Jan. 18, 1949. K. SCHLESINGER 2,459,187

DEFLECTION CIRCUIT FOR CATHODE-RAY TUBES

Filed Oct. 1, 1946 2 Sheets-Sheet 1

Fig. 1

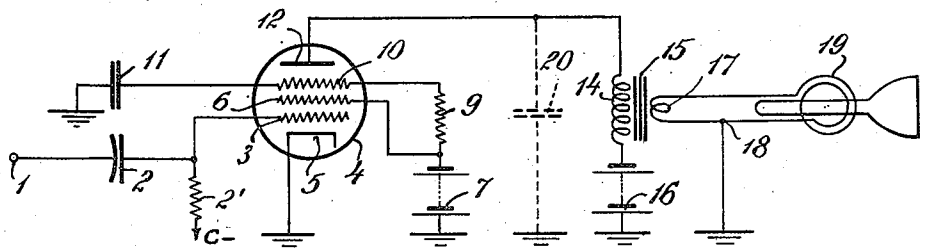


Fig. 2,

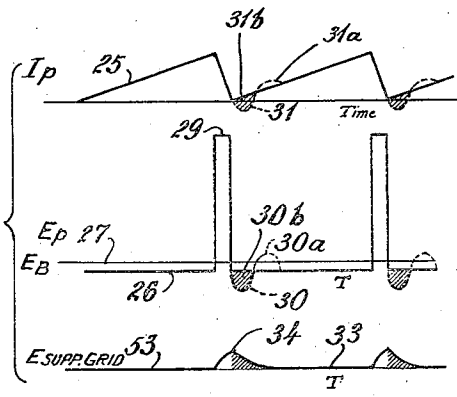


Fig. 3,

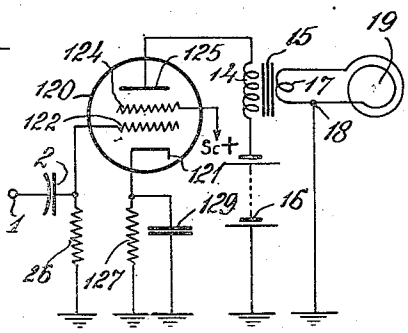


Fig. 4,

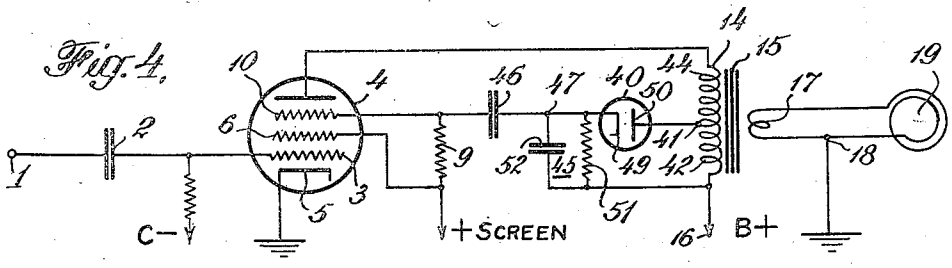
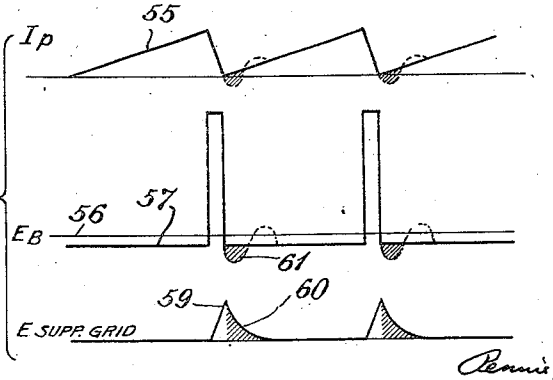


Fig. 5,



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Filed Oct. 1, 1946 2 Sheets-Sheet 2

Fig. 6,

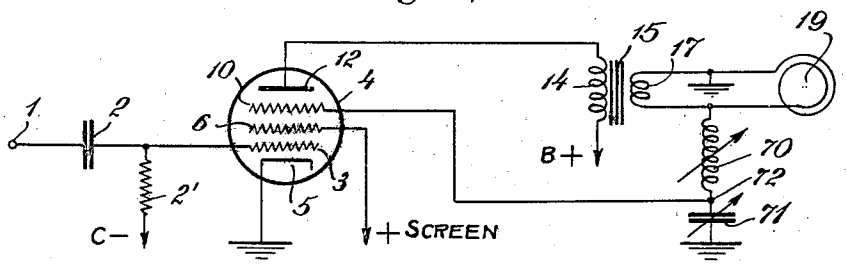


Fig. 7,

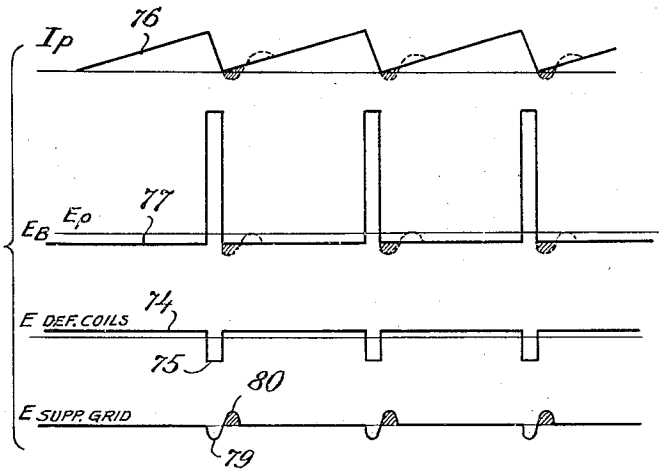
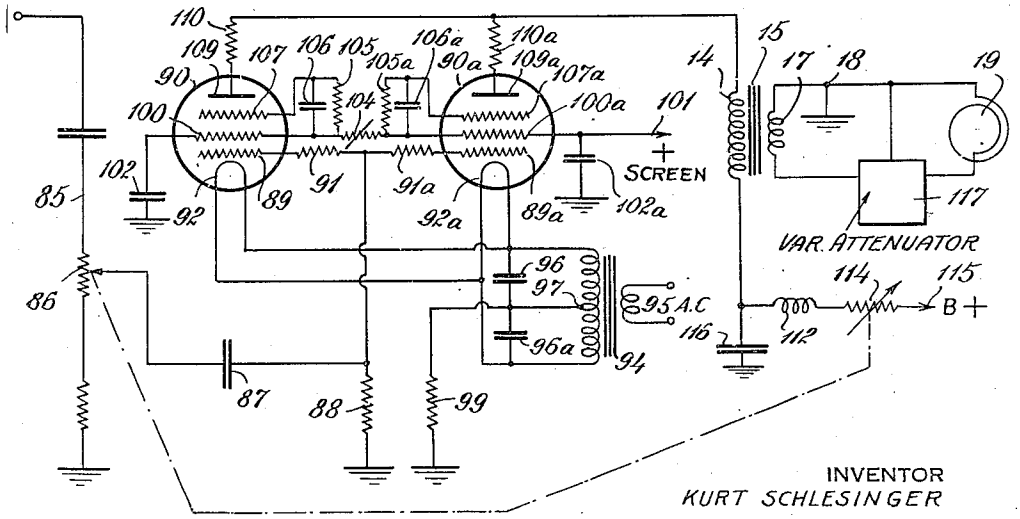


Fig. 8.



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DEFLECTION CIRCUIT FOR CATHODE-RAY TUBES

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Application October 1, 1946, Serial No. 700,495

28 Claims. (Cl. 315—27)

1

This invention relates to deflection circuits for cathode-ray tubes, especially to such circuits used in television transmitters and receivers. It is particularly concerned with the elimination of transient oscillations due to energy stored in the magnetic fields associated with a cathode-ray tube during the periods of sweep deflection, and released with relatively great rapidity during the collapse of those fields in the subsequent retrace periods.

Modern television systems commonly use cathode-ray tubes at transmitter and receiver for scanning and reproducing an object field. Deflection means are provided for horizontal line scanning at a relatively high frequency and vertical field scanning at a relatively low frequency. Although electrostatic deflection is sometimes employed, electromagnetic deflection now predominates. Examples are the Farnsworth image dissector tube and most receiver tubes, including both direct view and projection types.

In horizontal deflection circuits particularly, due to the high scanning frequencies involved, a considerable amount of power is required to produce the necessary deflection. This is especially true of color television systems where the line scanning frequency is usually higher than in black-and-white systems. The current practice in receiver tubes of utilizing increased accelerating potentials and wide angle beam deflection still further increases the power required for deflection.

Despite the high line frequencies involved, it is still necessary to keep the retrace time of the beam to a minimum, for efficiency. The time of the retrace is of the order of ten percent that of the sweep. Due to the rapid retrace and high power involved, a serious problem exists in the prevention of transient oscillations in electromagnetic deflection circuits.

During the sweep the deflecting current increases substantially linearly to the maximum value at the end of the sweep. At this time the energy in the electromagnetic deflecting field is a maximum. At the end of the sweep, the current reverses and decreases to effect the retrace of the electron beam to its initial starting position. In order to obtain the rapid flyback required for present-day high frequency line deflection circuits, it is undesirable to load the deflection circuit during the retrace or flyback period, since loading decreases the speed of retrace. Hence, at the end of the retrace a considerable amount of the energy stored in the electromagnetic field at the end of the previous sweep

2

remains undissipated. In addition to the inductance present in the deflecting coils and the commonly used deflection transformer, there is always present a certain amount of distributed capacitance. When a deflection transformer is used, most of the inductance and distributed capacitance is in the transformer. The combination of inductance and capacitance forms a resonant circuit so that transient oscillations are likely to be set up until the energy in the circuit is dissipated. These oscillations interfere with the linearity of the sweep and hence must be eliminated.

A number of methods have been proposed to absorb the energy of the electromagnetic field so as to prevent transient oscillations. Certain known methods provide a load which is effective during the retrace interval to absorb the energy and thus eliminate transient oscillations. Such methods have the defect that they slow down the retrace as above mentioned. It has also been proposed to employ diodes, with or without associated resistances, which become conductive immediately following the retrace to absorb quickly the energy remaining in the circuit and hence prevent oscillations. These latter methods avoid slowing down the retrace, but require the quick dissipation of a considerable amount of energy. With the higher powers employed in the deflecting fields at the present time, the problem of quick dissipation with such conventional circuits is troublesome. Furthermore, during the retrace high voltages are induced in the deflection circuit, particularly across the transformer primary and secondary, which are commonly many times the voltages present during the sweep. Hence, very severe problems of insulation of the energy absorbing components arise.

The present invention is designed to effectively eliminate transient oscillations during the sweep while avoiding the disadvantages and limitations of previously known circuits, some of which have been pointed out above. Instead of employing additional circuit components, the required damping is effected by means of the output tube or tubes supplying the deflection currents to the deflecting coil. To do this, emission currents are caused to flow in the output tube or tubes to provide a relatively low impedance damping circuit to dissipate or absorb the energy contained in the electromagnetic field at the end of the sweeps. The invention particularly contemplates causing secondary emission currents to flow from the anode of the output tube (or tubes) immediately after retrace to quickly absorb the energy without undesirably slowing down the retrace.

Secondary emission in ordinary vacuum tubes, such as tetrodes and pentodes, is a phenomenon which is commonly to be avoided. In a tetrode, for example, when the anode or plate potential drops substantially below the potential of the screen grid, secondary emission from plate to screen grid occurs and diminishes the power output of the tube. Hence, in circuits employing the tetrode care is usually taken not to permit the plate potential to drop substantially below that of the screen grid. It is for this reason that the pentode was developed with an additional suppressor grid, usually held at cathode potential, to repel secondary electrons emitted from the plate and hence prevent the flow of secondary emission currents from plate to screen grid. Also, beam forming electrodes have been used in tetrodes of the type known as "beam tetrodes" or "beam power tubes," which prevent secondary electron currents by a concentrated negative space charge between screen grid and anode.

In accordance with the present invention, secondary emission currents are allowed to flow during the interval immediately following the retrace so as to provide a path of relatively low resistance and quickly absorb the energy remaining in the deflection circuit. The flow of secondary emission currents in effect loads the deflection circuit during the interval immediately following the retrace. Since the secondary emission currents do not flow during the retrace itself, the deflection circuit is not loaded at this time and the retrace can take place quickly.

A tetrode may be employed in the present invention by applying an appropriate potential to the screen grid to promote the flow of secondary electrons immediately following the retrace. However, it is preferred at the present time to employ a pentode and apply appropriate potentials to the suppressor grid. The bias potentials applied to the screen or suppressor grids, or both, may be fixed and are advantageously selected so that after the energy resulting from the magnetic field is absorbed, further secondary emission is minimized. It is also possible, in accordance with the invention, to apply a variable bias to one or more of the electrodes, for example, to the suppressor grid of a pentode, which promotes the flow of secondary emission currents immediately following the retrace and is then reduced for the remainder of the sweep to minimize further flow of secondary emission currents.

A number of specific embodiments are given hereinafter to illustrate the application of the invention. Specific advantages of certain embodiments will in part be pointed out and in part be understood by those in the art.

In the drawings:

Fig. 1 is a schematic circuit diagram illustrating one embodiment of the invention;

Fig. 2 shows in graphic form explanatory voltage and current relations occurring in various parts of the circuit of Fig. 1;

Fig. 3 is a schematic diagram of another embodiment of the invention employing a tetrode;

Fig. 4 is a schematic circuit diagram illustrating another form of the invention using a varying suppressor grid bias;

Fig. 5 is a graphic representation of explanatory voltage and current relations in the circuit of Fig. 4;

Fig. 6 is a schematic circuit diagram illustrating a different embodiment of the invention employing a resonant circuit to apply a varying suppressor grid bias;

Fig. 7 is a graph showing explanatory relations in the circuit of Fig. 6; and

Fig. 8 is a circuit diagram showing a detailed circuit for use in supplying deflection currents.

In Fig. 1, a schematic circuit is illustrated for supplying sawtooth deflection currents to the usual electro-magnetic deflecting coils of a cathode-ray tube in a television system. A sawtooth wave applied at terminal 1 from a suitable source, not shown, is passed through a coupling condenser 2 and resistor 2' to the control grid 3 of a pentode 4. Suitable grid bias is obtained from a C— supply. Pentode 4 may have a cathode 5 of any satisfactory type but is illustrated as being of the heater type with the heating coils omitted for clarity. Screen grid 6 has applied thereto a positive bias by battery 7 or an equivalent source of steady potential. The screen grid bias potential is applied through a dropping resistor 9 to suppressor grid 10, which is shunted to ground through a capacitance 11. Thus, instead of operating as a normal pentode with suppressor at cathode potential, pentode 4 acts more like a tetrode.

The anode 12 is connected through primary winding 14 of a deflection current transformer 15 to a positive or B+ source of power 16. The secondary 17 of the deflection current transformer 15 is connected to the usual horizontal deflecting coils 19 of a cathode-ray tube. Vertical deflection coils and an associated circuit will be understood to be employed, although not illustrated for simplicity.

The closed circuit formed by secondary 17 and coils 19 is grounded conventionally at 18. The distributed capacity of the transformer primary, output capacitance of tube 4, wiring capacitance, etc., is represented by the dotted-line showing of capacitance 20. This distributed capacitance, together with the inductance of the transformer, forms a resonant circuit in which oscillations would be built up by currents induced during the rapid collapse of the fields surrounding deflection coils 19, were it not for the corrective measures described below.

During the sweep period, the current through tube 4, transformer 15, and deflection coils 19 increases substantially linearly to produce a linear line sweep. The induced voltage across primary 14 opposes the B+ supply so that the potential of anode or plate 12 is below that of source 16. During the retrace, current reverses in the secondary circuit to return the scanning beam quickly to its initial position. Due to this reversal, and also the fact that retrace takes place in a fraction of the sweep interval, a high positive voltage is induced in primary 14 and anode 12 is driven highly positive, usually of the order of thousands of volts.

Immediately following the retrace, the linear sweep should begin and anode 12 should resume its normal potential during the sweep period, which is below that of supply 16 as above mentioned. However, in the absence of sufficient damping, transient oscillations would occur due to the non-dissipation of the energy in the magnetic field at the end of the previous sweep. Such transients induce a voltage in primary 14 which varies the voltage of anode 12 below and then above its normal potential during the sweep period. This varying transient voltage decreases as the magnetic energy is dissipated.

In Fig. 1, instead of maintaining suppressor grid 10 at cathode potential to prevent secondary emission flow from the anode 12, the grid 10

is maintained at a positive potential which is selected to allow the flow of secondary emission current from the anode immediately following the retrace, thus providing a path of relatively low impedance to quickly dissipate the energy remaining in the deflecting circuit and thus avoid transient oscillation.

The effect is illustrated graphically in Fig. 2, in which, plotted against time, 25 represents a sawtooth current wave flowing through tube 4 and transformer primary 14, and 26 represents the potential at anode 12. Under normal operation, with the plate resistance of tube 4 large compared with the input impedance of transformer 15, the anode current through tube 4 will be approximately proportional to the voltage on control grid 3. Also, the deflecting current through secondary 17 and coil 19 will be similar to that in primary 14. Therefore curve 25 may be considered to represent grid voltage and deflecting current as well as anode current, except for the undesired oscillatory effects to be dealt with below. If desired, of course, the grid voltage wave might be peaked to insure cutoff of the tube during retrace.

The potential 26 at anode 12 will be smaller during sweep than the potential 27 (E_B) at the anode power source 18 by virtue of the drop through primary 14. During retrace, the rapid decrease of current in coils 19 induces a high positive potential, proportionally multiplied by transformer 15, at the anode. This increased potential at the anode is illustrated at 29 in Fig. 2.

At the end of the retrace, the potential at anode 12 will drop abruptly and, due to the undissipated energy remaining in the deflection coil circuit, will tend to drop to a value less than the average during trace, as indicated at 30. Correspondingly, the anode current would tend to drop below the value it should properly have at the beginning of a pure sawtooth sweep, as shown at 31. Because of the resonant circuit provided as described above by the inductance of the deflection circuit, especially that of primary 14, and the distributed capacitance to ground 20, oscillations would then occur which would continue as indicated by dotted lines of anode potential and current 30*a* and 31*a* until the energy released from the magnetic field of coils 19 was used up. This undesired effect is eliminated in accordance with the present invention by quickly absorbing the released energy by secondary emission from the plate of output tube 4.

To promote the absorption, a positive bias is applied to suppressor grid 10 which may, for example, be of the order of, or greater than, the average value 26 of anode voltage during the trace. Under these conditions, secondary emission will occur as the anode voltage drops below such average value. Usually sufficient power will be abstracted during the first negative half-cycle (shaded at 30*b* and 31*b*) to discourage subsequent oscillations, but if such should occur the secondary emission current would again flow during any subsequent negative half-cycle of the oscillatory period in which the potential at the anode is below the average value during sweep.

The best suppressor grid bias to select is subject to some variation depending upon other circuit conditions and the particular application involved. The inductance and capacitance in the circuit are of primary importance in determining how much damping is required. With too low a bias there will be insufficient damping action and oscillations will occur. With a high bias allowing considerable secondary emission throughout the sweep, power will be lost and efficiency reduced, and insufficient deflection amplitude may result. Biasing to a value which will allow sufficient secondary emission immediately following the retrace to damp out oscillations but will not allow secondary emission to persist for the remainder of the sweep appears attractive. However, in practice it has been found satisfactory to pick a bias somewhat higher than this value so as to insure sufficient damping even though some secondary emission flows during the remainder of the sweep. Care should be taken to avoid burning out the suppressor grid.

In a particular case, where circuit constants are known, it is possible to calculate approximately the damping resistance required to eliminate oscillations. Then measurements may be made on the output tube or tubes to determine the bias conditions under which secondary emission provides a sufficiently low damping resistance. In practice, however, it is often more convenient to select appropriate tubes and increase the positive bias until the transient oscillations disappear.

Since the electric field produced by the screen grid affects that produced by the suppressor grid, the bias of both grids should be determined in view of the above considerations. As shown in Fig. 1, the screen grid will commonly be at a somewhat higher potential. Therefore some, and perhaps a major portion, of the secondary emission current from the plate will flow to the screen grid rather than to the suppressor grid.

Fig. 3 shows a modification employing a tetrode, rather than a pentode. Although the use of a pentode is preferred, the tetrode may be employed if desired, provided such a tube of adequate power dissipation for the purpose is available. Tetrode 120 has a cathode 121, a control grid 122, a screen grid 124, and an anode 125. The high-frequency line deflection sawtooth control wave is applied to grid 122 through the coupling capacitor 2 and grid resistance 126. Cathode bias is obtained by resistance 127 to ground, shunted by capacitance 129. The screen grid 124 is maintained at a suitable positive potential by source SC+. Other circuit elements are similar to those described in Fig. 1.

During sweep, screen grid 124 is maintained positive to anode 125. Hence there will be a substantial amount of secondary emission throughout the sweep, which establishes a shunt circuit across the transformer. By selecting the screen grid bias in accordance with the considerations given above, the resistance of the shunt circuit is made sufficiently low to make the system aperiodic. The anode potential rises immediately on beginning retrace to a value highly positive with respect to the screen grid 124, and so secondary emission will be cut off; this has the effect of reducing the flyback time to a minimum, while utilizing secondary emission again at the beginning of each sweep to absorb power released from the anode circuit and prevent undesired oscillations in the deflection field strength.

Instead of using a constant bias, it is also possible to employ an intermittent bias to obtain the desired secondary emission just after retrace. In such case the intermittent bias may be selected in magnitude and duration to effectively suppress transient oscillations, and can then be decreased for the remainder of the sweep periods to avoid further secondary emission and hence loss of power.

In Fig. 1, such an operation may be obtained by proportioning the resistive and capacitative elements of the suppressor grid circuit so that they have a very short time constant, which will permit the building up of an intermittent pulsating or A.-C. component to add to the steady bias. Thus the suppressor grid by-pass capacitance 11 may be made very small, so that the time constant with resistance 9 will be short. Advantageously it may be made substantially equal to the retrace time and also variable to permit control of sweep linearity. During the latter portion of a sweep, any flow of secondary emission current to the suppressor grid will produce a bias voltage in resistor 9, and the value of resistor 9 may be chosen to keep the secondary emission at a low value. Capacitor 11 is charged to the resultant bias voltage shown at 33 in Fig. 2. At the end of the sweep plate 12 goes highly positive, hence cutting off current to the suppressor grid. Capacitor 11 then charges up further through resistor 9 with a short time constant, and the A.-C. bias builds up toward the potential of source 7, as shown at 34 (Fig. 2). At the end of the flyback, secondary emission takes place and flows to the suppressor grid, thus reducing the charge on capacitor 11 and the suppressor grid bias. This is shown by the shaded portion of 34. In effect, positive voltage pulses are periodically supplied to the suppressor grid to promote secondary emission immediately after retrace. The magnitude and duration of the A.-C. bias need be only sufficient to effect the required damping to prevent oscillations.

Another circuit for developing an intermittent bias is illustrated in Fig. 4. Here a diode 40 is used as a rectifying means through which a biasing potential may be built up across a short time constant circuit. The primary 14 of deflection transformer 15 is divided by a tap 41 into two sections, a first, or bias-developing section 42, and a second section 44. Across the bias-developing section 42 are disposed in series the diode 40 and the shunt resistance capacitance storage network indicated generally as 45. The biasing effect is communicated to the suppressor grid 10 through a coupling condenser 46 connected to a common point 47 between the R-C circuit 45 and the diode 40.

The values of resistor 51 and capacitance 52 in the R-C network 45 are so chosen that the time constant will be very short, and it may be of the order of the retrace period. During the sweep period, it will be apparent that the tap 41 will be at less than the potential of source 16 due to the voltage drop through the transformer section 42, and so diode 40 will be nonconducting. As soon as the retrace begins, however, anode 50 will be driven positive and the diode will pass current to network 45 to charge capacitor 52. Thus a potential will be developed across the circuit 45 which will reach a peak at the end of the retrace. After the next trace begins, it will decay gradually in accordance with the circuit time constant. Due to the extremely high anode voltage during retrace, however, there will be no secondary emission currents in tube 4. At the beginning of the next trace, at which time the anode potential will drop, the bias on the suppressor grid from circuit 45 will be effective to drain power from the anode circuit sufficient to prevent subsequent oscillations.

Example potential relations in the circuit have been illustrated in Fig. 5, with 55 representing a sawtooth current wave in tube 4, 56 the anode

battery potential, and 57 the potential at the anode of tube 4. The biasing potential built up in the network 45 during retrace and applied to suppressor grid 10 is shown at 59; 60 indicates the gradual reduction of that potential after retrace, during which time it is effective in promoting secondary emission; and 61 represents the anode potential variation during this period. The shading emphasizes that portion of the cycle in which power is removed from the circuit.

Another embodiment of the invention contemplates the use of a resonant circuit, instead of a rectifier, to provide the intermittent bias. As illustrated in Fig. 6, a resonant circuit comprising a variable inductance 70 and a variable capacitance 71, is shunted across the closed loop formed by deflection transformer secondary 17 and the deflecting coils 19. The common point 72 between inductance and capacitance is tied directly to the suppressor grid 10.

The resonant circuit is tuned to supply periodic positive voltage pulses immediately after retrace periods. After proper values have been determined, the elements could be made fixed or semi-fixed. For example, the resonant circuit may be tuned so that a half-cycle is approximately equal to the retrace or flyback period.

It will be apparent that a reversed potential of greatly increased magnitude will be developed across the deflecting coils 19, and hence across the resonant circuit, during retrace. The potential drop across deflecting coils 19 is illustrated in Fig. 7 at 74 during sweep and at 75 during retrace, for comparison with the sawtooth current 76 and the varying plate potential 77 of tube 4. This wave 74, 75 is effective across the resonant circuit 70, 71.

If the resonant circuit is tuned as indicated above, a negative potential will be developed thereacross during retrace, which will have the form at the common point 72 shown schematically at 79. As soon as the sweep begins, a corresponding positive half-cycle, indicated at 80, will appear on suppressor grid 10. During the positive swing, secondary emission will occur, accomplishing the desired result. The area under the positive half-cycle 80 in Fig. 7 has been cross-hatched to emphasize the absorption of power during this period.

The circuits thus far described are representative of the means which may be utilized to put into effect the principles of the invention for the suppression of undesired oscillations by damping within the output tube supplying deflection currents.

In Fig. 8 is illustrated a preferred embodiment particularly applicable to television deflection circuits. It has been used successfully for high frequency line deflection in a color television system operating at 31.5 and 37.8 kilocycles. The deflecting wave is received from sawtooth generator, linearization, and voltage amplifier means, not shown, whose output appears across an output circuit, indicated generally as 85. The desired amplitude is obtained from potentiometer 86 in the output circuit 85 and applied through a coupling condenser 87 and grid resistor 88 to the control grids 89 and 89*a* of the parallel connected pentodes 90 and 90*a*. These tubes and their corresponding elements are described hereafter by using the same reference numeral, followed by the letter "*a*" in the case of the second tube, 90*a*. Potentiometer 86 is ganged with an anode potential control, to be described later, in

order to obtain properly coordinated adjustment of the deflection currents and picture size.

Small resistors 91 and 91a are disposed in circuit with each of control grids 89 and 89a respectively to suppress parasitic oscillations. Cathodes 92 and 92a are shown as being energized in parallel from a filament transformer 94 fed by a suitable A.-C. source 95. Filtering capacitors 96 and 96a are disposed across the secondary of transformer 94, which is center-tapped at 97, with a return to ground provided through cathode resistor 99. Screen grids 100 and 100a are biased from a suitable positive bias source 101 by-passed to ground by condensers 102 and 102a. Connection is provided directly between the screen grids through a variable compensating resistor 104.

From each of the screen grids 100, 100a, a dropping resistor 105, 105a, shunted by a by-pass capacitor 106, 106a, respectively, is extended to connect to the corresponding suppressor grid 107 or 107a, providing a positive bias thereon less than that on the screen grids 100. The values of screen grid potential and the dropping resistors are so coordinated that the bias on the suppressor grids 107 will effect the desired secondary emission damping. These considerations have been discussed hereinbefore, particularly in connection with Fig. 1. As actually operated, the joint screen and suppressor grid current dropped to substantially zero during retrace and showed a sharp peak immediately following retrace, thus indicating secondary emission damping.

The anode potential is applied from a suitable power source 115 through the transformer primary 14 to the plates 109, 109a. A variable resistor 114 and R-F choke 112 are in series with source 115, and by-passed to ground by capacitor 116. Small resistors 110, 110a are inserted in the plate circuits of the tubes to suppress parasitic oscillations.

Variable resistor 114 is mechanically linked to the previously described potentiometer 86. Thus continuous control of the amplitude of the deflecting currents, and hence of the picture size, is obtainable by the simultaneous variation of control grid input voltage by potentiometer 86, and of the plate voltage and current by resistor 114.

Primary or approximate deflection size control may be provided by an inductive attenuator 117 of suitable design disposed in circuit between the deflection transformer secondary 17 and the deflecting coils 19. Attenuator 117 is so arranged that the impedance looking in from the output tubes remains constant for any adjustment. The finer adjustment necessary for continuous control is provided as described above.

It will be appreciated that the circuit shown in Fig. 8 is exemplary of the type of operation described in connection with Fig. 1 above, so far as the arrangement for providing the desired bias is concerned. In some cases it may be possible to operate with the dropping resistor of so small a value that the suppressor grid is effectively connected directly to the screen grid, or a tetrode might be used instead of the pentode, as in the embodiment of Fig. 3.

The circuit illustrated in Fig. 8 is equally suited to use with projection type cathode-ray tubes and with tubes of the image dissector type. For such different applications, the power required may be comparable in spite of widely different beam velocities because of the differences in volume enclosed by the deflecting coils. Likewise, different inductances in the deflecting coils require different transformer impedances to match in the two cases.

It will be obvious to those in the art that it may be desirable to utilize a centering circuit to adjust the image position on the screen of the cathode-ray tube. A conventional circuit of this type is preferably connected in the deflection circuit of each of the illustrated embodiments but is omitted from the figures for the sake of clarity. Also, instead of applying a strictly linear sweep voltage to the control grids of the tubes in the several figures, some predistortion may be introduced to correct for any nonlinearities in the deflection circuit.

While it is feasible in accordance with the invention to practically completely eliminate transient oscillations during the sweep period, in some applications this may not be essential. For example, if a receiver cathode-ray tube is gated so that the initial portion of the sweep begins before a signal is allowed to be reproduced visibly, a slight transient may be permissible during this initial portion of the sweep, so long as it does not persist to an adverse degree during the visible portion of the sweep.

From the above description, it will be seen that this invention provides a simple and effective method for dealing with the power returned to the circuit during retrace from the collapsing deflecting fields. Although described particularly in connection with television systems, wherein it is especially useful, the invention may readily be applied to deflection circuits for other purposes. In general the principle of eliminating deflection current transients by secondary emission, as described herein, is especially useful in those cases requiring rapid retrace. An example is in cathode-ray oscilloscopes and allied fields.

While a number of specific embodiments have been described, many modifications may be made therein and different circuits employed by those in the art within the scope of the invention, as particularly pointed out in the claims.

I claim:

1. In a deflection circuit for a cathode-ray tube having electromagnetic deflecting means, the combination which comprises a vacuum tube including an anode, an output circuit associated with said vacuum tube for supplying to said deflecting means deflection currents having sweep periods alternating with relatively shorter retrace periods, and means for effecting the flow of emission currents from said anode during a portion of said sweep periods to damp out transient oscillations in said output circuit.

2. In a deflection circuit for a cathode-ray tube having electromagnetic deflecting means, the combination which comprises a vacuum tube including cathode, control grid, anode and at least one other electrode, an output circuit associated with said vacuum tube for supplying to said deflecting means deflection currents having sweep periods alternating with relatively shorter retrace periods, and means for biasing said other electrode to promote the flow of secondary emission currents from said anode following each of said retrace periods.

3. In a deflection circuit for a cathode-ray tube having electromagnetic deflecting means, the combination which comprises a vacuum tube including cathode, control grid, anode and at least one other electrode, an anode output circuit associated with said vacuum tube for supplying to said deflecting means deflection currents having periods of increase alternating with relatively

shorter retrace periods of decrease, and means for biasing said other electrode to promote the flow of emission current from said anode following each of said retrace periods, whereby transient oscillations following retrace may be substantially eliminated.

4. In a television system, a deflection circuit for a cathode-ray tube having an electromagnetic deflecting coil for line deflection which comprises a vacuum tube including cathode, control grid, anode and at least one other electrode, an anode output circuit associated with said vacuum tube for supplying to said deflecting coil sawtooth currents at line scanning frequency which increase substantially linearly during sweep periods and decrease abruptly during relatively shorter retrace periods, the potential of said anode being substantially higher during said retrace periods than during said sweep periods, and means for biasing said other electrode to promote the flow of secondary emission current from said anode immediately following said retrace periods, the bias of said electrode being insufficient during said retrace periods to promote substantial flow of secondary emission currents, whereby rapid retrace with substantial elimination of transient oscillations during sweep periods may be obtained.

5. In a deflection circuit for a cathode-ray tube having electromagnetic deflecting means, the combination which comprises a vacuum tube including cathode, control grid, screen grid, suppressor grid and anode, an output circuit associated with said vacuum tube for supplying to said deflecting means deflection currents having periods of increase alternating with relatively shorter periods of decrease, and means for biasing said suppressor grid to promote the flow of emission current from said anode following each of said periods of decrease of said deflection currents.

6. In a deflection circuit for a cathode-ray tube having electromagnetic deflecting means, the combination which comprises a vacuum tube including cathode, control grid, screen grid, suppressor grid and anode, an output circuit associated with said vacuum tube for supplying to said deflecting means deflection currents having sweep periods alternating with relatively shorter retrace periods, and means for biasing said suppressor grid to a value at least equal to the average value of potential at said anode during a sweep period to promote secondary emission currents from the anode immediately following retrace and damp out transient oscillations in said output circuit.

7. In a deflection circuit for a cathode-ray tube having electromagnetic deflecting means, the combination which comprises a vacuum tube including cathode, control grid, screen grid, suppressor grid and anode, an anode output circuit associated with said vacuum tube for supplying to said deflecting means deflection currents having sweep periods alternating with relatively shorter retrace periods, and means for biasing said suppressor grid to a value of the order of the average value of potential at said anode during a sweep period, whereby secondary emission current from said anode is encouraged after each of said retrace periods to absorb power from said output circuit and damp out transient oscillations.

8. In a deflection circuit for a cathode-ray tube having electromagnetic deflecting means, the combination which comprises a vacuum tube including cathode, control grid, screen grid, suppressor grid and anode elements, an anode output circuit associated with said vacuum tube for supplying to said deflecting means deflection currents having periods of increase alternating with relatively shorter periods of decrease, and means for biasing said screen and suppressor grids to effect the flow of secondary emission current thereto from said anode following each of said periods of decrease, whereby transient oscillations may be substantially avoided.

9. In a deflection circuit for a cathode-ray tube having electromagnetic deflecting means, the combination which comprises a vacuum tube including cathode, control grid, screen grid, suppressor grid and anode elements, an anode output circuit associated with said vacuum tube of supplying to said deflecting means deflection currents having sweep periods of increase alternating with relatively shorter retrace periods of decrease, means for biasing said screen grid above the potential of the anode during sweep periods, and means for biasing the suppressor grid below screen grid potential during sweep periods but at a sufficiently high potential to effect the flow of secondary emission currents from said anode immediately following retrace, whereby transient oscillations in said output circuit following retrace may be substantially avoided.

10. In a television system, a deflection circuit for a cathode-ray tube having electromagnetic deflecting means for line deflection which comprises a vacuum tube including cathode, control grid, screen grid, suppressor grid and anode elements, an anode output circuit associated with said vacuum tube for supplying to said deflecting means deflection currents at line scanning frequency having sweep periods of current increase alternating with relatively shorter retrace periods of current decrease, the potential of said anode being substantially higher during retrace periods than during sweep periods and being subject to a transient oscillatory voltage immediately following retrace, means for biasing said screen grid above the potential of the anode during sweep periods, and means for biasing said suppressor grid to a value of the order of the average anode voltage during a sweep period to promote secondary emission currents from said anode immediately following retrace periods and damp out oscillations in the output circuit and to minimize secondary emission currents for the remainder of the sweep periods.

11. In a television system, a deflection circuit for a cathode-ray tube having electromagnetic deflecting means for line deflection which comprises an output tube including cathode, control grid, screen grid, suppressor grid and anode, an anode output circuit associated with said tube for supplying deflection currents to said deflecting means, means for supplying a sweep control voltage wave to said control grid to produce deflection currents at line scanning frequency having sweep periods of increase alternating with relatively shorter retrace periods of decrease, means for biasing said screen grid, a series resistance connecting said suppressor and screen grids and a capacitor in shunt with said resistance for maintaining the suppressor grid at an elevated potential below that of the screen grid sufficient to promote secondary emission from said anode immediately following retrace periods, whereby transient oscillations during sweep periods may be substantially avoided.

12. In a deflection circuit for a cathode-ray tube having electromagnetic deflecting means, the

combination which comprises an output tube including cathode, control grid, anode and at least one other electrode, an output circuit associated with said tube for supplying to said deflecting means deflection currents having sweep periods alternating with relatively shorter retrace periods, and means for applying a varying bias to said other electrode which is relatively higher immediately following retrace periods to promote secondary emission from said anode and relatively lower for the remainder of the respective sweep periods.

13. In a deflection circuit for a cathode-ray tube having electromagnetic deflecting means, the combination which comprises an output tube including cathode, control grid, screen grid, suppressor grid and anode, an output circuit associated with said tube for supplying to said deflecting means deflection currents having sweep periods alternating with relatively shorter retrace periods, means for applying operating bias to said screen grid, and means for applying a varying bias to said suppressor grid which is relatively higher immediately following retrace periods to promote secondary emission from said anode and relatively lower for the remainder of the respective sweep periods, whereby transient oscillations in said output circuit during sweep periods may be substantially avoided.

14. In a deflection circuit for a cathode-ray tube having electromagnetic deflecting means, the combination which comprises an output tube including cathode, control grid, screen grid, suppressor grid and anode, an output circuit associated with said tube for supplying to said deflecting means deflection currents having sweep periods alternating with relatively shorter retrace periods, means for applying operating bias to said screen grid, and means for supplying a bias to said suppressor grid through a series resistor having a capacitor in shunt therewith, the time constant of the resistor-capacitor circuit being short compared to a sweep period whereby the suppressor grid bias is higher immediately following retrace periods to promote secondary emission from said anode and relatively lower for the remainder of the respective sweep periods.

15. In a deflection circuit for a cathode-ray tube having electromagnetic deflecting means, the combination which comprises an output tube including cathode, control grid, screen grid, suppressor grid and anode, an anode output circuit associated with said tube for supplying to said deflecting means deflection currents having sweep periods of current increase alternating with relatively shorter retrace periods of current decrease, means for applying operating bias to said screen grid, and means for supplying a bias to said suppressor grid through a series resistor having a capacitor in shunt therewith, the time constant of the resistor-capacitor circuit being of the order of a retrace period so that the suppressor grid bias is higher immediately following retrace periods to promote secondary emission from said anode and relatively lower for the remainder of the respective sweep periods, whereby transient oscillations in said output circuit during sweep periods may be substantially avoided.

16. In a television system, a deflection circuit for a cathode-ray tube having electromagnetic deflecting means for line deflection which comprises an output tube including cathode, control grid, screen grid, suppressor grid and anode, an anode output circuit associated with said tube for supplying to said deflecting means deflection currents at line scanning frequency having sweep periods of current increase alternating with relatively shorter retrace periods of current decrease, means for applying operating bias to said screen grid, a series resistor connecting said suppressor and screen grids and a capacitor in shunt with said resistor, the time constant of the resistor-capacitor circuit being of the order of a retrace period so that the suppressor grid bias is higher immediately following retrace periods to promote secondary emission from said anode and relatively lower for the remainder of the respective sweep periods, whereby transient oscillations in said output circuit during sweep periods may be substantially avoided.

17. In a deflection circuit for a cathode-ray tube having electromagnetic deflecting means, the combination which comprises an output tube including cathode, control grid, screen grid, suppressor grid and anode, an anode output circuit including a transformer for supplying to said deflecting means deflection currents having sweep periods alternating with relatively shorter retrace periods, means for applying bias potentials to said screen and suppressor grids, a rectifier circuit including a storage circuit disposed across a portion of said transformer, said rectifier being connected to periodically pass current to the storage circuit during retrace intervals to develop a periodic voltage and the time constant of the storage circuit being shorter than a sweep period, and means for supplying said periodic voltage to said suppressor grid to provide an additional positive bias effective for short intervals after respective retrace periods to promote secondary emission from said anode, whereby transient oscilliations in said output circuit during sweep periods may be substantially avoided.

18. In a deflection circuit for a cathode-ray tube having electromagnetic deflecting means, the combination which comprises an output tube including cathode, control grid, screen grid, suppressor grid and anode, an anode output circuit including a transformer for supplying to said deflecting means deflection currents having sweep periods alternating with relatively shorter retrace periods, means for applying a substantially fixed bias to said screen grid and a lower substantially fixed bias to said suppressor grid, a rectifier in series with a shunt resistor-capacitor circuit disposed across a portion of said transformer, said rectifier being connected to charge said capacitor periodically during retrace periods and the time constant of the resistor-capacitor circuit being short compared to a sweep period, and means for supplying the voltage periodically developed in said resistor-capacitor circuit to said suppressor grid to provide an additional positive bias effective for short intervals after respective retrace periods to promote secondary emission from said anode, whereby transient oscillations in said output circuit during sweep periods may be substantially avoided.

19. In a television system, a deflection circuit for a cathode-ray tube having electromagnetic deflecting means for line deflection which comprises an output tube including cathode, control grid, screen grid, suppressor grid and anode, an anode output circuit including a transformer for supplying to said deflecting means deflection currents at line scanning frequency having sweep periods of current increase alternating with relatively shorter retrace periods of current decrease, means for applying a substantially fixed bias to said screen grid and a lower substantially fixed

bias to said suppressor grid, a rectifier in series with a shunt resistor-capacitor circuit disposed across a portion of the primary of said transformer, said rectifier being connected to charge said capacitor periodically during retrace periods and the time constant of the resistor-capacitor circuit being short compared to a sweep period, and means for supplying the voltage periodically developed in said resistor-capacitor circuit to said suppressor grid to provide an additional positive bias effective for short intervals after respective retrace periods to promote secondary emission from said anode, whereby transient oscillations in said output circuit during sweep periods may be substantially avoided.

20. In a deflection circuit for a cathode-ray tube having an electromagnetic deflecting coil, the combination which comprises an output tube including cathode, control grid, anode and at least one other electrode, an output circuit associated with said tube for supplying to said deflecting coil deflection currents having sweep periods alternating with shorter retrace periods, a resonant circuit coupled to said output circuit and tuned to supply periodic positive voltage pulses immediately after retrace periods, and means for supplying said positive voltage pulses to said other electrode to promote the flow of secondary emission currents in said output tube after retrace periods, whereby transient oscillations in said output circuit during sweep periods may be substantially avoided.

21. In a deflection circuit for a cathode-ray tube having an electromagnetic deflecting coil, the combination which comprises an output tube including cathode, control grid, anode and at least one other electrode, an anode output circuit associated with said tube for supplying to said deflecting coil deflection currents having sweep periods alternating with shorter retrace periods, a resonant circuit coupled to said output circuit and tuned to a half-period approximately equal to a retrace period to supply periodic positive voltage pulses immediately after retrace periods, and means for supplying said positive voltage pulses to said other electrode to promote the flow of secondary emission currents in said output tube after retrace periods, whereby transient oscillations in said output circuit during sweep periods may be substantially avoided.

22. In a deflection circuit for a cathode-ray tube having an electromagnetic deflecting coil, the combination which comprises an output tube including cathode, control grid, screen grid, suppressor grid and anode, an anode output circuit associated with said tube for supplying to said deflecting coil deflection currents having sweep periods of increase alternating with shorter retrace periods of decrease, operating bias supply for said screen grid, a series resonant circuit connected to said output circuit and tuned to supply periodic positive voltage pulses immediately after retrace periods, and means for supplying said positive voltage pulses to the suppressor grid to promote the flow of secondary emission currents from said anode immediately after retrace periods, whereby transient oscillations in said output circuit during sweep periods may be substantially avoided.

23. In a television system, a deflection circuit for a cathode-ray tube having an electromagnetic deflecting coil for line deflection which comprises an output tube including cathode, control grid, screen grid, suppressor grid and anode, an anode output circuit including a transformer for supplying to said deflecting coil deflection currents at line scanning frequency having sweep periods of increase alternating with shorter retrace periods of decrease, operating bias supply for said screen grid, a series resonant circuit connected to the secondary circuit of said transformer and tuned to supply periodic positive voltage pulses immediately after retrace periods, and means for supplying said positive voltage pulses to the suppressor grid to promote the flow of secondary emission currents from said anode immediately after retrace periods, whereby transient oscillations in said output circuit during sweep periods may be substantially avoided.

24. In a deflection circuit for a cathode-ray tube having an electromagnetic deflecting coil in the output circuit of a vacuum tube, the method which comprises supplying said deflecting coil with output deflection currents having sweep periods alternating with relatively shorter retrace periods, and effecting the flow of secondary emission currents in said tube immediately following retrace periods to provide damping of said output circuit and substantially avoid transient oscillations therein during sweep periods.

25. In a deflection circuit for a cathode-ray tube having an electromagnetic deflecting coil in the anode output circuit of a vacuum tube having cathode, control grid, anode and at least one other electrode, the method which comprises supplying said deflecting coil with output deflection currents having sweep periods alternating with relatively shorter retrace periods, and biasing said other electrode to effect the flow of secondary emission currents from said anode immediately following retrace periods, whereby transient oscillations in said output circuit during sweep periods may be substantally avoided.

26. In a television deflection circuit for a cathode-ray tube having an electromagnetic deflecting coil for line deflection, said coil being in the anode output circuit of a vacuum tube having cathode, control grid, anode and at least one other electrode, the method which comprises applying a control wave to said control grid to produce deflection currents in said output circuit which increase substantially linearly during line sweep periods and decrease rapidly during relatively shorter retrace periods, the potential of said anode being substantially lower during sweep than during retrace periods, and biasing said other electrode to effect the flow of secondary emission currents from said anode immediately following retrace periods in amounts sufficient to substantially damp out transient oscillations in said output circuit during sweep periods.

27. In a deflection circuit for a cathode-ray tube having an electromagnet deflecting coil in the anode output circuit of a vacuum tube having cathode, control grid, anode and at least one other electrode, the method which comprises supplying said deflecting coil with output deflection currents having sweep periods alternating with relatively shorter retrace periods, and periodically increasing the bias on said other electrode to promote the flow of secondary emission currents from said anode immediately following retrace periods, whereby transient oscillations in said output circuit during sweep periods may be substantially avoided.

28. In a television deflection circuit for a cathode-ray tube having an electromagnetic deflecting coil for line deflection, said coil being in the anode output circuit of a vacuum tube having cathode, control grid, screen grid, sup-

pressor grid and anode, the method which comprises applying a control wave to said control grid to produce deflection currents in said output circuit which increase substantially linearly during line sweep periods and decrease rapidly during relatively shorter retrace periods, the potential of said anode being substantially lower during sweep than during retrace periods, biasing said screen grid above the anode potential during sweep periods, and biasing said suppressor grid below said screen grid but sufficiently high to promote the flow of secondary emission currents from said anode immediately following retrace periods in amounts to substantially damp

out transient oscillations in said output circuit during sweep periods.

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