Jan. 28, 1969 W. H. CLINGMAN, JR 3,424,939

VOLTAGE SWITCHING APPARATUS FOR COLOR KINESCOPES

Filed May 31, 1966 Sheet 1 of 2

FIG. 1.

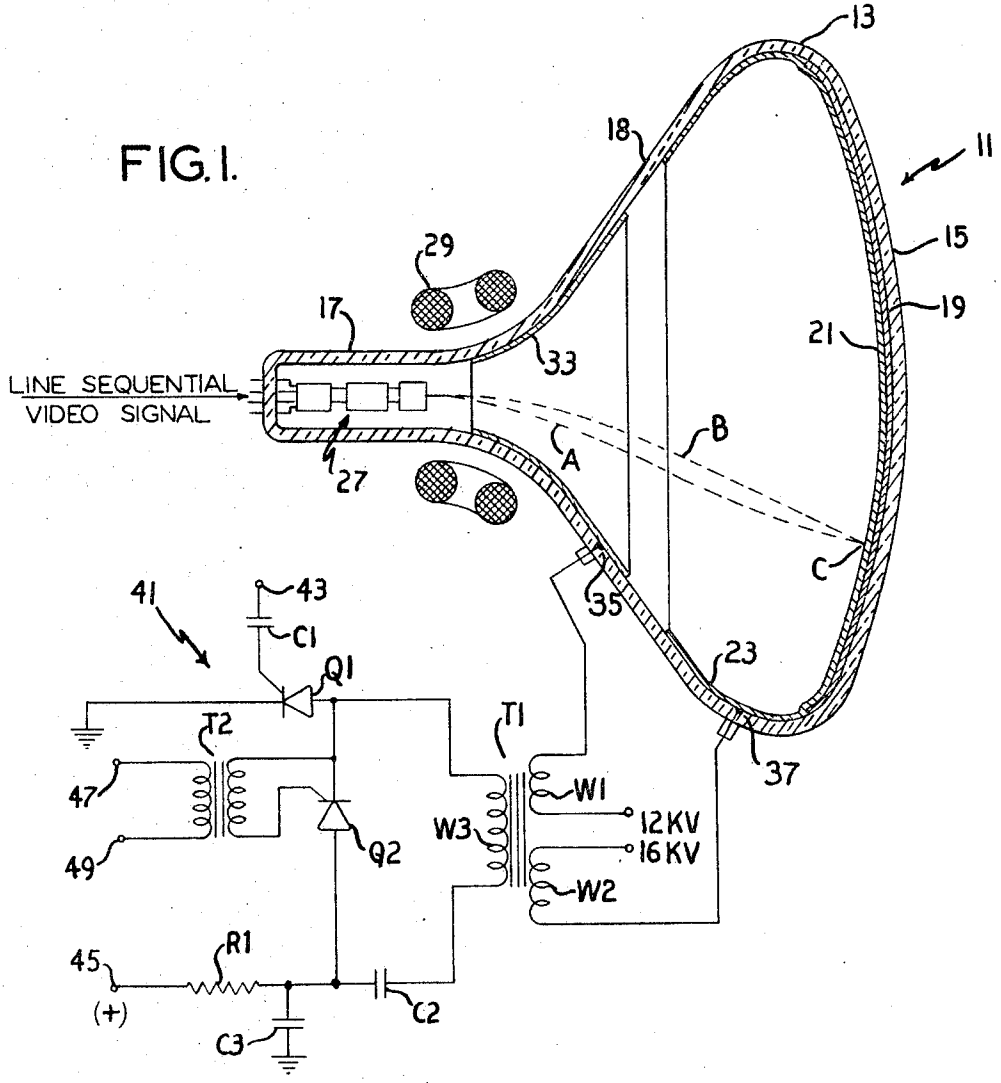
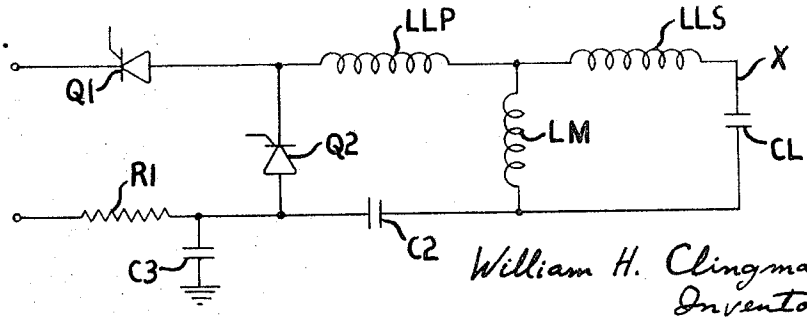


FIG. 2.



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VOLTAGE SWITCHING APPARATUS FOR COLOR KINESCOPES

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FIG. 3.

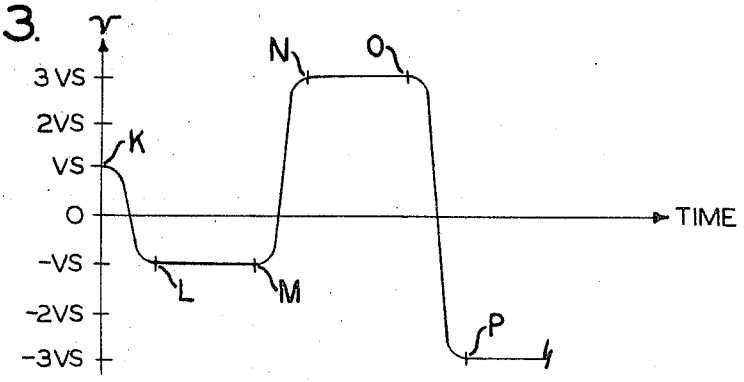


FIG. 4.

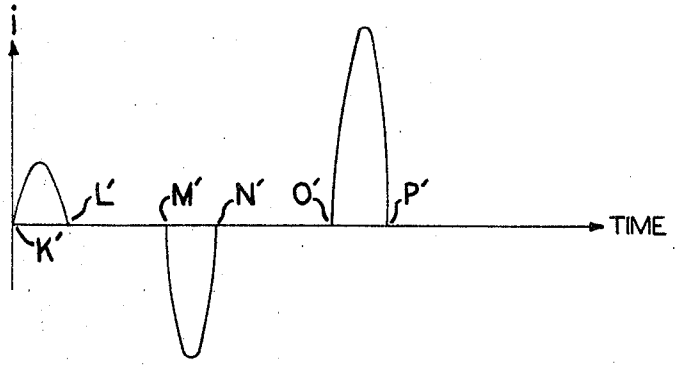
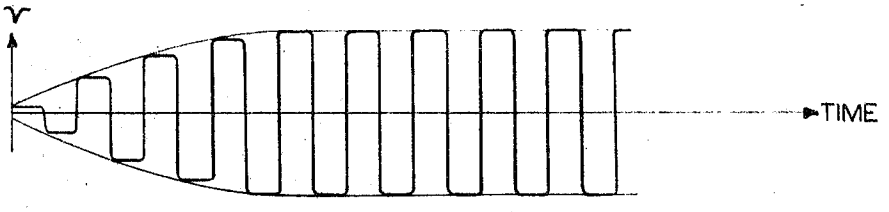


FIG. 5.



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VOLTAGE SWITCHING APPARATUS FOR COLOR KINESCOPES

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Filed May 31, 1966, Ser. No. 553,946
U.S. Cl. 315—14 8 Claims
Int. Cl. H01j 29/46, 29/56

ABSTRACT OF THE DISCLOSURE

Disclosed is a voltage switching apparatus which can be used for applying a high voltage square wave to a color kinescope tube of the type in which phosphors of red and cyan are coated on the inside face of the tube, the red phosphors being energized by electrons of a first energy, and the cyan phosphors being energized by electrons of a higher energy. The tube has a first transparent conducting layer which is coated upon its face over the phosphors, and a second conducting layer coated on the neck portion of the tube thereby presenting a capacitive load to which mutually out-of-phase high voltage pulses formed by the switching apparatus of the invention can be applied. The switching apparatus comprises two switching circuits, each connected to the primary winding of a high-voltage transformer, the first switching circuit being an SCR (silicon controlled rectifier) which is connected in parallel with a primary winding of the transformer and a capacitor and with its gate connected to a first trigger circuit, the second switching circuit being a second SCR connected from the primary winding of a transformer to ground and with its gate connected through a capacitor to a second trigger circuit, whereby when the SCR's are alternately triggered, a square wave is formed on the secondary winding of the transformer. The square wave is then applied to the conducting layer on the face of the tube and the conducting layer in the neck of the tube to alternately accelerate the electrons emitted from the electron gun at high and low energies thereby to excite either the red or cyan phosphors.

This invention relates to voltage switching apparatus and more particularly to such apparatus for switching electron accelerating voltages in a color kinescope.

In color kinescopes of the variable penetration type employing a phosphor screen having a plurality of phosphors which emit light of different colors when struck by electrons of different energies, it is typically necessary to switch the screen voltage between at least two different levels so that electrons directed toward the screen are accelerated to at least two different energy levels for producing light of different colors. The voltage changes required are typically relatively high, being on the order of several kilovolts, and the switching must be accomplished at a relatively rapid rate in synchronism with the color signals applied to the kinescope, e.g., at a line sequential rate which requires the voltage to be switched more than 10,000 times per second. Since the screen typically constitutes a capacitive load to the voltage source, it has been difficult to obtain a satisfactory stepped voltage waveform providing electron accelerating voltages at several distinct levels so as to produce satisfactory color separation.

Among the several objects of the present invention may be noted the provision of voltage switching apparatus which will apply a stepped voltage to a capacitive load such as the phosphor screen of the color kinescope; the provision of such apparatus which will produce such a stepped voltage which spans a voltage range of several

kilovolts; the provision of such apparatus which will switch voltage levels at relatively high repetition rates; the provision of such apparatus providing a waveform which steps relatively abruptly from one distinct voltage level to another; the provision of such apparatus which is relatively simple and inexpensive; and the provision of such apparatus which is highly reliable. Other objects and features will be in part apparent and in part pointed out hereinafter.

Briefly, voltage switching apparatus according to the present invention is adapted for applying a stepped voltage to a capacitive load. The apparatus includes a transformer having a primary winding and a secondary winding for connection to the capacitive load. A first switching circuit including an SCR and a capacitor in series with each other is provided for connecting the primary winding across a voltage source. A second switching circuit including a second SCR is connected across the primary winding and the capacitor. When either of the SCR's are triggered, the leakage reactance of the transformer causes the capacitive load to be charged to a respective voltage which then reverse biases that SCR thereby cutting off conduction therein. Thus, when the SCR's are alternately triggered, the capacitor is switched repetitively between at least two different voltage levels each of which persists until the next SCR is triggered.

The invention accordingly comprises the constructions hereinafter described, the scope of the invention being indicated in the claims that follow the description.

In the accompanying drawings in which one of various possible embodiments of the invention is illustrated,

FIGURE 1 is a partially schematic diagram of a color kinescope provided with voltage switching apparatus of this invention for varying the electron beam accelerating voltage;

FIGURE 2 is an equivalent circuit diagram of the voltage switching apparatus of FIGURE 1;

FIGURE 3 is a graph representing the behavior of a voltage occurring within the voltage switching apparatus of FIGURE 1;

FIGURE 4 is a graph similarly representing a current flow; and

FIGURE 5 is a graph representing the same voltage as FIGURE 3 over a relatively long period of time.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

Referring now to FIGURE 1, there is indicated at **11** a color kinescope of a type with which the present invention is useful. Kinescope **11** includes a conventional glass envelope **13** having a screen portion **15**, a neck portion **17** and a bell-shaped intermediate portion **18** connecting the neck and screen portions. Coated on the inner surface of the screen portion **15** is a phosphor screen or layer **19** which includes phosphors which emit light of different colors when struck by electrons of different energies. Phosphor screen **19** may, for example, be constituted by a mixture of two different kinds of phosphor particles one of which emits red light when energized by electrons having energies above a relatively low predetermined level and the other of which emits cyan light when energized by electrons having energies above a relatively high predetermined level. Such a screen will emit red light when struck by electrons at the relatively low level and white or substantially achromatic light when struck by electrons at the relatively high energy level, which electrons can energize both of the phosphors. Such red-white image displays are used in the art for the presentation of color images and images so presented appear to have a relatively wide range of hues subjectively having a greater saturation than that which is actually present in the colorimetric sense. Methods of preparing phosphors useful in

making such a screen are disclosed in copending application Ser. No. 459,582, filed May 28, 1965.

Over phosphor screen **19** is deposited a film **21** of aluminum which is conductive and yet is also thin enough to be substantially electron permeable. By means of film **21** suitable electron accelerating voltages may be applied to the phosphor screen **19**. Aluminum film **21** also extends beyond the face portion **15** of kinescope **11** onto a preselected margin of the intermediate portion **18** of envelope **13** thereby constituting a first conductive band **23** on the inner surface of the intermediate portion.

Within the neck portion **17** of envelope **13** there is mounted a conventional electron gun **27** for emitting a beam of electrons directed toward phosphor screen **19**. For the purpose of the example described herein, it is assumed that this color display system is operated in a line-sequential mode. For this purpose a line-sequential, color video signal is applied to gun **27** for varying the electron beam current, that is, the rate at which electrons are emitted by the gun. The video signal thus controls the instantaneous brightness of the light produced by the beam on phosphor screen **19**. It should be understood, however, that other modes of presentation, such as field-sequential, may also be employed by appropriately varying the different switching rates described hereinafter and applying a corresponding video signal to gun **27**.

Electrons emitted from gun **27** pass through the magnetic influence of a deflection yoke **29**. Yoke **29** is energized in conventional manner to deflect the beam of electrons in a scanning raster over the envelope face portion **15**. However, as is understood by those skilled in the art, the raster will be of uniform size only if the electrons emitted by gun **27** are all accelerated to the same energy or if compensation is made for the different deflection effects undergone by electrons having different energies.

The inner surface of the part of the intermediate envelope portion **18** adjacent neck **17** is coated with a conductive band as indicated at **33** thereby to constitute a generally annular, horn-shaped electrode which is concentric with gun **27** and through which the beam of electrons emitted by the gun pass on their way to phosphor screen **19**. Band **33** may conveniently be constituted by a so-called "dag" coating on envelope **13**. As is explained in greater detail hereinafter, electrode band **33** is employed to exercise a radial corrective effect on the deflection of the electron beam passing therethrough.

Electrical connections are made to the electrode band **33** and to the phosphor screen-covering aluminum film **21** as indicated at **35** and **37**, respectively, and these connections extend through envelope **13** by means of conventional feed-through terminals.

Screen **19** and electrode band **33** are provided with out-of-phase stepped voltages, and in particular with voltage waves of rectangular waveform and of several kilovolts amplitude, by the circuit indicated generally at **41**. For this purpose electrode band **33** and the screen band **23** are connected to respective secondary windings W1 and W2 of a transformer T1. The opposite ends of the transformer secondary windings are provided with respective D.C. biasing potentials. Appropriate nominal D.C. potentials for electrode band **33** and screen band **23** are approximately 12 and 16 kilovolts, respectively. Transformer T1 also includes a primary winding W3, one end of which is connected to ground through the anode-cathode circuit of an SCR (silicon controlled rectifier) Q1. Triggering signals applied to a terminal **43** are coupled to the gate terminal of SCR Q1 through a coupling capacitor C1. The other end of winding W3 is connected to a positive supply terminal **45** through a D.C. blocking capacitor C2 and a current limiting resistor R1. The voltage existing between capacitor C2 and resistor R1 is smoothed by a filter capacitor C3. Primary winding W3 and capacitor C2 together are shunted by the anode-cathode circuit of second SCR Q2. Triggering signals for SCR Q2 applied to a pair of terminals **47** and **49** are coupled to the gate-cathode circuit of the SCR Q2 by a transformer T2.

When SCR's Q1 and Q2 are triggering alternately, the circuit **41** operates, as described in greater detail hereinafter to apply respective stepped voltage waveforms to the electrode band **33** and to the screen **19**, the two voltages being switched out-of-phase with each other. Electrons emitted by gun **27** during the different time intervals corresponding to the two different voltage levels of the waveform applied to screen **19** are thus accelerated to different energy levels before reaching phosphor screen **19**. The energy levels are chosen in relation to the characteristics of the phosphors which make up screen **19** so that the lower energy electrons excite only the red phosphor while the higher energy electrons excite both the red and cyan phosphors, thereby causing white light to be emitted.

The frequency of the rectangular wave is adjusted and synchronized by appropriately controlling the triggering of SCR's Q1 and Q2 so that the different accelerating voltages are produced during periods which correspond to the sequencing of the color video signal applied to gun **27**. The beam current is thus modulated to reproduce the various image components in their respective colors. In the example illustrated this is assumed to be at a line-sequential rate.

Registration between the different color image components is maintained in the folowing manner: During the display of a white line, the screen **19** is driven to the higher of its two potential levels and electrons emitted from gun **27** are accelerated to a relatively high energy level. These electrons thus produce white light when they strike the phosphor screen **19** as explained previously. As the screen **19** is driven to its more positive voltage, the electrode band **33** is driven to its more negative voltage level. Accordingly, electrons emitted from gun **27** during this period are not greatly accelerated as they first leave the gun but rather attain only a relatively low velocity in the region of the yoke **29**. These electrons are thus relatively highly subject to deflection by the yoke's field and therefore follow a path having an early high curvature as represented at A in FIGURE 1. As these electrons leave the vicinity of electrode **33**, however, they are subjected to a relatively intense electric field and are thus accelerated to approach screen **19** at a relatively steep angle, impinging at a point indicated at C.

When a red line is being displayed, the screen **19** is driven to the lower of its two voltage levels. The total acceleration undergone by electrons emitted by gun **27** during this line period is thus relatively small and only the red phosphor is energized. While the screen is at its lower voltage level, the electrode band **33** is driven to the higher of its two voltage levels and thus electrons emitted from gun **27** are rapidly accelerated as they first leave the gun. These electrons are thus not greatly deflected in the region of the yoke and therefore follow a path substantially as indicated at B in FIGURE 1. However, as screen **19** is then at the lower of its two voltage levels, these electrons are not greatly further accelerated before reaching the screen and therefore approach the screen substantially at the angle determined by their earlier deflection, striking the screen substantially at the same point C as the higher energy electrons following the path A.

As the particular configuration of kinescope **11** will affect the distribution of the electric fields within its envelope, as will the boundaries of the electrode band **33** and the aluminum screen coating **21**, it may be seen that the particular D.C. biasing voltages and the amplitudes of the steps between the two voltage levels applied to these elements will vary from tube to tube in order to achieve best registration. Typically, the amplitude of the steps between the two voltage levels will be different for the electrode **33** and the screen **19**, the windings W1 and W2 being shown of different size in FIGURE 1 for this reason.

The operation of circuit 41 may be understood by referring to the equivalent circuit diagram in FIGURE 2. In this diagram the transforming effect of the turns ratio of transformer T1 is neglected and the capacitive loads constituted by the electrode band 33 and the screen 19 are represented by a single capacitance CL. The transformer T1 is represented in FIGURE 2 by an inductance LM which represents the mutual inductance between the primary and secondary windings and a pair of inductances LLP and LLS which represent the leakage inductances attributable to the primary and secondary windings respectively. At the switching frequencies involved, the impedance of the inductance LM is relatively large and, essentially, this component has no effect on the oscillatory or A.C. mode of operation described hereinafter. Similarly, the capacitance C2 is relatively large so that, at the switching frequencies involved, its impedance is relatively low and it does not substantially effect the transfer of A.C. energy.

FIGURE 3 represents the behavior of the voltage at a point X in the circuit of FIGURE 2, which voltage may be taken as representative of the stepped component of the voltages applied to electrode 33 and screen 19. FIGURE 4 similarly represents the current flowing into the capacitive load CL.

When a positive supply voltage VS is first applied to the terminal 45, neither of the SCR's Q1 or Q2 conducts and the capacitances CL and C2 remain uncharged. When SCR Q2 is triggered, the point X rises to the supply voltage VS, as shown in FIGURE 3. Then, when SCR Q1 is triggered, the leakage reactances LLP and LLS and the load capacitance CL react in an oscillatory manner so that the voltage at point X behaves essentially as illustrated by the portion K–L of the curve of FIGURE 3. As may be seen, the curve between these points comprises 180° of a sine-wave function, the period of which is determined by the relative magnitudes of the leakage reactances LLP and LLS and the load capacitance CL. As is understood by those skilled in the art, the phase of the current flowing through capacitance CL is shifted 90° with respect to the applied voltage and thus behaves substantially as represented by section K'–L' of the curve of FIGURE 4. At the end of the period K'–L', the oscillatory or resonant circuit comprising reactances LLP and LLS and capacitance CL tends to drive the current in the reverse direction. However, since Q1 can conduct in one direction only, it therefore ceases conduction and appears as an open circuit to the reactive circuit elements in series therewith. The voltage at point X therefore persists or remains at the level of point L until the SCR Q2 is triggered at the point of time indicated at M.

At time M the voltage across SCR Q2 is equal to twice the supply voltage since the point X is charged to a voltage which is equal and opposite to the supply voltage with respect to ground. When SCR Q2 is then triggered, the voltage of the point X behaves in the oscillatory manner represented by the portion of the curve of FIGURE 3 between the points M and N, this portion of the curve comprising a 180° of a sine-wave centered about the supply voltage VS. The current flowing through load CL during this interval behaves substantially as represented by the portion M'–N' of the curve of FIGURE 4. At the end of the interval M'–N', when the oscillatory circuit tends to reverse the flow of current, SCR Q2 is reverse biased and ceases conduction. The voltage at the point X thus persists at the level which it had reached at the point N. The voltage across SCR Q1 at this time is, as may be seen from FIGURE 3, substantially equal to three times the supply voltage VS. Thus when SCR Q1 is again triggered, the oscillatory action of the circuit causes the voltage at the point X to swing to a negative voltage whose absolute magnitude is substantially equal to three times the source voltage.

From the preceding explanation it can be seen that the leakage reactances LLP and LLS together with the capacitive load CL constitute an oscillatory system which can be "pumped" by alternate triggering of the SCR's Q1 and Q2 so that the energy stored in the oscillatory system is progressively increased. However, since current can flow through the oscillatory system only by passing through one of the SCR's Q1 and Q2, the oscillatory or sinusoidal waveform is interrupted at various points, e.g., the intervals L–M and N–O, until the next SCR is triggered. In actual practice these intervals may be made quite long relative to the time required for switching the voltage so that an essentially stepped waveform is obtained in which the voltage changes relatively abruptly from one discrete level to another.

Assuming an entirely lossless system, the voltage at point X would build up substantially according to the following progression:

$$+1, -1, +3, -3, +5, -5, +7, \text{ etc.}$$

However, the system necessarily involves some losses and thus the waveform builds up only util the power consumed equals the power dissipated by the losses and then the waveform reaches a stabilized level. This build up and stabilization of the waveform is represented in FIGURE 5.

As noted previously, the inductance LM and the capacitance C2 have little effect on the A.C. components of the waveform at the switching frequencies involved. When the positive and negative of the waveform are of substantially equal duration, the capacitor C2 takes on very little D.C. charge. However, it is an advantage of the present circuit that it may be employed where the positive and negative portions of the wave are not of equal duration. Such operation may be highly desirable in color display systems of the type illustrated in FIGURE 1 when it is desired to display two lines of one color for every one line of the other color. Such an operation may be expedient to obtain a desirable color balance or to cause the system to operate at a desired multiple of the verticle scanning rate so that so-called flicker or line crawl, phenomena are avoided. When the SCR's Q1 and Q2 are triggered to produce unequal durations of the positive and negative portions of the stepped voltage wave the capacitor C2 charges to a D.C. voltage which balances the net D.C. current flow through the SCR's Q1 and Q2 thereby causing a satisfactory waveform to be produced.

Voltage switching apparatus of this invention may also be modified, by the addition of a voltage divider and a third SCR, to provide a third voltage level step intermediate the extreme voltage steps. The three SCR's are then triggered sequentially, the time of triggering of the third SCR being in between the alternate triggering of the other two. This third level may, for example, be useful in three-component color displays. Accordingly, as used herein, the term stepped voltage should be understood to include both a rectangular or square wave and also a wave having three or more voltage steps at different levels.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Voltage switching apparatus for applying a stepped voltage to a capacitive load, said apparatus comprising:

a transformer having a primary winding and a secondary winding, said secondary winding being adapted to be connected to said load;

a first switching circuit for connecting said primary winding across a voltage source, said first switching circuit including an SCR and a capacitor in series with each other and with said primary winding;

a second switching circuit including a second SCR

which is connected across said primary winding and said capacitor from a first junction between said SCR of said first switching circuit and said primary winding to a second junction on the side of said capacitor and primary winding opposite said SCR of said first switching circuit; and

means for applying signals to the gate terminals of said SCR's for triggering said SCR's into conduction alternately, said transformer having leakage reactance which, upon triggering of either of said SCR's, causes said capacitive load to be charged to a respective voltage which then reverse-biases that SCR thereby cutting off conduction therein, whereby said load is switched repetitively between at least two different voltage levels each of which persists until the next SCR is triggered.

2. Voltage switching apparatus as set forth in claim **1** including a capacitor for coupling triggering signals to the SCR in said first switching circuit.

3. Voltage switching apparatus as set forth in claim **1** including a transformer for coupling triggering signals to said second SCR.

4. Voltage switching apparatus as set forth in claim **1** wherein said transformer comprises a pair of secondary windings for providing out-of-phase stepped voltages to the conductors of said capacitive load.

5. A color display system comprising:

a screen including phosphors which emit light of different colors when struck by electrons of different energies said screen forming a capacitive electrical load;

an electron gun for emitting a beam of electrons toward said screen;

field generating means for deflecting said beam of electrons in a scanning raster;

means for applying a D.C. bias voltage to said screen to accelerate electrons emitted from said gun toward said screen;

a transformer having a primary winding and a secondary winding, said secondary winding being adapted to be connected to said screen for applying a time-varying voltage thereto;

a first switching circuit for connecting said primary winding across a voltage source, said first switching circuit including an SCR and a capacitor in series with each other and with said primary winding;

a second switching circuit including a second SCR which is connected across said primary winding and said capacitor from a first junction between said SCR of said first switching circuit and said primary winding to a second junction on the side of said capacitor and primary winding opposite said SCR of said first switching circuit; and

means for applying signals to the gate terminals of said SCR's for triggering said SCR's into conduction alternately, said transformer having leakage reactance which, upon triggering of either of said SCR's, causes said capacitive load to be charged to a respective voltage which then reverse-biases the triggered SCR thereby cutting off conduction therein, whereby said screen is switched repetitively between at least two different voltage levels each of which persists until the next SCR is triggered and whereby said electrons are accelerated to at least two different energies for energizing said screen to produce multiple-color images.

6. A color display system comprising:

a screen including phosphors which emit light of different colors when struck by electrons of different energies;

an electron gun for emitting a beam of electrons toward said screen;

field generating means for deflecting said beam of electrons in a scanning raster;

a generally annular electrode concentric with said gun and axially displaced therefrom toward said screen and into the region of the field produced by said field generating means, said screen and said electrode forming capacitive electrical loads;

means for applying D.C. bias voltages to said screen and said electrode to accelerate electrons emitted from said gun toward said screen;

a transformer having a single primary winding and secondary windings adapted to be connected to said screen and said electrode for applying out-of-phase time-varying voltages thereto;

a first switching circuit for connecting said primary winding across a voltage source, said first switching circuit including an SCR and a capacitor in series with each other and with said primary winding;

a second switching circuit including a second SCR which is connected across said primary winding and said capacitor from a first junction between said SCR of said first switching circuit and said primary winding to a second junction on the side of said capacitor and primary winding opposite said SCR of said first switching circuit; and

means for applying signals to the gate terminals of said SCR's for triggering said SCR's into conduction alternately, said transformer having leakage reactance which, upon triggering of either of said SCR's, causes said capacitive loads to be charged to respective voltages which then reverse bias the triggered SCR thereby cutting off conduction therein, whereby said screen and said electrode are switched repetitively between at least two different respective voltage levels each of which persists until the next SCR is triggered and whereby said electrons are accelerated to at least two different energies for energizing said screen to produce multiple-color images having color image components which are in substantiial registration.

7. A color display system as set forth in claim **6** wherein said screen and said electron gun are supported within a kinescope envelope and wherein said electrode comprises a conductive layer on the inner surface of said envelope.

8. A color display system as set forth in claim **6** wherein said transformer comprises separate secondary windings for said screen and said electrode and wherein said D.C. bias voltages are applied to the screen and said electrode through the respective windings.

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U.S. Cl. X.R.

307—125

Notice of Adverse Decisions in Interferences

In Interference No. 97,206 involving Patent No. 3,424,939, W. H. Clingman, Jr., VOLTAGE SWITCHING APPARATUS FOR COLOR KINESCOPES, final judgment adverse to the patentee was rendered Jan. 19, 1973, as to claims 39 and 40.

[*Official Gazette July 10, 1973.*]