Feb. 10, 1953 J. E. BRIDGES 2,628,326

TELEVISION APPARATUS

Filed March 10, 1951

Fig. 1

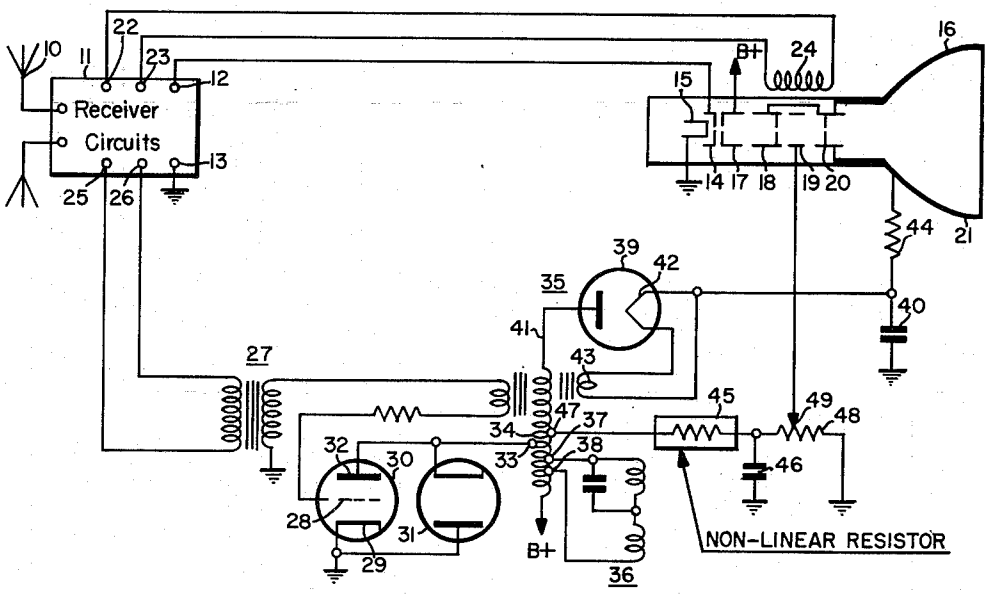


Fig. 2

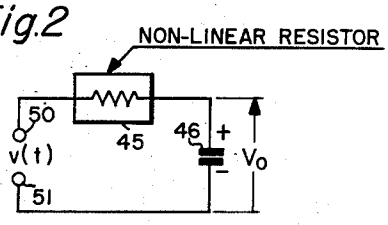


Fig. 3

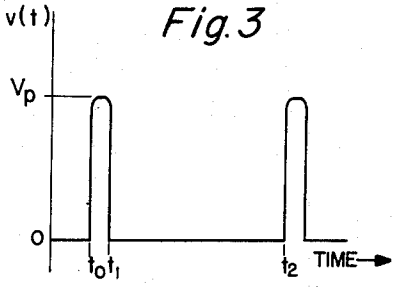


Fig. 4

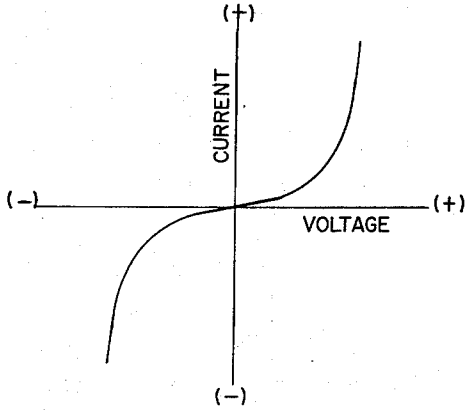
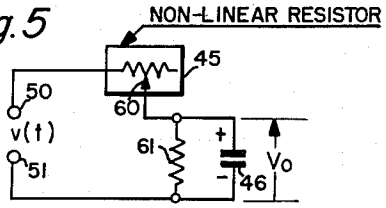


Fig. 5



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TELEVISION APPARATUS

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Application March 10, 1951, Serial No. 214,970

4 Claims. (Cl. 315—31)

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This invention relates to television apparatus and more particularly to such apparatus employing a cathode-ray tube having at least one electrode which requires a high positive unidirectional operating potential relative to the cathode.

Numerous arrangements are known for focusing the electron beam of a cathode-ray tube. Generally, the desired focusing action may be obtained by means of a magnetic field, an electrostatic field, or a combination of both. In electrostatic-focusing arrangements, two or more electrodes between the electron gun and the fluorescent screen are constructed and arranged to constitute a convergent electron lens upon application thereto of predetermined different unidirectional operating potentials. For example, such an electron lens may comprise a pair of cylindrical electrodes of the same or different diameters operated at different unidirectional potentials. Another known electron lens arrangement comprises three focusing electrodes with the first and third of these electrodes connected together and operated at the potential of the final anode and the intermediate focusing electrode operated at a unidirectional potential intermediate that of the anode of the electron gun and the final anode. In general, to obtain the desired focusing action with an electrostatically-focused cathode-ray tube, it may be necessary to supply at least one unidirectional operating potential which is greater than the output voltage of the direct-voltage supply or B-supply for the associated receiver apparatus, and for convenience throughout the specification and the appended claims, the terms "high voltage" and "high potential" are employed to describe an operating voltage greater than the B-supply voltage.

It is well known in the television art that the pulse voltage developed in the sweep-transformer primary winding of the line-frequency scanning system may be rectified and filtered to provide a desired high unidirectional operating potential. Systems of this type have employed a diode or other peak-rectifying device in conjunction with a storage condenser and are commonly used to supply the high operating potential for the final anode of the picture tube. This expedient has proved quite satisfactory in the mass production of television receivers employing magnetically focused cathode-ray tubes, since only one high unidirectional operating potential is required. In a television receiver employing an electrostatically-focused cathode-ray tube, however, two different high unidirectional operating

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potentials may be required. While it is possible to employ a bleeder resistor in shunt with the storage condenser associated with the conventional high voltage rectifier to provide the second high unidirectional operating potential, such an arrangement is uneconomical of power and is therefore undesirable. Voltage multipliers employed in connection with the standard B-supply may also be employed, but such arrangements require a considerable number of additional circuit components and are therefore costly and impractical.

It is an important object of the present invention to provide a new and improved television apparatus of the type employing a cathode-ray tube of the electrostatically-focused type.

It is a further object of the invention to provide a simple and economical system for developing a high unidirectional operating potential for application to one of the focusing electrodes of an electrostatically-focused cathode-ray tube.

Still another object of the invention is to provide a new and improved system for developing two different high unidirectional operating potentials for application to the focusing electrodes of an electrostatically-focused cathode-ray tube.

Yet another object of the invention is to provide a system of this type which is readily adaptable to a conventional television receiver and which requires a minimum number of additional circuit components.

In accordance with the invention, a television receiver includes a cathode-ray tube comprising a cathode and at least one other electrode requiring a high positive unidirectional operating potential with respect to that of the cathode. The receiver also comprises an asymmetrical voltage-wave source including an electron-discharge device. A series network comprising a non-linear resistor and a condenser is coupled to the electron-discharge device and is responsive to the asymmetrical voltage-wave to develop a high unidirectional voltage across the condenser. Means are provided for applying at least a portion of the unidirectional voltage developed across the condenser between the aforementioned other electrode of the cathode-ray tube and its cathode.

In interpreting the specification and the appended claims, it must be borne in mind that there is a fundamental difference between a non-linear resistor and other types of non-linear circuit elements such as rectifiers, crystals, and electron-discharge devices. While non-linear

operating characteristics may be achieved with circuit elements of the latter type, such elements are unilaterally conductive and permit current flow in one direction only. In contrast, a non-linear resistor of the type employed in accordance with the present invention, while possessing a non-linear volt-ampere characteristic, is bilaterally conductive and permits current flow in both directions.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may best be understood, however, by reference to the following description taken in connection with the accompanying drawings, in the several figures of which like reference numerals indicate like elements, and in which:

Figure 1 is a schematic circuit diagram of a television receiver constructed in accordance with the present invention;

Figure 2 is a schematic diagram of a portion of the receiver of Figure 1;

Figures 3 and 4 are graphical representations useful in understanding the operation of the invention; and

Figure 5 is a schematic diagram, similar to that of Figure 2, of another embodiment of the invention.

In the receiver of Figure 1, incoming composite television signals are intercepted by means of an antenna 10 and applied to the customary receiver circuits 11. The circuits represented by rectangle 11 may be entirely conventional in construction and operation and constitute no part of the present invention. Composite video signals developed between terminals 12 and 13 of receiver circuits 11 are applied between the control grid 14 and the cathode 15 of a cathode-ray tube 16 which also comprises a first anode 17, electrostatic-focusing electrodes 18, 19 and 20, a final anode 21, and a fluorescent screen (not shown). Field-frequency sweep-signals developed between terminals 22 and 23 of receiver circuits 11 are applied to a field-frequency magnetic-deflection coil 24 associated with cathode-ray tube 16.

Line-frequency synchronizing-signal pulses from terminals 25 and 26 of receiver circuits 11 are applied by means of an input transformer 27 between the control grid 28 and the cathode 29 of an electron-discharge device 30, which may conveniently be of the triode type. A second electron-discharge device 31, preferably a diode, is connected directly across the discharge path of device 30 but with opposite polarity, so that devices 30 and 31 together constitute a bidirectional electronic switch. The anode 32 of device 30 is connected to a tap 33 on the primary winding 34 of a sweep transformer 35, and one terminal of winding 34 is directly connected to the customary unidirectional voltage supply of the receiver, conventionally designated B+ in the figure, so that a portion of the primary winding 34 of sweep transformer 35 is included in the output circuit of device 30. The line-frequency magnetic-deflection coil 36 associated with cathode-ray tube 16 is connected between a pair of taps 37 and 38 on the portion of primary winding 34 which is included in the output circuit of device 30. Preferably, the location of taps 37 and 38 is determined in accordance with the copending application of Robert Adler et al., Serial No. 176,258, filed July 28, 1950, for Transformers, and assigned to the present assignee, in order to minimize undesired ringing currents in the line-frequency deflection coils and attendant velocity-modulation of the line-frequency scansions.

A rectifier 39 and a storage condenser 40 are connected in series between the high-potential terminal 41 of primary winding 34 and ground, the filament 42 of rectifier 39 being energized by means of an auxiliary winding 43 magnetically coupled to primary winding 34. Filament 42 is also coupled to the final anode 21 of cathode-ray tube 16 by means of a resistor 44.

A series network, comprising a non-linear resistor 45 and a storage condenser 46, is connected between a tap 47 on primary winding 34 and ground, being thereby effectively connected across the portion of primary winding 34 between tap 47 and the B+ terminal. A potentiometer 48 is connected in parallel with condenser 46, and a variable tap 49 on potentiometer 48 is connected to focusing electrode 19 of cathode-ray tube 16.

In operation, devices 30 and 31 and their associated circuit components constitute a line-frequency scanning-signal generator for impressing a scanning current of substantially sawtooth waveform on line-frequency deflection coils 36. Devices 30 and 31 collectively function as a bidirectional electronic switch, and the current through the portion of primary winding 34 between tap 33 and B+ increases substantially linearly at a rate primarily determined by the applied unidirectional voltage and the circuit inductance until such time as a negative-polarity pulse is applied between control grid 28 and cathode 29 of device 30. When current flow in the output circuit is interrupted in this manner, substantially one-half cycle of free oscillation occurs to complete the scanning cycle.

Operation of the scanning-signal generator results in the appearance of periodic positive-polarity pulses of extremely large magnitude across the entire primary winding 34 of sweep transformer 35. These pulses are rectified by device 39, and the high unidirectional voltage developed across condenser 40 is applied to final anode 21 by means of resistor 44. The external focusing electrodes 18 and 20 of the unipotential electron lens may conveniently be connected together and to final anode 21 so that these focusing electrodes are also energized by the voltage developed across condenser 40. In practice, the operating voltage of anodes 18, 20 and 21 may be of the order of 10 kilovolts.

In a unipotential electron lens of the type schematically illustrated in Figure 1, a second high unidirectional operating potential may be applied to the intermediate focusing electrode 19. In practice, the operating potential of intermediate focusing electrode 19 may be of the order of 20% of the final anode operating voltage. Such a potential is at least an order of magnitude greater than that customarily available from the conventional B+ source or B-supply. In accordance with the invention, the operating potential for intermediate focusing electrode 19 is developed by means of the series network comprising non-linear resistor 45 and condenser 46 effectively connected across at least a portion of the primary winding 34 of sweep transformer 35. The variable voltage-divider 48 is provided in order to permit fine control of the focusing of the electron beam of cathode-ray tube 16.

As has been indicated previously, there is a fundamental difference between a non-linear resistor of the type employed in accordance with the present invention and other non-linear circuit elements such as grid-controlled electron

tubes, rectifiers, and the like. Elements of the latter type are unilaterally conductive and hence may be employed to rectify any type of alternating input signals. On the other hand, the non-linear resistor is bilaterally conductive and has substantially no rectifying effect on an input signal of symmetrical waveform.

One type of non-linear resistor suitable for use in accordance with the present invention is constructed of silicon carbide pressed with a suitable ceramic binder and fired at a temperature of about 1,200 degrees centigrade. Such non-linear resistors are marketed commercially by the General Electric Company under the trade name "Thyrite" and are available in a large number of sizes and shapes. Resistors of this type do not operate in a manner comparable with that of ordinary, linear resistance elements; instead of behaving in accordance with Ohm's law, "Thyrite" resistors have a volt-ampere characteristic in accordance with the relation

$$i=Ke^n \tag{1}$$

where i represents the instantaneous current, e is the instantaneous applied voltage, K is a constant representing the current drawn with an applied voltage of one volt, and n is an exponent greater than unity. The constant K is dependent upon the resistivity and the dimensions of the particular "Thyrite" resistor, a typical value being of the order of 10^{-29}. The exponent n depends on various factors in the manufacturing process and is usually at least 3.5; in some instances, n may be as high as 7 or more.

In order to explain the operation of the invention, it has been convenient to reproduce in Figure 2 the portion of the circuit of Figure 1 comprising the series network of non-linear resistor 45 and condenser 46. The voltage wave applied to this series network from the portion of primary winding 34 between tap 47 and the B+ terminal is graphically represented in idealized form in Figure 3, which is a plot of the applied voltage $v(t)$ as a function of time. In practice, the actual waveform of the voltage appearing across the portion of primary winding 34 between tap 47 and the B+ terminal is displaced slightly in a negative direction with respect to the zero or reference axis; however, the waveform plotted in Figure 3 represents a sufficiently close approximation for purposes of circuit analysis. The applied voltage $v(t)$ is impressed between terminals 50 and 51 of the equivalent circuit of Figure 2 and is of asymmetrical waveform, comprising periodic positive-polarity pulses each of a duration corresponding to the line-frequency retrace interval (about 14% of the line-scanning cycle in accordance with present governmental standards).

The volt-ampere characteristic of the "Thyrite" resistor 45 is reproduced in graphical form in Figure 4. Since the applied voltage wave is asymmetrical as shown in Figure 3, and since the volt-ampere characteristic of the "Thyrite" resistor is non-linear, it may readily be understood as a qualitative matter that a net unidirectional voltage is developed across condenser 46 with the polarity indicated in Figure 2, the current drawn during the pulse intervals being many times greater than that drawn during the intervening intervals. At the outset, condenser 46 is completely discharged, and the application of the first positive-polarity pulse between terminals 50 and 51 results in a large current flow through condenser 46, charging the condenser with the polarity indicated in Figure 2. During the interval between the first and second pulses, the applied potential is of opposite polarity but of much lower magnitude, so that the resistance of the non-linear resistor increases and the condenser is only partially discharged through non-linear resistor 45. After several cycles, the voltage across condenser 46 assumes an equilibrium value intermediate zero and the peak amplitude V_p of the applied pulses. As a practical matter, the magnitude of the voltage V_0 developed across condenser 46 may be of the order of 40% of the peak amplitude V_p of the applied pulses.

More rigorously, the magnitude of the unidirectional voltage developed across condenser 46 may be determined from a mathematical consideration of the volt-ampere characteristic set forth by Equation 1. For a condition of equilibrium, the electrical charge acquired by the condenser during each pulse interval must equal the charge lost during the remainder of the operating cycle. This condition may be expressed by the equation

$$\int_{t_0}^{t_1} i(t)\,dt = \int_{t_1}^{t_2} i(t)\,dt \tag{2}$$

where

$$i(t)=K(V_p-V_0)^n \tag{3}$$

for

$$t_0 \leqq t \leqq t_1 \tag{4}$$

and

$$i(t)=KV_0^n \tag{5}$$

for

$$t_1 \leqq t \leqq t_2 \tag{6}$$

Performing the indicated operations and reducing to simplest terms,

$$V_0=\frac{V_p}{\left(\frac{t_2-t_1}{t_1-t_0}\right)^{\frac{1}{n}}+1} \tag{7}$$

Under the assumed condition that the pulse duration is about 14% of the operating cycle,

$$V_0=\frac{V_p}{6^{\frac{1}{n}}+1} \tag{8}$$

Combining Equations 8 and 7 and assuming an exponent n of 5 for the particular "Thyrite" resistor, it is apparent that the maximum unidirectional voltage obtainable across condenser 46 is of the order of 40% of the peak amplitude of the positive-polarity pulses. Moreover, the magnitude of the unidirectional voltage appearing across condenser 46 is independent of K, and is not greatly affected by variations in n, if n is large. By making n as large as possible, the magnitude of the output voltage may be made to approach 50% of the peak amplitude of the positive-polarity pulses and, at the same time, may be made substantially independent of ambient temperature.

From the foregoing analysis, it is apparent that a non-linear resistor of the type utilized in accordance with the present invention is a different type of circuit element than either a linear resistor or a conventional rectifier of the unilaterally conductive type. The "Thyrite" resistor differs from an ordinary resistance element in the exponential nature of its volt-ampere characteristic and from a conventional rectifier in its property of symmetrical bilateral conductivity. Because of the non-linear variation of

current with voltage, a unidirectional output voltage may be developed from an asymmetrical alternating input voltage. Because of the property of bilateral conductivity, the maximum unidirectional voltage which may be developed in this manner is restricted to somewhat less than one-half the peak voltage of the applied asymmetrical wave. This limitation is not objectionable, however, in a system such as that shown and described in connection with Figure 1, where the desired unidirectional operating potential is much smaller than the peak amplitude of the available asymmetrical voltage-wave.

The use of a non-linear resistor such as "Thyrite" for developing a high unidirectional operating potential has several advantages over conventional high-voltage supply systems. In the first place, the "Thyrite" resistor is a simple two-terminal element, and no auxiliary transformer winding is required for filament energization as in the case of systems employing a diode rectifier. "Thyrite" resistors are also somewhat less expensive, more durable, and require less frequent replacement, as a general rule, than suitable diode rectifier tubes. Moreover, the addition of the circuit comprising "Thyrite" resistor 45 and condenser 46 results in an additional power dissipation comparable to that imposed by known arrangements for obtaining high voltage from the sweep system; consequently, the system of the present invention has the advantage over the use of a bleeder resistor in conjunction with the high-voltage supply for the final anode that a considerably smaller additional load is placed on the sweep circuits. The voltage regulation obtainable with the system of the present invention is within 10%, a figure which is quite acceptable in connection with high-voltage supplies for electrostatic focusing.

In order to avoid the necessity for maintaining stringent tolerances in the mass production of television receivers, it is desirable to provide means for varying the operating potential applied to at least one of the focusing electrodes. Moreover, the provision of a variable high-voltage supply also permits the consumer to make fine adjustments in the beam focus under actual operating conditions. In the system of Figure 1, a variable voltage-divider such as potentiometer 48 is connected in shunt with condenser 46, and a variable tap on the potentiometer is connected to one of the focusing electrodes. The desired objective may also be achieved in the manner illustrated schematically in Figure 5, wherein non-linear resistor 45 is provided with a sliding contact 50, and a resistor 51 having a resistance of the order of 100 megohms or more is connected in parallel with condenser 46; with this arrangement, the positive terminal of condenser 46 is directly connected to focusing electrode 19. The voltage developed across condenser 46 may be varied by varying the position of slider 50 on "Thyrite" resistor 45; movement of the slider changes the voltage ratio between the active portion of non-linear resistor 45 and resistor 51. In practice, focusing electrode 19 may draw sufficient beam current to provide the desired effective resistance across condenser 46, so that no external circuit element corresponding to resistor 51 is required.

While the invention has been shown and described in connection with an auxiliary high-voltage supply system for furnishing an operating potential intermediate that of the B-supply and that applied to the final anode of the picture tube, it is contemplated that the present invention may also be employed to advantage in furnishing high unidirectional voltage for other operating electrodes of the picture tube. As has been already explained, the maximum unidirectional voltage obtainable by employing a non-linear resistor is somewhat less than one-half the peak amplitude of the available asymmetrical voltage-wave. Since the peak amplitude of the pulses developed in the sweep transformer of a conventional television receiver is of the order of from 10 to 12 kilovolts, and since the required operating potential for the final anode of present day cathode-ray tubes is of the same order of magnitude, it is apparent that the system of the invention is not presently suitable for providing the final-anode operating voltage. However, in the event that an asymmetrical voltage-wave of larger amplitude should become available, or if future developments should include a practical television tube operable with a final-anode voltage of the order of 5 kilovolts or less, it is apparent that a non-linear resistor and a condenser may be employed in accordance with the invention to provide the desired operating voltage for the final anode.

In the system shown and described in connection with Figure 1, the sweep transformer 35 is of the autotransformer type, employing judiciously positioned taps on a single transformer winding. It is of course within the scope of the present invention to employ a sweep transformer having one or more separate secondary windings in place of the autotransformer of Figure 1. Thus for example, the series network comprising "Thyrite" resistor 45 and condenser 46 may be connected across a separate secondary winding which is magnetically coupled to the primary winding. In an arrangement of this type, the series network is "effectively connected across at least a portion of the primary winding," within the meaning of the appended claims.

It is not essential for the purposes of the present invention that a sweep-signal generator of the type shown in Figure 1 be employed. Other types of sweep-signal generator may be substituted for that shown in Figure 1 with equally good results. In any event, it is essential that the asymmetrical voltage-wave source comprise an electron-discharge device to which the series network comprising the non-linear resistor and the condenser is coupled. This electron-discharge device may be either a sawtooth-current generator as in the system of Figure 1, or a sweep amplifier in the event that the sawtooth wave is developed in a preceding stage. Indeed, it is within the invention in its broadest aspects to employ an entirely separate asymmetrical voltage-wave source which performs no other function than that of supplying power to the series network comprising the non-linear resistor and storage condenser.

Thus, the present invention provides a new and improved high-voltage supply system which is particularly useful to furnish a desired high unidirectional operating potential for a focusing electrode of an electrostatically-focused cathode-ray tube. The system is simple, reliable and inexpensive and imposes but a nominal increase in the power dissipation of the apparatus. The obtainable voltage regulation is well within commercially accepted limits.

While particular embodiments of the present invention have been shown and described, it is apparent that various changes and modifications

may be made, and it is therefore contemplated in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

1. In a television receiver: a cathode-ray tube comprising a cathode and at least one other electrode requiring a high positive unidirectional operating potential with respect to that of said cathode; an asymmetrical voltage-wave source including an electron-discharge device; a series network comprising a bilaterally conductive non-linear resistor and a condenser coupled to said device and responsive to said asymmetrical voltage-wave to develop across said condenser a high unidirectional voltage; and means for applying at least a portion of said unidirectional voltage between said other electrode and said cathode.

2. In a television receiver: a cathode-ray tube comprising a cathode and at least two focusing electrodes each requiring a different high unidirectional operating potential with respect to that of said cathode; a scanning-signal generator comprising an electron-discharge device having an input circuit and an output circuit; a sweep transformer having a primary winding a portion of which is included in said output circuit; a rectifier and a condenser effectively connected in series across said primary winding; a series network comprising a bilaterally conductive non-linear resistor and a condenser effectively connected across at least a portion of said primary winding; means for impressing an input signal on said input circuit to induce a periodic asymmetrical pulse-voltage wave in said primary winding, whereby different high unidirectional voltages are produced across said respective condensers; means for applying one of said unidirectional voltages between one of said focusing electrodes and said cathode; and means for applying at least a portion of the other of said unidirectional voltages between the other of said focusing electrodes and said cathode.

3. In a television receiver: a cathode-ray tube comprising a cathode and at least two focusing electrodes each requiring a different high unidirectional operating potential with respect to that of said cathode; a scanning-signal generator comprising an electron-discharge device having an input circuit and an output circuit; a sweep transformer having a primary winding a portion of which is included in said output circuit; a rectifier and a condenser effectively connected in series across said primary winding; a series network comprising a bilaterally conductive non-linear resistor and a condenser effectively connected across at least a portion of said primary winding; means for impressing an input signal on said input circuit to induce a periodic asymmetrical pulse-voltage wave in said primary winding, whereby different high unidirectional voltages are produced across said respective condensers; means for applying one of said unidirectional voltages between one of said focusing electrodes and said cathode; and means including a variable voltage-divider for applying a variable portion of the other of said unidirectional voltages between the other of said focusing electrodes and said cathode.

4. In a television receiver: a cathode-ray tube comprising a cathode and at least two focusing electrodes each requiring a different high unidirectional operating potential with respect to that of said cathode; a scanning-signal generator comprising an electron-discharge device having an input circuit and an output circuit; a sweep transformer having a primary winding a portion of which is included in said output circuit; a rectifier and a first condenser effectively connected in series across said primary winding; a series network comprising a variable bilaterally conductive non-linear resistor and a second condenser effectively connected across at least a portion of said primary winding; means for impressing an input signal on said input circuit to induce a periodic asymmetrical pulse-voltage wave in said primary winding, whereby different high unidirectional voltages are produced across said respective condensers; means for applying the unidirectional voltage appearing across said first condenser between one of said focusing electrodes and said cathode; and means for applying the unidirectional voltage appearing across said second condenser between the other of said focusing electrodes and said cathode.

JACK E. BRIDGES.

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