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Sunstein

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[54] **HIGH VOLTAGE INTERCONNECTION SYSTEM FOR CATHODE-RAY TUBES AND THE LIKE**

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[52] **U.S. Cl.** ..... **307/202,** 315/1, 317/11 R, 317/11 C, 317/33, 328/8, 328/231, 328/259, 338/21

[51] **Int. Cl.** **H02h 7/20**

[58] **Field of Search** ..... 307/202; 328/7–10, 231, 259; 315/1, 35; 317/3, 9, 11 C, 11 R, 33, 61.5, 101 R, 103 R; 330/11 P; 338/21, 216

[56] **References Cited**

UNITED STATES PATENTS

2,563,952	8/1951	Nichol	123/148
3,614,422	10/1971	Katsuta et al.	328/259 X
3,167,255	1/1965	Point et al.	317/3 UX
3,448,323	6/1969	Owens	315/1
3,191,132	6/1965	Mayer	333/79
3,551,821	12/1970	Griffey	328/8

Primary Examiner—Stanley D. Miller, Jr.
Attorney—Howson and Howson

[57] **ABSTRACT**

One or more linearly distributed resistance elements, such as flexible cables having an outer layer of high-voltage insulating material surrounding an inner continuous core of partially conductive material, are utilized as the interconnecting high-voltage wires in a high-voltage supply, whereby the intensities and frequencies of currents produced in the interconnecting wires upon the occurrence of an arc-over in the high-voltage supply are reduced below the values which would otherwise induce damaging effects in nearby sensitive elements such as transistors, semiconductor diodes or other similar solid-state devices. Similar linearly distributed resistance elements may also be used to connect to other elements to which arc-over from a high-voltage conductor may occur.

6 Claims, 13 Drawing Figures

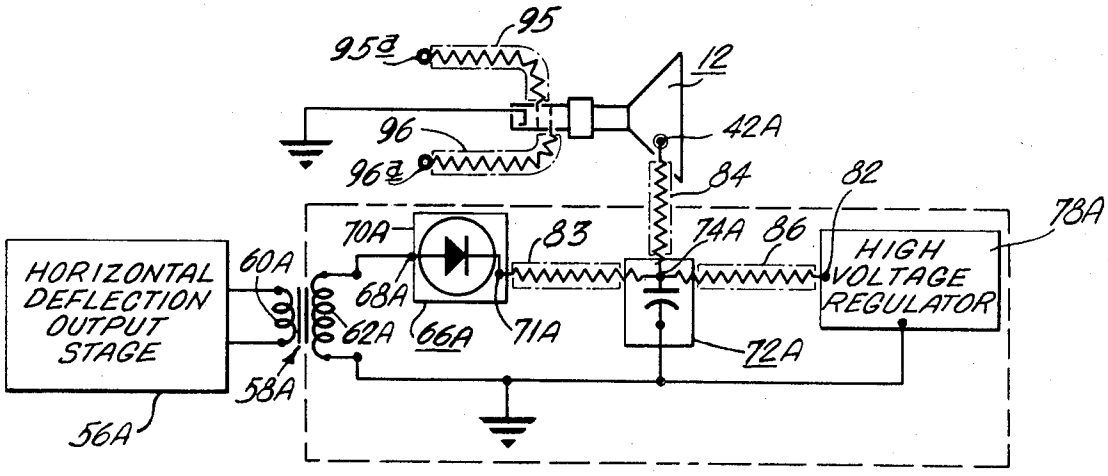

FIG. 1.

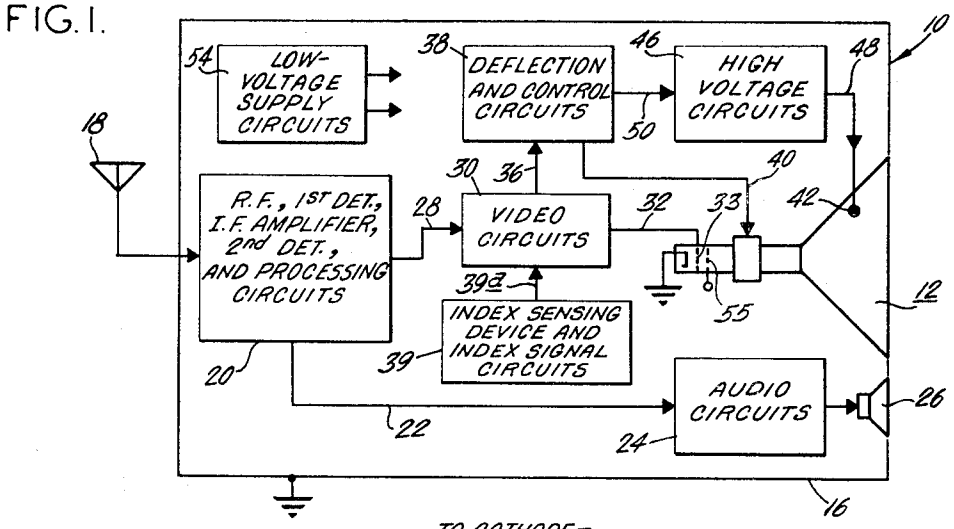

FIG. 2.
(PRIOR ART)

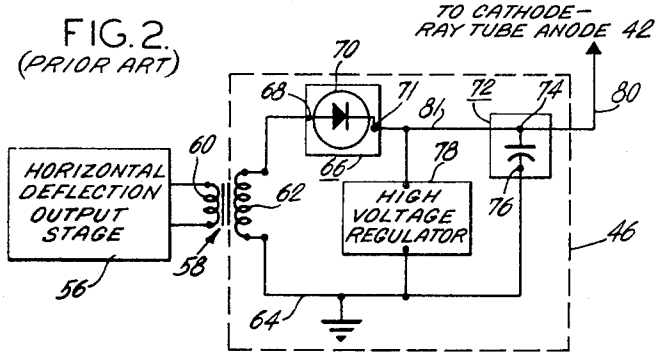

FIG. 3.

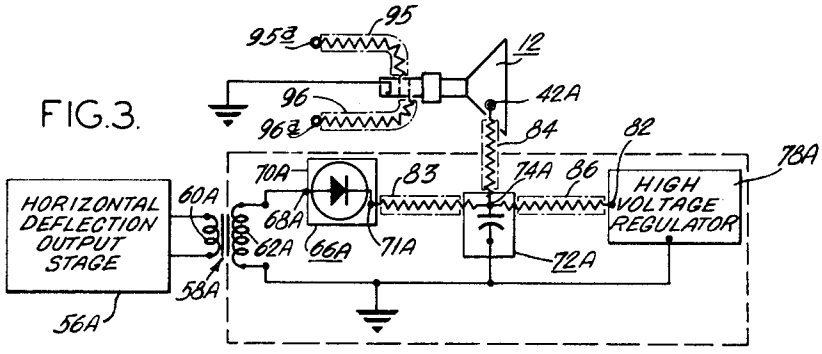

FIG. 9.

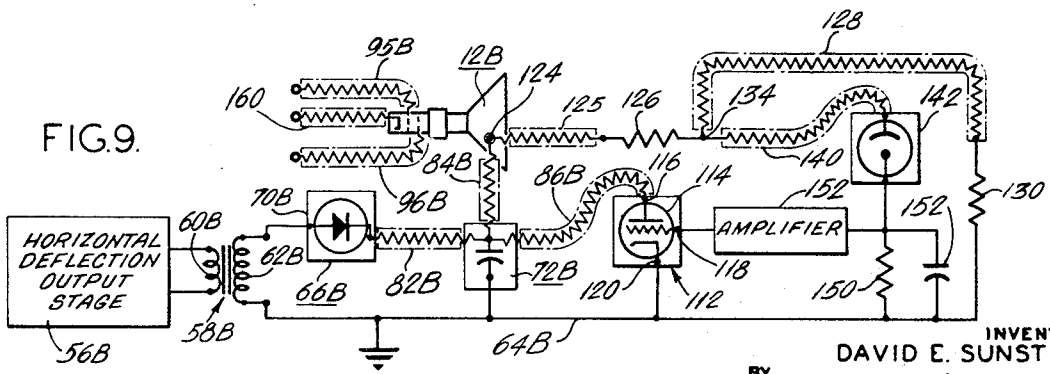

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FIG. 4.

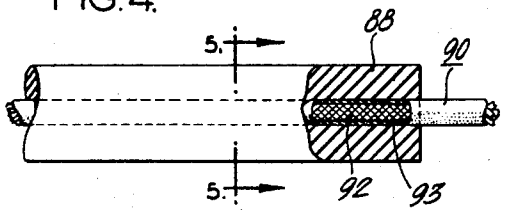


FIG. 6.

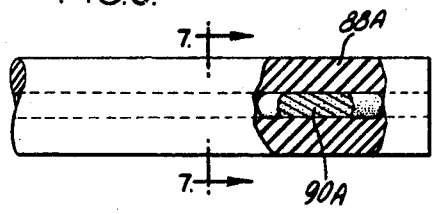


FIG. 5.

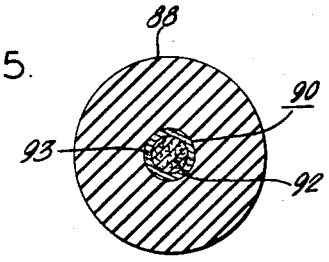


FIG. 7.

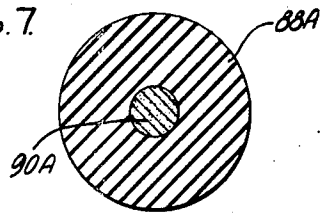


FIG. 8.

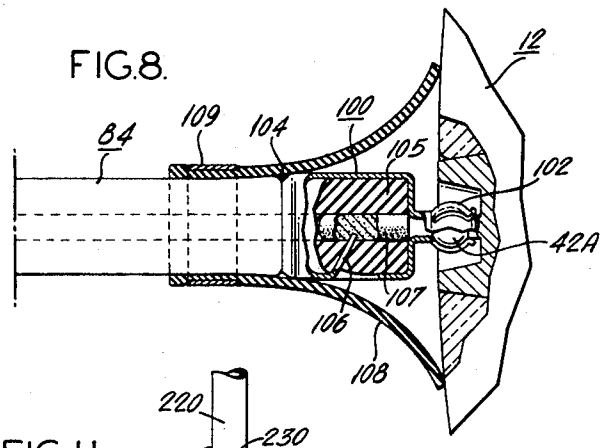


FIG. 10.

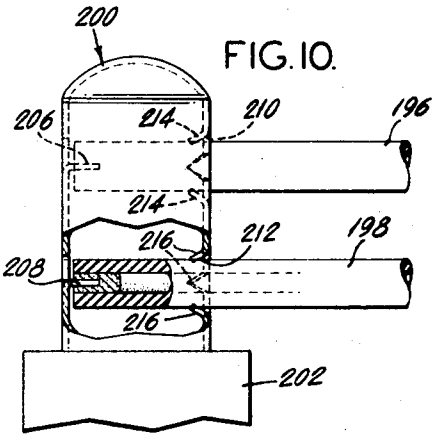


FIG. 11.

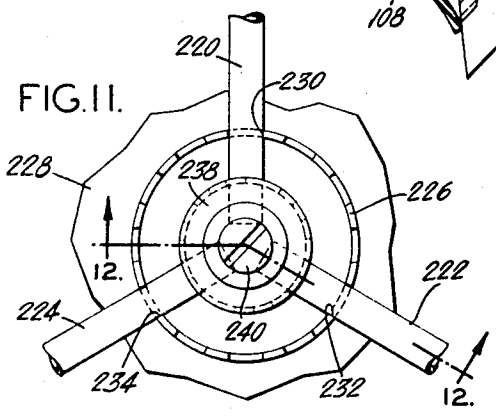


FIG. 13.

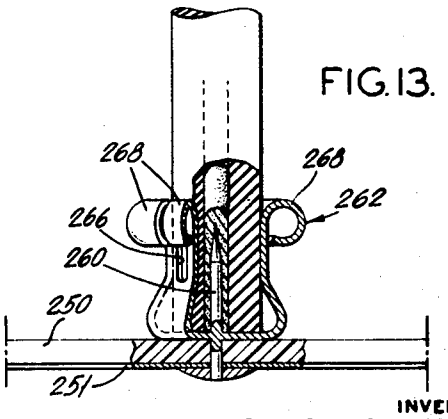
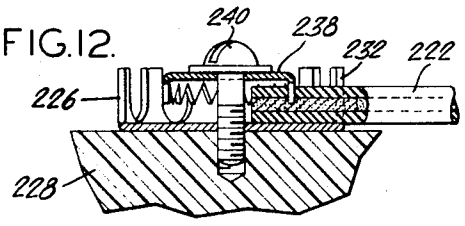


FIG. 12.



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HIGH VOLTAGE INTERCONNECTION SYSTEM FOR CATHODE-RAY TUBES AND THE LIKE

BACKGROUND OF INVENTION

There are a variety of applications in which a high-voltage supply system is used to supply high voltage, and usually current, to an electronic device to render it operative, and in which the system is subject to at least occasional harmful arc-overs which not only interfere with operation during their occurrence but may also produce long term or permanent damage to the supply, to the electronic device, or to nearby sensitive apparatus and devices. One specific system for which I have found that this is true, and with particular reference to which the present invention will be described, is the color television system described in my U.S. Pat. Nos. 2,892,123, 3,013,113 and 3,305,788, wherein high-voltage is supplied to a cathode-ray tube, and sensitive index circuits and control circuits are employed which experienced occasional but catastrophic damage from high voltage arcs, prior to the use of my invention herein.

More generally, in apparatus utilizing cathode-ray tubes, for example television receivers or monitors using a cathode-ray tube as the image-presentation device, or in such device as image intensifiers or in flying spot scanners, or in image pick-up tubes, it is normally necessary to supply a high operating voltage to a terminal on the electron beam tube, which terminal is generally connected internally of the tube to the final anode of the tube. It is this high voltage which accelerates the electrons from a cathode toward a screen or target of the tube. In cathode-ray tubes, larger tubes and higher image brightness generally require correspondingly higher voltages. In the case of color television, the voltage required to be applied to the high-voltage terminal of the cathode-ray tube is generally substantially higher even than for black-and-white television tubes of the same size, and voltages of the order of 25,000 volts are common in such applications. While a variety of forms of circuit are available for generating the required high voltage, in the vast majority of cases this high voltage is applied to an energy-storage device, typically a high-voltage capacitor, which serves to smooth or filter out variations or ripple tending to occur in the high-voltage from the original generating source. Merely by way of example, the high-voltage may be developed by rectifying the so called "fly-back" pulse created in a step-up winding on the horizontal-deflection output transformer. In some cases a simple single rectifier tube may be used for this purpose, although in other cases more than one rectifier tube with one or more pulse-coupling capacitors may be employed in a voltage-doubling or voltage-tripling circuit. The rectifier may instead be a solid-state device.

The direct output voltage of the rectifier is normally supplied to the high-voltage terminal of the cathode-ray tube, and a high-voltage capacitor is usually connected in parallel with the source of rectified high voltage to effect the above-mentioned smoothing action. The capacitor may be a conventional lumped-circuit high-voltage capacitor; however, by connecting the high-voltage terminal of the cathode-ray tube to a conductive coating on the inside of the cathode-ray tube surfaces and providing an external conductive coating on the outside of the cathode-ray tube envelope, the inner and outer envelope coatings may be used as capacitor plates. The latter type of capacitor typically has a relatively small value of capacitance, and can be used (with power supplies which derive high voltage from rectification of scan frequency AC sources), as the total smoothing capacitance for the high-voltage, or as a way of reducing the value of the conventional lumped capacitance required for adequate filtering, thereby reducing the cost of the assembly.

It has been found that such high-voltage supplies for cathode-ray tubes, even when well designed, are usually subjet to at least occasional arcing of the high voltage to a point at a lower potential, such as ground. While it is possible in some cases for such arcing to occur through insulating material or entirely through the air, particularly under humid atmospheric conditions, when the supply is well designed such arcing will more typically occur along a path lying at least partly on the surfaces of insulators which have been contaminated by foreign matter of lower breakdown strength than the originally employed materials. One reason for this is that dust or other foreign material in the atmosphere tends to be attracted toward, and deposited near, the high-voltage connections because of the attracting electrostatic fields existing at such points. In an unclean atmosphere, similar deposits may form even on surfaces of those electrical components which are at low electrical potentials.

In any event, regardless of the mechanism involved, high-voltage arcing is known to occur in such cathode-ray tube high-voltage supplies, with a sudden relatively intense flow of current through the arc. Particularly because of the high-voltage capacitor of substantial value typically employed in such high-voltage supplies, the intensity of the arc current during such break-down may be very high, the capacitor serving in effect as a relatively low impedance source of current for the arc until the condenser is heavily discharged by the arc current. Typically, when the condenser has been substantially discharged the arc will extinguish, having produced a single short, audible "tick" or "spat"; when the generator of the high-voltage has again recharged the capacitor, another such brief arc may occur. However, after the occurrence of the first arcing, or a very small number of such arcings, the deposited foreign material causing the arcing typically will have been burned-off or vaporized, so that when the capacitor is fully recharged, arcing may not occur again for a substantial period of time.

While such arcings rarely cause trouble in apparatus utilizing vacuum tubes as the active or nonlinear devices, it has been found that where the apparatus employs sensitive solid-state devices, such as transistors, solid-state rectifiers, integrated circuits, etc., such devices may be severely and even permanently damaged or burned out when one or more arcs occur in the high-voltage supply circuit. While all of the exact mechanisms by which such arcing can damage sensitive electronic components in nearby apparatus are not fully known, the following are believed to be among the most important mechanisms causing such damage.

During an occurrence of an arc such as described above, extremely high currents flow for a short interval through common ground conductors such as grounding straps or metal chassis parts, so that even though the resistance in such grounding elements is low, the product of the high current of steep waveform and the finite AC impedance of the ground circuits, can result in volt-

age differences of substantial magnitude between different parts of the elements which, in the design of the circuit, are assumed to be at the same potential, thereby in some cases applying excessive voltages to the sensitive solid-state devices, sufficient in some cases to cause such devices to burn out. In another mechanism, the intense current passing through the length of wire between the high-voltage terminal of the high-voltage capacitor and the point at which the arc occurs can produce radiated fields which may be picked up by wire leads in the circuits associated with the sensitive solid-state elements, thereby inducing voltages sufficient to cause damage to the solid-state devices. In other cases, the initial arc may occur directly to a sensitive solid-state element or its leads, or the initial arc may be to other wires or leads which are thereby raised to a potential such that secondary arcs can occur to additional leads, ultimately providing a relatively low-resistance path from the high-voltage supply to a sensitive solid-state element such as to produce damage or burn-out of the latter element.

Accordingly it is an object of the invention to provide new and useful apparatus for protecting against the effects of undesired arc-overs in a high-voltage supply system for an electronic device.

Another object is to provide a new and useful high-voltage system for cathode-ray tubes and the like.

Another object is to provide new and useful apparatus for supplying high voltage to a cathode-ray tube or the like.

Another object is to provide such apparatus which is effective in mitigating or eliminating the harmful effects of high-voltage arcs occuring in such apparatus for supplying high voltage to a cathode-ray tube or the like.

It is also an object to provide such apparatus which is inexpensive, and easy to construct and install.

It is also an object to provide new and useful high-voltage interconnecting means for use with cathode-ray tubes.

A further object is to provide new and useful apparatus for making connections to a high-voltage charge-storage device in a high-voltage supply for cathode-ray tubes.

Another object is to provide a new and useful construction of regulated high-voltage system for a cathode-ray tube or the like.

SUMMARY OF THE INVENTION

In accordance with the invention, the foregoing objects are achieved by the use of linearly-distributed resistance means for the high-voltage interconnecting means in the high-voltage supply for an electronic device such as a cathode-ray tube or the like. Preferably the linearly-distributed resistance means comprises a flexible cable having an outer high-voltage insulating covering surrounding a continuous electrically-lossy inner conductor connected to the terminals between which interconnection is desired. In the preferred embodiment, in which a high-voltage charge-storage means is supplied with high-voltage from a source, and the voltage on the charge-storage means applied to the high-voltage terminal of the electronic device, preferably all connecting means extending from the high-voltage terminal of the charge-storage means are of the linearly-distributed resistance type. As a result, the intensities of the currents produced along paths of substantial length upon the occurrence of an arc are greatly reduced, as are the component frequencies of the current variations produced by arcing, and the harmful effects of the arcing upon remote sensitive components correspondingly reduced or eliminated. By connecting similar linearly distributed resistance means in the connections to other elements of the electronic device, circuit components connected to such other elements are protected against high-voltage arc-over. By also using such linearly distributed resistance means in a feedback type or other type of high-voltage regulator, the desired protection can be obtained while at the same time minimizing variations in high voltage due to changes in the current supplied to the high-voltage terminal of the cathode-ray tube. The resistance per unit length, and the length, of the linearly-distributed resistance means employed in any given application is such that its total resistance will provide the desired protection against the effects of arcs but will not interfere seriously with the desired normal operation of the circuit in which it is connected.

BRIEF DESCRIPTION OF FIGURES

These and other objects and features of the invention will be more readily understood from a consideration of the following detailed description, taken together with the accompanying drawings, in which:

FIG. 1 is a block diagram of a television receiver in which the invention may be employed;

FIG. 2 is a schematic diagram, partly in block form, illustrating one form for the high-voltage circuits of FIG. 1, known in the prior art;

FIG. 3 is a schematic diagram like that of FIG. 2, but showing how one form of the invention may be applied thereto;

FIG. 4 is a fragmentary elevational view, partly in section, of one form of linearly distributed resistance means suitable for use in the invention;

FIG. 5 is a sectional view along lines 5—5 of FIG. 4;

FIG. 6 is a fragmentary elevational view, partly in section, of another form of linearly distributed resistance means suitable for use in the invention;

FIG. 7 is a sectional view taken along lines 7—7 of FIG. 6;

FIG. 8 is a fragmentary elevational view, partly in section, of a high-voltage connector suitable for use in applying the invention;

FIG. 9 is a schematic diagram, partly in block form, of a cathode-ray tube supply system including means for regulating the high-voltage supplied to the final anode, and constructed according to the invention;

FIGS. 10 and 13 are elevational views, partly in section, illustrating two ways of making connections to the linearly distributed resistance means; and

FIGS. 11 and 12 are plan and sectional views, respectively, of another arrangement for making connections to linearly distributed resistance means.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Turning now to the specific embodiments of the invention illustrated in the drawings by way of example only, FIG. 1 represents in broad diagrammatic form a television receiver 10, which may be a color television receiver, having image presentation apparatus in the form of a cathode-ray tube 12 on the face of which the television picture is displayed during operation. The

rectangle 16 may represent the conductive chassis on which the components are normally mounted, and the receiver in this instance is assumed to be supplied with normal transmitted television signals by way of an antenna 18. Typically the received signal will be passed through the R.F., first detector, I.F. amplifier, second detector and processing circuits 20 so as to deliver signals representative of the audio component of the received signal over line 22 to suitable audio circuits 24 and thence to a loudspeaker 26. Circuits 20 normally will also provide video frequency signals over a line 28 to the video circuits 30, whence the video signals are supplied over line 32 to the beam intensity controlling element 33 of the cathode-ray tube 12.

By way of examples to render television pictures in color the index sensing device and index-signal circuits 39 may be employed as described in my U.S. Pat. Nos. 3,013,113, and 3,305,788, issued Dec. 12, 1961 and Feb. 21, 1967 respectively. These are used to sense the instantaneous position of the cathode-ray tube beam as it scans the image-forming color phosphors, to provide signals indicative of such position, and to cause the video circuits 30, when feed with index signals over line 39A, to control the beam intensity properly as the beam traverses the phosphor stripes of different colors, thereby to portray the desired color images. Signals from the video circuits 30 are normally also supplied over a line 36 to suitable deflection and control circuits 38, which supply the cathode ray tube 12 with suitable deflection and control signals over output line 40.

The cathode-ray tube 12 is normally provided with a high-voltage electrode 42 to which high voltage is supplied in order to accelerate the electron beam with sufficient energy to produce a television image of acceptable brightness. For this purpose there are normally employed high-voltage circuits 46 and connecting means 48 for transferring the high voltage to terminal 42. In one popular form of television receiver, the high-voltage circuits are supplied with a fly-back pulse from the deflection and control circuits 38, as by way of line 50; from this fly-back pulse, the high-voltage circuits derive the high voltage required for operating the cathode-ray tube. Suitable low-voltage supply circuits 54 are also employed and supply operating voltages to the various elements of the receiver as required, including the conventional first anode 55 of the cathode-ray tube 12.

FIG. 2 shows in more detail an arrangement in accordance with the prior art by means of which the required high voltage may be produced for delivery to the cathode-ray tube. The horizontal deflection output stage 56, which typically is a part of the deflection and control circuits 38, generates the waveform of current required for horizontal deflection of the electron beam in the cathode-ray tube, this current being produced in a transformer 58 having a primary winding 60 and in many cases having a plurality of secondary windings utilized for different purposes including beam deflection; in the present example, only a single secondary winding 62 is shown, which comprises the winding with the most turns, across which the high-voltage pulse is generated during the so called fly-back interval. The secondary winding 62 is connected between a reference potential line 64, here designated as at ground potential, and the anode of a rectifying device 66. In this example the rectifying device includes an anode terminal 68 connected to the anode of a semiconductor high-voltage diode assembly 70. The high-voltage diode assembly 70 may in turn comprise a plurality of series-connected rectifying diode elements, in order to provide sufficient voltage breakdown capability to withstand the inverse voltages encountered. Terminal 71 is connected to the cathode of the diode assembly 70. Because both of the terminals 68 and 71 will normally be operating at very high voltages, they are typically mounted on high-voltage insulating supports, as by placing the entire support for the rectifying device on a structure separated from the TV chassis by high-voltage insulators.

In this example the transformer secondary 62 may be considered the original source of high voltage which, however, is normally alternating in nature, the secondary 62 and the rectifier assembly 70 together serving as a source of unidirectional high voltage, delivered between the cathode terminal 71 and the ground line 64. While the latter voltage is unidirectional, without further filtering it would tend to vary in value, whereas a relatively smooth and constant high voltage is normally desired to operate the cathode-ray tube high-voltage anode. To provide the desired smoothing of ripple or similar variations, a high-voltage charge storage device 72 is connected between high-voltage cathode terminal 71 and groundline 64, by means of the terminals 74 and 76 thereof. Normally the device 72 is a commercial high-voltage capacitor, mounted at one end to the television chassis.

It is also common, although not necessary in all cases, to employ a high-voltage regulator 78, commonly connected across the high-voltage appearing between cathode terminal 71 and ground line 64; the usual purpose of such a regulator is to compensate for tendencies of the high voltage to vary in its DC level at a slow rate due to any of a variety of factors, such as supply voltage variations, changes in cathode-ray tube current, etc. Such regulators may take any of a variety of forms, one of which will be exemplified hereinafter with reference to subsequent figures. The high voltage terminal 74 of the charge storage means 72 is connected by way of an ordinary wire 80 having suitable high voltage insulation, to the high-voltage terminal 42 of the cathode-ray tube 12.

It will be seen from FIG. 2 that there are high-voltage connecting means employed which interconnect the cathode-ray tube high-voltage terminal 42, the high-voltage terminal 74 of the charge-storage device 72, the high-voltage cathode terminal 71 of the rectifier device 66, and the high-voltage terminal of the high-voltage regulator 78. In the prior art, these normally comprise well-insulated copper conductors. As pointed out previously, even in well-designed apparatus arcs will typically occur at least occasionally from these high-voltage connecting means to points at lower potential, such as the ground line 64 or the grounded chassis 16 or other conductors operating at about the same potential. As also described previously, as a result of an high voltage arc, sequential jumps of voltage or arcings may also occur between different components or conductors operating at lower potentials in the receiver. When such a voltage breakdown or arc occurs in the prior-art system exemplified, extremely high currents flow, at least momentarily, in certain of the conductors.

For example, assume that an arc occurs from the rectifier terminal 71 to ground. Charge storage device 72

will then discharge to ground through the conductive loop comprising, in sequence, terminal 74, the high-voltage wire 81 connecting terminal 74 to terminal 71, the arc, and the return ground line connected to he other terminal 76 of the charge storage means 72. If for example this conductive loop is equivalent in inductance and resistance to a circular loop of 3-inch radius made of copper wire of 0.03 inch diameter, and assuming that the charge storage means 72 is a normal high-voltage filter capacitor having a capacitance of about 500 micromicrofarads and is charged to about 20,000 volts, a peak current of about 500 amperes will flow in this loop, and typically the capacitance of device 72 and the inductance of the leads through which it discharges will produce a resonant condition resulting in oscillations of current. The current surge occurring upon arcing, then, is of extremely high intensity and contains also strong high-frequency components; for example in the particular case assumed, the resonant frequency of the circuit may be of the order of 10mHz, and in addition will contain a relatively broad spectrum of high frequency oscillations.

Accordingly, not only may the high current produced by the arc cause excessive and damaging voltages in nearby sensitive devices due to direct conduction to the sensitive device or by means of common conductive paths such as ground paths, but in addition the fields produced by the arc may induce hundreds or even thousands of volts across nearby circuits, particularly if some of these circuits are resonant at frequencies prominent in the frequency spectrum of the arc current, or near harmonics thereof. For such reasons, sensitive devices in the television receiver, or even in equipment adjacent but not a part of the receiver, may be seriously damaged or destroyed in response to the occurrence of such arcs.

As another example, if at least a part of the high-voltage capacitance is provided by conductive coatings on the inside and outside of the cathode-ray tube, extremely large currents occurring during arcing can cause fracture and resultant damage to one or both of the conductive coatings.

Referring now to the embodiment of the invention represented in FIG. 3, in which elements corresponding to those of FIG. 2 are represented by the same numeral followed by the suffix A, it will be seen that the circuit is generally the same as that shown in FIG. 2 with the important exceptions that the connecting means by which the high-voltage terminal 74A of the charge storage means 72A is connected to rectifier cathode terminal 71A, to cathode-ray tube high-voltage terminal 42A, and to the high-voltage terminal 82 of the high-voltage regulator 78A comprise not the usual insulated copper conductor, but instead comprise respectively the linearly distributed resistance means 83, 84 and 86 each designated by the usual symbol for a resistor plus broken parallel lines on either side thereof suggestive of the high-voltage insulation employed, so as to distinguish the elements from ordinary resistors. These connecting means are denoted as linearly distributed resistance means to distinguish them from so-called lumped or discrete resistance elements, and are characterized in that they exhibit a predetermined resistance per unit length. Preferably each is flexible and in the form of an outer high-voltage insulating covering around a continuous electrically-lossy resistive inner conductor.

Typical forms for the linearly distributed resistance means are shown in one embodiment in FIGS. 4 and 5, and in another form in FIGS. 6 and 7. As shown in FIGS. 4 and 5, for example, an outer insulating covering 88 of a suitable rubber or plastic material, preferably flexible, surrounds an electrically lossy resistive inner conductor or core 90 composed of a bundle of central substantially nonconductive flexible fibrous filaments 92, having a thin coating 93 of a moderately conductive material such as conductive carbon, preferable in the form of graphite, deposited on its outer surface; or, alternatively, conductive carbon dust may be dispersed within the interstices of the bundle of fibrous filaments. The conduction characteristics of carbon and the amount of carbon employed are typically such as to produce an electrical resistance of about 1,000 to 5,000 ohms per linear foot of the cable, depending on the exact construction of the cable. The actual resistance value is not generally critical in the practice of my invention. In using the cable of FIG. 4, a connection is made at each end to the carbon 93 by any suitable clamping or lug arrangement.

FIGS. 6 and 7 illustrate a cable similar to that of FIG. 4, corresponding parts being indicated by corresponding numerals with the suffix A, comprising an outer high-voltage insulating covering 88A and an inner, lossy, resistive conductor or core 90A; however, in this case the inner conductor is not coated with a conductive material, but instead is impregnated with the conductive material, such as conductive carbon, dispersed substantially uniformly along its length. Rubber, loaded with an excess of conductive carbon, is suitable. While again connection may be made to opposite ends of the inner conductor by extending the inner-conductor beyond the high-voltage insulation and securing it to appropriate clamps or lugs, it is also possible to use a connector of a type provided with a sharp prong which is inserted into the center of the inner conductor as will be described with reference to FIG. 13.

The cable may in some cases have other layers of insulation, layers of sheathing, etc. to achieve the desired insulation and partial conduction in an economical manner, or to assist in the steps of manufacture of the cable. In the short runs of cable usually employed in the high-voltage supply for a cathode-ray tube, the cable is typically self-supporting between its end connections and will maintain its configuration when placed in operating position, thereby enabling uniformity of high-voltage lead dress and corresponding uniformity and control of the arcing characteristics, to a substantial extent.

Preferably the linearly distributed resistance means extends the entire distance between the elements which it interconnects, and the lengths of any ordinary conductors or connectors used in series with them are kept to a minimum, particularly in the connection to the high-voltage terminal 74A of the charge storage means 72A.

The effect of this arrangement is to limit the arcing to current paths which are either extremely short or else include substantial series resistance in them. This is accomplished without introducing an amount of resistance in the interconnecting leads such as would interfere with the desired operation of the high-voltage supply. For example, if one uses a cable having a resistance of 1,500 ohms per foot, a 6 inch length for the cable 83 between the rectifier cathode terminal 71A

and the high-voltage terminal 74A of the capacitor 72A will produce a series resistance of about 750 ohms, and if for example the peak current through the rectifier tube 70A is of the order of 30 milliamperes this will cause only a 22.5 volt drop in the high-voltage of perhaps 20,000 volts, a drop which is negligible. A similar cable about 8 inches in length used as cable 84 between the high-voltage terminal 74A of the energy storage device and the high-voltage terminal 42A of the cathode-ray tube will have a resistance of about 1,000 ohms, and when the cathode-ray tube anode current is about 1 milliamphere the resultant voltage drop will only be about 1 volt, again a negligible amount and in fact much less than the variation normally occurring in the high-voltage even when regulated. Accordingly the use of the linearly distributed resistance cables does not interfere with normal operation.

From the foregoing it will be appreciated that should an arc occur, for example, from the high-voltage terminal 42A of the cathode-ray tube to ground, cable 84 will produce a resistance of about 1,000 ohms in series with the current path for the arc, as compared with a very small fraction of an ohm when ordinary copper conductors are utilized, resulting in a proportionate reduction in the arc current, typically to values of the order of an ampere or so. In addition, because of the presence of the distributed cable resistance in series in the circuits from the capacitor, the radiated frequency components produced during arcing are reduced in frequency very greatly, for example by about 500 times, placing much of the radiated energy in the 20,000 Hz area in a case of a 500 picofarad high-voltage condenser, rather than in the 10 mHz frequency region, and the radiations are therefore much less likely to induce harmful magnitudes of voltage in nearby circuitry.

Similarly, should an arc occur from the cathode terminal 71A of the rectifier to ground, the current to the arc flowing from the capacitor 74A will have to flow through the substantial resistance of the intervening resistive cable 83, and the currents produced as well as the frequencies radiated will be greatly reduced from that obtaining when ordinary copper conductor is utilized. If, as usual, the high voltage terminal of the capacitor is exposed, it is possible for an arc to occur directly from that terminal to the ground terminal of the capacitor, or to a very nearby ground. However, the current loop through which the arc current would then flow is very small in area, and is limited to paths which are not generally in common with other current loops in the television receiver. In addition, when the conductive material in the cable is electrically lossy, it tends to absorb rather than to conduct the very high frequency electrical oscillations, which are produced upon the occurrence of an arc from the high-voltage terminal of the capacitor, and coupling of such high-frequency energy to sensitive and easily-damaged solid-state devices nearby is thereby greatly reduced.

Also shown in FIG. 3 is an additional pair of linearly distributed resistance means in the form of the two resistive cables 95 and 96 connected respectively to the connecting pins or socket terminals for the control grid and the first anode of the cathode-ray tube 12, the opposite terminals 95*a* and 96*a* of the cables being connected to the circuits normally supplying voltage to the control grid and first anode. Cables 95 and 96 provide substantial series resistance to current flow in the event that there is a voltage breakdown from the second anode 42A (or from elements connected to it within the cathode-ray tube) to either the control grid or first anode, thereby protecting the circuits supplying the control grid and first anode as well as preventing secondary arcs or high-energy radiations from being produced in such circuits upon the occurrence of such voltage breakdown. A similar cable may be used for supplying voltage or current to focusing electrodes, if such are employed. In each case the cable may be like that described previously, with a length and resistance per unit length to provide an overall resistance which is either small enough so as not to interfere with the normal operation of the circuit and electrode, or which alternatively, is of a finite non-negligible value which is properly taken into account in the design of the sources of voltages or signals which feed the cables. In the case illustrated in FIG. 3 it is assumed that the cathode of the cathode-ray tube 12 is grounded either directly or through a low impedance B+ bypass condenser, and therefore ordinarily the cathode lead will not require separate protection.

FIG. 8 illustrates one manner in which cable 84 may be connected to the button of second anode terminal 42A. A tubular metal member 100 is provided at one end with a spring clip 102 formed integrally therewith and adapted to slip over the generally-spherical button of the second anode terminal. The metal member is placed over the end of cable 84, crimped to it at 104, and a tab 106 is formed and bent inward from one side of the metal member through the insulating covering 105 until it contacts the inner partially-conductive core 107. An insulating hood 108 of rubber or the like may be secured around the end of the cable by a crimped metal band 109 and extend forwardly against the cathode-ray tube to minimize corona discharge. Contact is made by merely pressing the spring clip against and over the anode terminal button.

FIG. 9 illustrates another arrangement of the invention which is similar to that shown in FIG. 3 with the exception that a preferred general form and connection of the high-voltage regulator is shown in detail. Parts corresponding to those in FIG. 3 are indicated by the same numerals but with the suffix B instead of A.

The high-voltage regulator system in this example comprises a shunt regulator 112 including a shunt regulator tube 114 having an anode terminal 116, a grid control terminal 118 and a cathode terminal 120. The anode terminal 116 is connected to the resistive cable 86B, the cathode terminal 120 is connected to the ground line 64B and the grid control terminal 118 is connected to the cathode-ray tube high-voltage terminal 124 by a feedback circuit which responds to increases in the voltage supplied to the terminal 124 to render the tube 114 more highly conductive and thus counteract the tendencies for increase of the voltage at terminal 124.

More particularly, the high-voltage terminal 124 is also connected to the ground-potential line 64B by way of the series combination of resistive cable 125, the ordinary lumped-circuit resistor 126, the resistive cable 128, and the additional ordinary lumped-circuit resistor 130. Resistors 126 and 130 have values such as to produce the desired voltage level at tap point 134 and may each be large in resistance value compared with the resistances of cables 125 and 128 so as to be the principal determinative elements in determining the ratio of the voltage at tap point 134 to the voltage at

terminal 124; alternatively, resistors 126 and 130 may be omitted and cables 125 and 128 made with the appropriate resistance values to produce the desired tap voltage.

The tap point 134 is connected by resistive cable 140 to the high-voltage terminal of the voltage-reference device 142; in this example a so-called corona discharge tube is used, but a zener diode or a gaseous glow regulator tube could also be used. The cathode of the discharge tube is connected to the ground potential line 64B by way of the parallel combination of ordinary lumped-circuit resistor 150 and shunt capacitor 152. The cathode of tube 142 is also connected through an amplifier 152 to the grid of the tube 114. In general, the voltage at tap 134 varies in proportion to changes in the high-voltage at cathode-ray tube terminal 124, the corona discharge tube 142 drops the DC level of the voltage at tap 134 to a level suitable for application to amplifier 152 and thence to the grid of tube 114, and the desired negative feedback circuit is thereby completed so as to counteract tendencies for variation in the high voltage at terminal 124.

The values of the resistive elements in series with the voltage reference device 142 are preferably selected in a manner known in the art so that the corona discharge tube operates in a steep portion of its current-voltage characteristic. Capacitor 152 is a low-voltage capacitor used to limit the voltage applied to the amplifier in case of an arc across the voltage reference device 142. For this purpose capacitor 152 preferably has a value several times that of the high-voltage charge storage device 72B, for example 0.1 microfarad, and resistor 150 is preferably relatively small in value to aid in limiting the voltage across it in case of an arc across the corona discharge tube. While the resistive cables 140 and 128 are not essential in all cases, they do provide additional protection against the effects of arcing, as described hereinbefore.

It is particularly noted that since the voltage regulator system is connected to operate in response to changes at the high-voltage terminal 124 of the cathode-ray tube, its regulating action is effective to maintain the latter voltage substantially constant despite any changes in the latter high voltage which may tend to be produced by variations in supply voltage or by variations in the current of the cathode-ray tube. Accordingly, the slight variations in high-voltage at the cathode-ray tube second anode which the use of the resistive cables may in some cases tend to produce are effectively eliminated.

FIG. 9 also shows not only resistive cables 95B and 96B for the cathode-ray tube grid and first anode, but also a similar protective cable 160 connected at one end to the cathode of the tube 12, as it may be used especially in cases where the cathode is not directly grounded but instead is connected to circuits for biasing and/or applying signal to the cathode.

FIG. 10 shows how a pair of resistive cables 196 and 198 of the type illustrated in FIG. 6 may be connected to a common terminal 200, which may be a metal cap electrically connected to one terminal of a capacitor 202. The cap is provided with a pair of inwardly-stamped spikes 206 and 208 positioned opposite a pair of openings 210 and 212 respectively, formed also by inward stamping of the cap. The cables are inserted until the spikes penetrate the inner resistive cores of the cables, and the circular inwardly-bent tabs 214 and 216 act on the outer insulating coverings of the cables to help hold the cables against any pull-out forces.

FIGS. 11 and 12 show another way in which a plurality of resistive cables 220, 222, 224 may be interconnected. An upwardly-open metal cap 226 is located on an insulating support 228 and provided with side openings such as 230, 232, 234 for receiving the cable ends. A metal contact member 238 having downwardly-extending peripheral teeth is positioned within the cup and forced downwardly against the cables by a screw 240 threaded into insulator 228, until the teeth penetrate to the partially-conductive cores of the cables.

FIG. 13 illustrates how a resistive cable such as is shown in FIGS. 4 or 6 can be connected to a printed-circuit board 250 having a copper layer 251 on the underside for making connections to other elements. Basically, a metal pin 260 is affixed to the board in an upright position and the cable pushed onto it so that the pin pierces the inner partially-conductive core or region of the cable. In the form shown, a spring clip arrangement 262 aids in retaining the cable, and comprises a concentric generally-cylindrical clip member of spring material secured to the board and into the sides of which several slits such as 266 have been cut to permit formation of spring fingers such as 268 protruding radially inward to bear against the cable. Preferably the upper edges of the fingers are rolled over to minimize corona discharge therefrom. In the form shown, the pin 260 extends through the board 250 and layer 251 and is soldered to the layer 251 at its lower end, and the cup member and pin are integral.

While the invention has been described with particular reference to specific embodiments in the interest of complete definiteness, it will be understood that it may be embodied in any of a large variety of forms diverse from those specifically shown and described, without departing from the scope and spirit of the invention as defined by the appended claims.

What is claimed is:

1. In a cathode-ray tube display system, high-voltage supply circuits comprising electrostatic high-voltage charge storage means having a high-voltage terminal, a current source having a high-voltage terminal for supplying charge to said charge-storage means, a cathode-ray tube having a high-voltage terminal, means for interconnecting all of said terminals to supply high voltage to said tube, and sensitive semiconductor components subject to damage in the event of their overload due to an electrical arc in said high-voltage circuits,

the improvement in accordance with which said interconnecting means comprises at least two current-carrying circuits each of which comprises a distributed resistance cable having a resistance sufficiently low to enable normal high-voltage circuit functions in the absence of an arc but sufficiently high to reduce the current of said arc many fold, to a level below that for which said damaging overload will occur.

2. A display system according to claim 1, in which the distributed resistance of each of said cables extends at least two-thirds of the distance between those of said terminals which it interconnects

3. A display system in accordance with claim 1, in which the distributed resistance of each of said cables extends substantially the entire distance between those of said terminals which it interconnects.

4. In a television receiver comprising a cathode-ray tube having a high-voltage terminal, high-voltage rectifier means having a high-voltage terminal, high-voltage capacitor means having a high-voltage terminal, high-voltage leads interconnecting said high-voltage terminals to supply high voltage from said rectifier to said tube, and low-voltage semiconductor elements positioned so as to be subject to damage in response to large surges of arcing current in any of said leads:

the improvement according to which each of said leads connected to said high-voltage terminal of said capacitor comprises a flexible distributed-resistance cable, the resistance and disposition of each said cable being such as to reduce the current therethrough in the event of arcing to a level below that productive of said damage.

5. The apparatus of claim 4, wherein said capacitor means comprises a majority of the capacitance for filtering said high voltage.

6. The apparatus of claim 4, comprising regulator means for regulating said high voltage, and distributed resistance cable means supplying said regulator means with said high voltage.

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