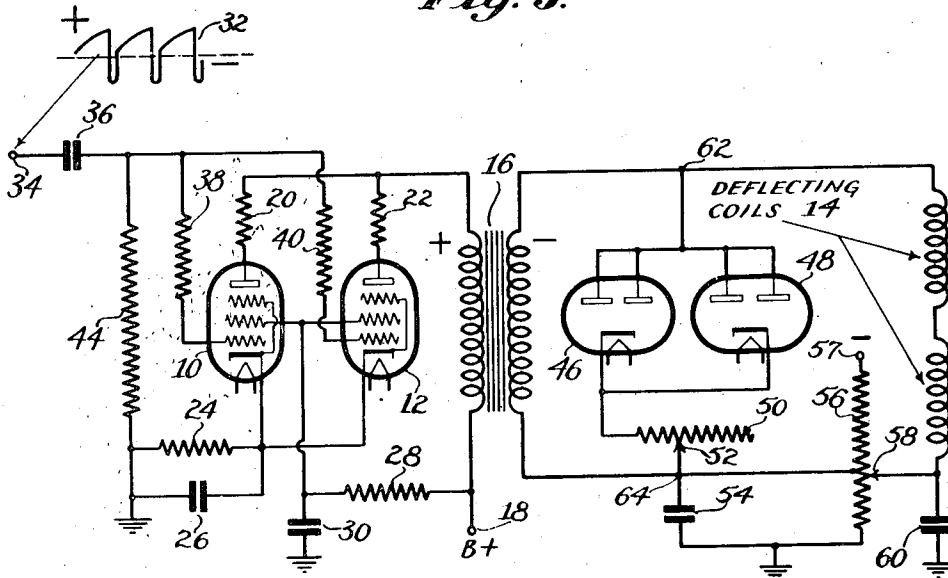
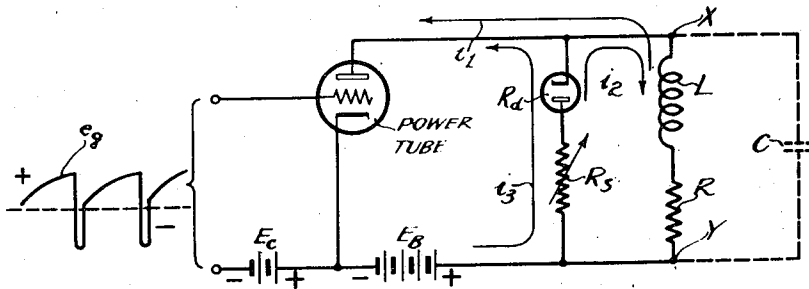


Fig. 1.



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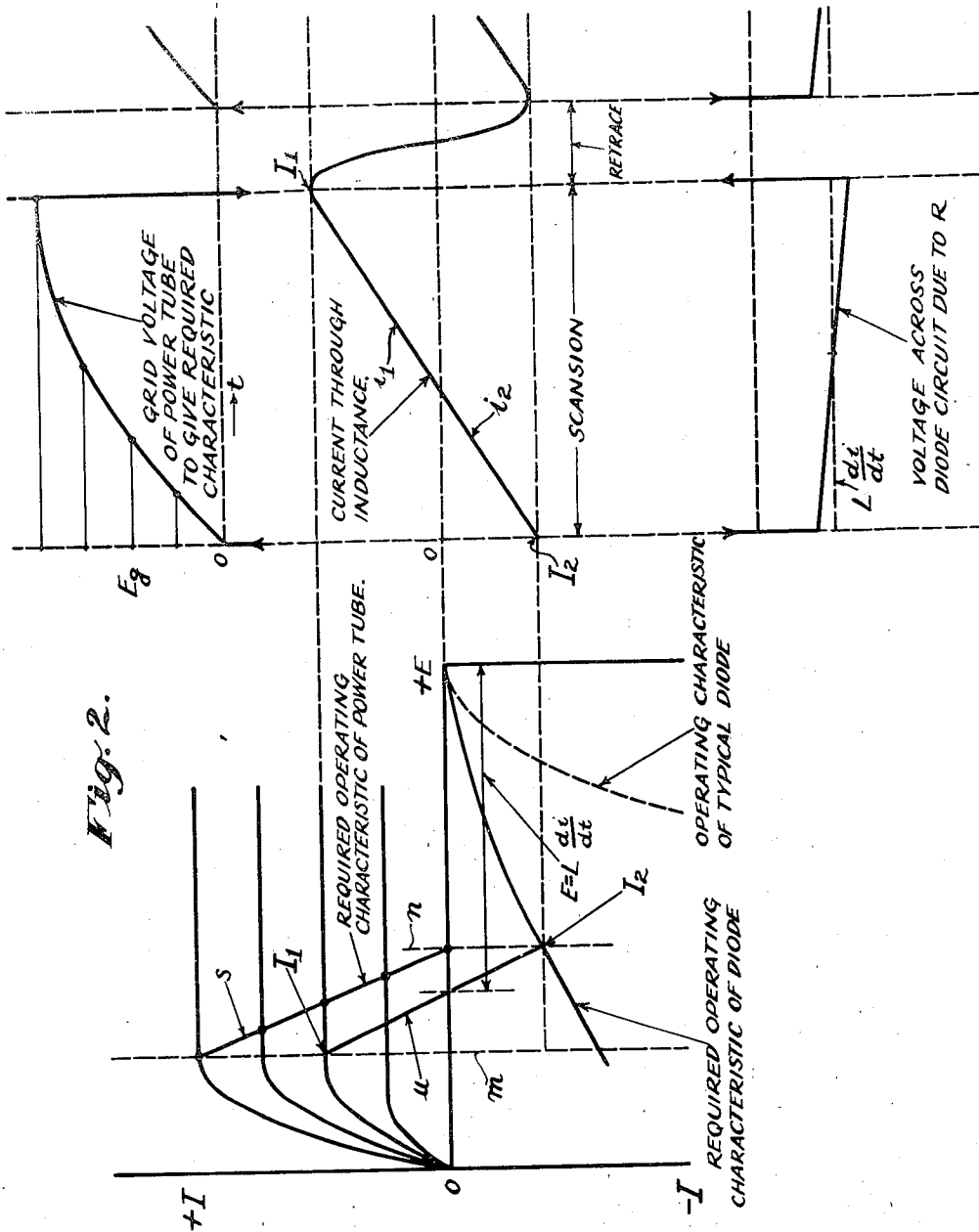
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2 Sheets-Sheet 2

Fig. 2.



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CATHODE-RAY TUBE DEFLECTING SYSTEM

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Application January 18, 1945, Serial No. 573,437

4 Claims. (Cl. 175-335)

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The present invention relates to circuits for generating non-sinusoidal oscillations such for example as those adapted to produce periodic deflection of the beam of a cathode ray tube.

The wave form of the current flowing through the deflecting coils of a cathode ray tube determines the manner in which the cathode ray beam is deflected. If the wave form of the current is linear during a portion of each cycle, as is the case for example when the current wave is of sawtooth configuration, then the deflection of the cathode ray beam during this interval of linearity of current flow will be at a constant rate with respect to time.

It is especially important that the wave form of current flow through the cathode ray beam deflecting coils be linear during a portion of each cycle in systems where this linear current flow is utilized for the time-base deflection of a cathode ray beam in any electronic device used for television or oscillographic purposes. In television receivers, for example, where reconstitution of a line of the transmitted image occurs during the linear motion of the beam, any departure of the wave form of the current flowing through the deflecting coils from linearity during this interval of reconstitution will affect the rate of motion of the beam and hence result in distortion of the reproduced image.

A number of circuits have been developed for the purpose of obtaining linearity of current flow through deflecting coils or other inductance elements. One of the circuits, which is especially adapted for use in television transmitters and receivers, employs a power tube connected to the beam deflecting coils of a cathode ray tube through a coupling transformer. Across the secondary of the coupling transformer a controlled suppressor tube is connected, the purpose of which tube is to damp out parasitic oscillations and also to regulate the rate of current decrease in the secondary circuit. When so regulated, the current in the secondary circuit supplements the current flowing in the primary circuit to a linear summation characteristic, this linear summation current being that which actually flows through the deflecting coils to produce linear deflection of the cathode ray beam.

A circuit operating on the above principles is described and claimed in co-pending Schade application Serial No. 572,712, filed January 13, 1945. One feature of this co-pending application is the provision of means to shape the voltage variations appearing on the control electrode of the suppressor tube so that the wave form of these variations will be such as to produce a

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current flow through the suppressor tube which varies in a predetermined manner.

Circuits such as the above which include a controlled suppressor tube are generally efficient and give good linearity of current flow when the wave form of the voltage variations applied to the control electrode of the suppressor tube is correctly determined. However, they require the use of a suppressor tube containing at least one control electrode and, in addition, necessitate the inclusion in the circuit of means for deriving the voltage variations to be applied to this control electrode. The above factors are a disadvantage in the manufacture of television equipment in the lower price ranges where production costs must be held to a minimum.

The simplest circuit which includes a suppressor or damping tube, and the circuit which is consequently the lowest in cost, is the one employing a diode connected both across the secondary winding of the coupling transformer and across the deflecting coils. A circuit of this nature not only uses less expensive tubes but, in addition, since the diode is not externally controlled, eliminates the circuit elements which in the controlled suppressor tube circuit are required to derive the voltage variations to be applied to the control electrode of the suppressor tube.

Systems of the type last described employing "damping diodes" are well known. The principal reason why the "damping diode" type of scanning circuit has been superseded to a large extent by the "controlled suppressor tube" form of circuit, even in view of the increased complexity and cost of the latter, is that the "damping diode" arrangement is always less efficient and in addition has not, in practical operation, produced an output which is sufficiently linear for quality reproduction of images.

While the non-linearity of output from the "damping diode" type of scanning circuit is recognized, the reason for this non-linearity has not been appreciated. Applicant has discovered the reasons for this non-linear output, and by means of the present invention corrects these defects so that the "damping diode" circuit will produce current variations through an inductive member such as a cathode ray beam deflecting coil which are linear with respect to time.

One object of the present invention, therefore, is to provide a simple and relatively inexpensive circuit for producing through an inductance element, such as a cathode ray beam deflecting coil, a cyclically varying current a portion of each cycle of which varies linearly with time.

A further object of the invention is to provide

a cathode ray beam deflecting circuit of the type utilizing a so-called "damping diode" in which linearity of current output is obtained.

A still further object of the invention is to provide a cathode ray beam deflecting system of the type utilizing a so-called "damping diode," in which the resistance of the diode circuit as it appears across the beam deflecting means may be adjusted to a certain particular value to give linearity and also to permit compensation for changes in the constants of the diode itself due to aging, replacement, or other reasons.

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

Fig. 1 shows schematically a circuit arrangement illustrating the principle involved in the present invention;

Fig. 2 is a set of curves illustrating the operation of the circuit of Fig. 1; and

Fig. 3 shows schematically a commercially practical circuit based on the principle illustrated in the circuit arrangement of Fig. 1.

Referring now to Fig. 1, there is shown a power tube having at least an anode, a cathode, and a control electrode. The anode of the power tube is connected to one end of an inductance element L, which may comprise a cathode ray beam deflecting coil. Inductance L has inherent resistance R and distributed capacity C, these being shown in the drawing as separate elements to facilitate the following description. Capacity C forms with the inductance L the equivalent of a tuned circuit, which will, under proper operating conditions, produce oscillations as is well known in the art. The inherent resistance R of the inductance L, which as above stated has been shown for purposes of illustration as a separate element, has one end connected to the inductance L and its other end connected to the cathode of the power tube through a battery or other source of potential E_b having the polarity indicated. A biasing battery or other source of potential E_c with its positive terminal connected to the cathode of the power tube is provided to maintain a proper operating potential on the control electrode of the power tube.

Across the inductance L and its inherent resistance R, or in other words between points x and y, is connected a diode circuit including a diode having an internal resistance R_d and an adjustable series resistor of value R_s . The diode is inverted as shown so that its cathode is connected to the anode of the power tube. The current flow i_1 indicated by the arrow in Fig. 1 represents the current flow due to the power tube, while the current flow i_2 represents the current flow through the diode circuit, the currents i_1 and i_2 flowing in opposite directions through the inductance L.

When a varying voltage such as that indicated by the wave form e_g is applied between the cathode and control electrode of the power tube, the circuit of Fig. 1 will operate to produce a cyclically varying current through the inductance L in the manner shown by the curves of Fig. 2. The upper part of the left hand diagram of Fig. 2 illustrates the control-bias family of current-voltage curves of the power tube, while in the lower part of the same diagram there is illustrated by the broken line the current-voltage curve of a typical diode. It will now be shown that a diode having a current-voltage characteristic as shown by this broken line can not

be employed to produce linearity of current flow through the inductance L unless the characteristics of the diode circuit appearing between points x and y in Fig. 1 are altered in the manner disclosed by the present invention.

As illustrated in the middle right-hand diagram of Fig. 2, the desired linear current flow through the inductance L during scan is the sum of the current component output i_1 of the power tube, which varies between zero and a peak value I_1 , and the current flow i_2 through the diode, which varies between zero and a peak value I_2 . The peak-to-peak current through L is therefore equal to $I_1 + I_2$. In ideal circuits $I_1 = I_2$, but I_2 is always less in practice due to circuit losses.

The linear rate of change of current flow through inductance L will produce a voltage between points x and y which is substantially constant with respect to time, as shown by the broken line in the lower right-hand diagram of Fig. 2, this voltage being equal to the inductance L multiplied by the rate of change of current

$$\frac{di}{dt}$$

However, due to the resistance R, which is the effective resistance of the tuned circuit LC, the voltage curve is not horizontal, but instead has a slope such as indicated by the solid line in the same diagram.

The effect of this change in voltage across the diode circuit due to the resistance R is shown in the left-hand diagram of Fig. 2, the levels of the peak currents I_1 and I_2 being projected across the figure from the middle right-hand diagram illustrating the current flow through inductance L.

If, as above brought out, the resistance R were of negligible value, then the voltage variation between points x and y in Fig. 1 during scan would be substantially zero, the actual voltage being equal to

$$L \frac{di}{dt}$$

a constant. The current line u of Fig. 2 would then be vertical, crossing the voltage coordinate E of the diagram when $I_1 = I_2 = 0$ at a point determined by

$$E = L \frac{di}{dt}$$

This current line u would extend vertically between points I_1 and I_2 , or in other words between the respective peak values of currents i_1 and i_2 .

As shown in the lower right-hand diagram of Fig. 2, however, the voltage across the diode circuit, or in other words between points x and y, is not constant during scan. For that reason the current line u of the left-hand diagram is not vertical, but instead has a slope determined by the voltage variation occurring as the current varies from zero to its peak value. The slope of the current line u is such that the line approaches the horizontal as the resistance R increases, since this increases the maximum voltage displacement as shown in the diagram on either side of the voltage point determined by

$$L \frac{di}{dt}$$

It will be clearly appreciated that in order to obtain a peak diode current I_2 at the voltage indicated, the diode must have an operating characteristic which passes through this point of peak current I_2 .

A diode which is chosen arbitrarily without regard to the above analysis will have an operating characteristic which passes through the point I_2 only by accident, and even should a diode be selected by experimentation which has the required current-voltage output, changes in the constants of the diode due to aging or other reasons will cause the operation of the tube to vary so that the current-voltage relations necessary in order that the curve pass through point I_2 will no longer prevail. In Fig. 2 for example, the operating characteristic of a typical diode as shown by the broken line does not pass through the point I_2 .

Assuming that a diode has been selected which has an operating characteristic such as shown by the broken line in the left-hand diagram of Fig. 2, then by the insertion of a particular value of unbypassed resistance in the diode circuit, an operating characteristic for this same diode may be obtained such as indicated by the solid line in Fig. 2, this solid line passing through the point I_2 as required. The particular value necessary for this resistance may be calculated from the following formula:

$$R' = R_s + R_d = \frac{L \frac{di}{dt} - I_2 R}{I_2}$$

where

R' = the resistance of the diode circuit appearing between points x and y in Fig. 1.

R_s = the external series resistance in the diode circuit indicated by R_s in Fig. 1.

R_d = the internal resistance of the diode.

L = the effective inductance of the tuned circuit.

$\frac{di}{dt}$ = the rate of change of current flowing through L .

I_2 = the peak current flow through the diode.

R = the effective resistance of the tuned circuit.

Although the value of I_2 in the above formula is not known, it may be obtained from the following equation:

$$I_2 = I_1 e^{-\frac{\pi}{2Q}}$$

where

I_1 = the positive peak current in L due to the power tube.

e = the logarithmic base, equal to 2.71828,

$$Q = \frac{2\pi f L}{R}$$

and also from the equation previously given:

$$I_1 + I_2 = \text{peak to peak current through } L.$$

When the total resistance R' of the diode circuit is obtained from the above formulas, it is only necessary to subtract therefrom the internal resistance R_d of the diode to obtain the required external resistance R_s which it is necessary to insert in series with the diode resistance R_d in order to obtain the entire diode circuit resistance R' .

When the resistance of the diode circuit appearing between points x and y in Fig. 1 has been correctly determined by a proper selection of resistance R_s , the characteristic curve of the diode will be as shown by the solid line in Fig. 2, and will pass through the point I_2 representing the peak current through the diode. The actual current flow through the diode is indicated by that portion of the characteristic curve lying between the limits identified by the vertical boundary lines m and n in Fig. 2, these boundary

lines m and n also enclosing the line u representing the current flow through the inductance L .

For a diode current flow such as shown by the portion of the diode operating curve lying between the boundaries m and n , there is only one characteristic curve of power tube output that will produce linearity of current flow through the inductance L under the circuit conditions as set forth in the curves of Fig. 2. The manner of deriving the operating characteristic of the power tube will now be described.

Since the power tube is the fundamental source of all the current flowing through the inductance L , the power tube must furnish not only the current i_1 which flows in the inductance L during the latter part of the scanning interval, as shown in the middle right-hand diagram of Fig. 2, but must also furnish a current i_2 to back out the rising diode current flowing through the diode circuit in the first part of the scanning period, as a rising diode voltage is required in order to obtain current linearity.

Referring again to the left-hand diagram of Fig. 2, the total power tube current must therefore be the sum of the current actually flowing through the inductance L , as represented by the line u , and the reverse current i_2 flowing through the diode during the first part of the scanning interval, and which is represented by that part of the diode characteristic curve lying between the limits m and n . When these two currents are added together, the resulting curve s is that which represents the total current which is furnished by the power tube. Looking at the above from a different viewpoint, the inductance current may be said to be the summation of the power tube current and the diode current, the former being positive and the latter negative.

It will be clear that for a certain wave form of diode current there will be only one wave form of power tube current that can be added thereto to provide a linear flow of current through the inductance (assuming fixed constants of L and R). By varying the external diode circuit resistance R_s , the characteristic curve of the diode may, in most practical cases, be altered so as to pass through point I_2 regardless of the location of such point on the current-voltage graph of the diode, and thus provide for a diode current flow which, when added to a power tube current output determined in accordance therewith, will produce linearity of current flow through the inductance L .

The output current curve s of the power tube as shown in the left-hand diagram of Fig. 2 cuts across the control-bias family of current-voltage curves for the power tube. If each point of intersection between these control-bias current-voltage curves and the required operating characteristic s is plotted separately as shown in the upper right-hand diagram of Fig. 2, a curve may be obtained showing the voltage variations which must be applied to the control electrode of the power tube in order that a current output therefrom as represented by the characteristic s may result.

Fig. 3 shows one form of commercially practical circuit which may be employed to carry out the principle of the invention described in Figs. 1 and 2. In Fig. 3 is shown a pair of power tubes 10 and 12 for supplying current to a pair of deflecting coils 14 through a coupling transformer 16. Each of tubes 10 and 12 may be of a type such as the RCA 807 and includes at least a cathode, a

control electrode, a screen electrode, and an anode.

The anodes of tubes 10 and 12 are each connected to the positive terminal 18 of a source of potential (not shown) through the primary winding of coupling transformer 16. Between such primary winding and the anode of tube 10 is connected an oscillation suppressor resistor 20, and a similar oscillation suppressor resistor 22 is connected between the primary winding of transformer 16 and the anode of tube 12.

The cathodes of tubes 10 and 12 are each connected to ground through a common biasing resistor 24 across which is shunted a by-pass condenser 26. A proper operating potential for the inter-connected screen electrodes of tubes 10 and 12 is obtained by means of a screen dropping resistor 28 connected between the screen electrodes of tubes 10 and 12 and the positive terminal 18 of the potential source. A screen by-pass condenser 30 is provided between the screen electrodes of tubes 10 and 12 and ground.

When voltage variations, such for example as those indicated by the wave form 32 in Fig. 3 and as shown in the upper right-hand diagram of Fig. 2, appear at the terminal 34, these voltage variations will be applied to the control electrode of tube 10 by way of coupling condenser 36 and suppressor resistor 38, and also to the control electrode of tube 12 by way of coupling condenser 36 and suppressor resistor 40. A grid leak resistor 44 is connected between coupling condenser 36 and ground.

The voltage variations applied in this manner to the control electrodes of tubes 10 and 12 produce nearly linear current variations in the primary winding of transformer 16, and these current variations induce corresponding currents in the transformer secondary. The secondary winding of transformer 16 is wound in a direction opposite to that of the primary winding, so that the adjacent ends of these two windings in the drawing will be of opposite polarity as indicated. A transformer of the nature set forth herein is described and claimed in co-pending Schade application Serial No. 572,712 above referred to.

A pair of duplex diodes 46 and 48 are connected in parallel across the secondary winding of transformer 16, except that between the joined twin cathodes of diodes 46 and 48 and the lower or A.-C. ground potential end of the transformer secondary winding is connected an adjustable resistor which, in the circuit shown, comprises a potentiometer 50 having a sliding contact 52. Contact 52 is connected to ground through a by-pass condenser 54.

Each of the duplex diodes 46 and 48 may be of any suitable type, such for example as an RCA 5V4-G. As illustrated, each duplex diode is formed with twin anodes connected together and to the upper end (in the drawing) of the secondary winding of transformer 16.

Sliding contact 52 of potentiometer 50 is also connected to a tap on a further potentiometer 56, the ends of this potentiometer 56 being connected respectively to ground and to a negative tap 57 on the source of potential (not shown) which has its positive terminal indicated by the reference numeral 18. A sliding contact 58 on potentiometer 56 is connected to the lower end of deflecting coils 14 and also to ground through a by-pass condenser 60. Adjustment of sliding contact 58 controls the centering of the cathode ray beam by regulating the amount of direct current flowing through the deflecting coils 14.

As hereinbefore stated, the resistance of the diodes 46 and 48 appearing across the secondary winding of transformer 16, or, in other words, between points 62 and 64, is critical. Since the critical character of this diode circuit resistance was not previously appreciated, no way is provided in conventional circuits by which the diode resistance as it appears between points 62 and 64 may be varied, the anodes and cathodes of the diodes in these conventional circuits being respectively directly connected to the ends of the secondary winding of the coupling transformer.

The present invention provides means by which the resistance of the diode circuit appearing between points 62 and 64 may be adjusted to control the current flow through the diodes 46 and 48 so that it will bear a particular relation to the current output of the power tubes 10 and 12. This means comprises the potentiometer 50 connected between the cathodes of diodes 46 and 48 and the lower end of the secondary winding of transformer 16. It will be noted that potentiometer 50 is not by-passed by a condenser. When it is desired to obtain a certain particular resistance for the diode circuit between points 62 and 64 so that the current flow through the diodes will be such as to produce linearity of current flow through the deflecting coils when added to the current output of the power tubes, the position of the sliding contact 52 is altered so as to vary the value of the potentiometer resistance introduced between point 64 and the cathodes of diodes 46 and 48. The linear current flow thus produced through the deflecting coils results in linearity of deflection of the cathode ray beam.

It will be observed that the potentiometer 50 not only provides means for obtaining the correct resistance for the diode circuit which bears a direct relation to the wave form of the voltage variations appearing at input terminal 34, but also permits correction of any change in the resistance of the transformer secondary or the deflecting coils 14 as developed between points 62 and 64. By means of the present invention, therefore, a desired operating characteristic for the deflecting system may be selected, and this characteristic thereafter maintained regardless of any resistance changes which may occur in the various components thereof.

The following values have been found in practice to be suitable for certain elements used in the disclosed system. However, they are being given merely as an example, and other values may be substituted for any or all of those given as may seem desirable or necessary:

Condensers

36=.01 mf.
26=20 mf.
30=8 mf.
54, 60=100 mf.

Resistors

44=250,000 ohms
38, 40=100 ohms
20, 22=50 ohms
24=100 ohms
28=1,700 ohms (approximately)

Value should be such that screen dissipation of power tubes 10 and 12 will not be exceeded.

56=5 to 10 ohms

50=depends on design of deflecting coils 14 and transformer 16. Typical values range from 50 to 200 ohms.

While I have illustrated and described, and have

pointed out in the annexed claims, certain novel features of my invention, it will be understood that various omissions, substitutions and changes in the form and details of the system illustrated may be made by those skilled in the art without departing from the spirit of the invention.

I claim:

1. In a circuit arrangement of the type in which cyclically varying current having a wave form a portion of each cycle of which is linear with respect to time is caused to flow through an inductive member having distributed capacity, the combination of a rectifier circuit connected across said inductive member, said rectifier circuit including an unby-passed resistance element and a unilaterally conducting device in series, and means for adjusting the value of said resistance element to change the resistance of said rectifier circuit as it appears across said inductive member to thereby maintain the linearity of said wave form portion.

2. In a circuit arrangement for developing current variations of substantially sawtooth wave form through a wound inductive element, the combination of an electron discharge tube having at least a cathode, an anode, and a control electrode, a transformer having its primary winding in the anode-cathode circuit of said electron discharge tube and its secondary winding connected across said inductive element, means for supplying voltage variations between the cathode and control electrode of said electron discharge tube, a two-element rectifier, means connecting one element of said rectifier to one end of the secondary winding of said transformer, an unby-passed adjustable resistance, and means connecting the other element of said rectifier to the remaining end of the secondary winding of said transformer through said adjustable resistance, the said connections being such that polarities on the electron discharge tube and rectifier are in the conductive directions thereof during the long

slope of the sawtooth wave, whereby upon adjustment of said resistance the effective impedance of said rectifier may be varied to bring about substantial linearity of current flow through said inductive element.

3. In a television circuit of the type in which a cyclically varying current having a wave form a portion of each cycle of which is linear with respect to time is caused to flow through an inductive member, the combination with such an inductive member of a grid-controlled power tube connected to supply unidirectional current thereto, and a rectifier damping circuit comprising a diode and an unby-passed resistor connected in series across said inductive member, said resistor being adjustable to adjust the impedance of said rectifier circuit and thereby to adjust the linearity of said wave-form portion in accordance with the characteristic curves of said power tube and diode.

4. In a beam deflecting system, a deflection coil and a damping circuit, the latter comprising a diode and only a resistance connected in series across said coil; said damping circuit and coil forming a resonant circuit the capacity across which is solely the distributed capacity present in said circuit.

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