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CIRCUIT ARRANGEMENT FOR PRODUCING A COMPARATIVELY HIGH VOLTAGE UTILIZING VOLTAGE DEPENDENT RESISTORS

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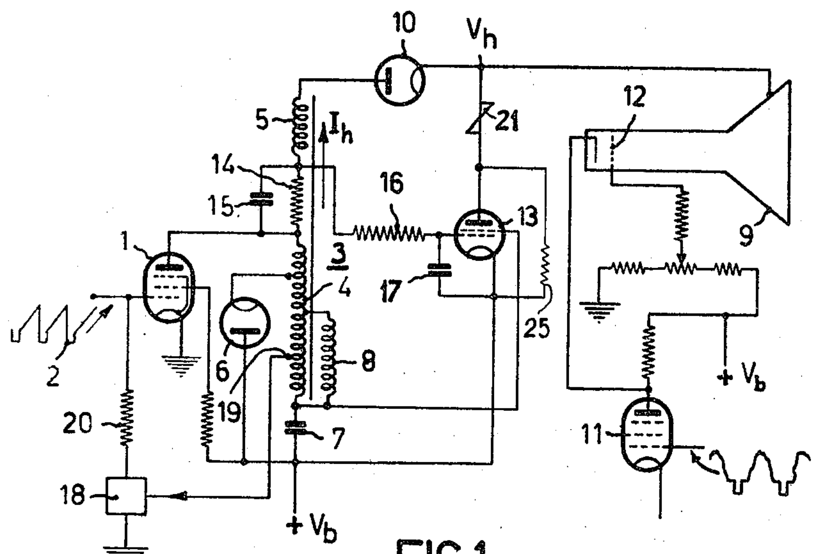

FIG.1

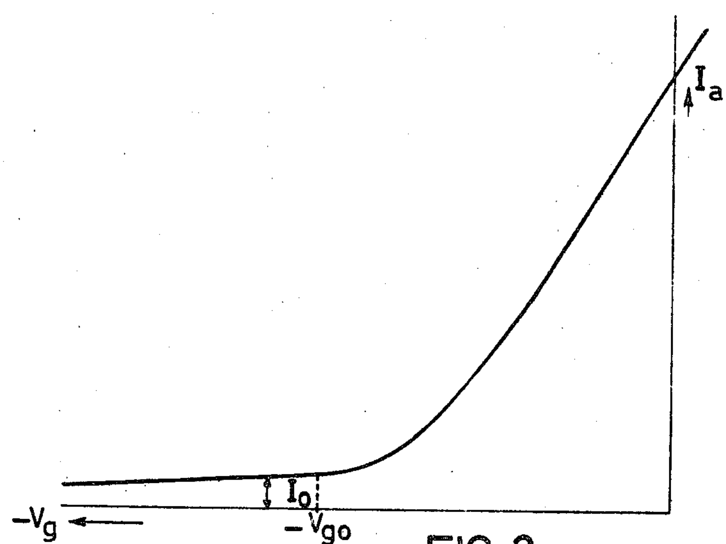

FIG. 2

INVENTOR
GERRIT H. P. ALMA.
WILLEM BUSSCHER.
BY
Frank R. Jifari
AGENT

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CIRCUIT ARRANGEMENT FOR PRODUCING A COMPARATIVELY HIGH VOLTAGE UTILIZING VOLTAGE DEPENDENT RESISTORS

Gerrit Hendrik Petrus Alma and Willem Busscher, Eindhoven, Netherlands, assignors to North American Philips Company, Inc., New York, N.Y., a corporation of Delaware

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11 Claims. (Cl. 323—22)

This invention relates to circuit arrangements for stabilizing a voltage by means of a ballast tube connected in parallel with the load on the circuit arrangement and controlled in opposite sense to, and dependently upon, the variations in the said load.

Such circuit arrangements are often used in television receivers for producing the high voltage for supplying the final anode of the picture tube. The high voltage is stabilized by means of the ballast tube so that variations in the beam current through the display tube, which constitutes the load for the circuit arrangement, do not produce variations in the high voltage produced.

However, the use of such a ballast tube has the disadvantage that it must be capable of dissipating a high power, since with the beam current cut off the full power delivered by the high voltage circuit must be dissipated by the ballast tube.

In addition, the full high voltage is set up across the ballast tube which must therefore be rated for a high breakdown voltage.

The foregoing requirements necessitate the use of a tube having very large dimensions. Due to its large bulb, the tube differs from the kind of tubes normally employed so that such bulbs would have to be manufactured either by hand, or on a special machine. Furthermore, the dimensions of the electrodes differ greatly from those of tubes normally employed and the manufacture of such a ballast tube would thus become extremely expensive.

In order to obviate these disadvantages, a circuit arrangement according to the invention is characterized by the addition of a voltage-dependent resistor connected in series with the anode of the ballast tube.

In order that the invention may be readily carried into effect, a possible embodiment of a circuit arrangement according thereto will now be described in detail, by way of example, with reference to the accompanying diagrammatic drawing, in which:

FIGURE 1 is a circuit diagram of one embodiment of the invention; and

FIGURE 2 shows a desired anode current-grid voltage characteristic of a ballast tube as used in the circuit of FIGURE 1.

In FIGURE 1, tube **1** constitutes the output stage of a line-deflection circuit in a television receiver. The control grid of tube **1** has applied to it a control voltage **2** which periodically releases tube **1**. The anode circuit of the tube **1** includes a line-output transformer **3** comprising a primary winding **4** and a secondary or high voltage winding **5**. Connected to a tapping on the primary winding **4** is the cathode of a series-booster diode **6**, the anode of which is connected to the positive terminal of a voltage source delivering a supply voltage of V_b volts. One end of the primary winding **4** is connected to one electrode of a capacitor **7**, the other electrode of which is also connected to the positive terminal of the voltage source. As is well-known, the capacitor **7** is associated with the circuit of the series-booster diode and a positive direct voltage considerably higher than the supply voltage V_b is set up at the junction point of the capacitor **7** and the primary winding **4**. Also connected to the primary winding **4** is a line-deflection coil **8** which is traversed by the sawtooth deflecting current produced, by means of which the beam current through the picture tube **9** is deflected in a horizontal direction.

The pulses produced during the fly-back period of the sawtooth current are stepped up by means of the winding **5**. A rectifier diode **10** is connected to the free end of the high voltage winding **5** and rectifies the pulses resulting in a high voltage V_h which serves to feed the final anode of the display tube **9**.

As is well-known, the beam current through the picture tube **9** may vary in several ways. This may be effected, on the one hand, by means of the video-signal which, in the present example, is supplied through a video-output tube **11** to the cathode of the display tube **9** or, on the other hand, by varying the bias potential at the Wehnelt cylinder **12** for adjusting the background brightness of the picture reproduced by the picture tube **9**.

A high voltage generator as described above for developing a high voltage V_h always has a comparatively high internal resistance, for example, in the order of 4 or 5 MΩ. Variation in the beam current would thus result in varition of the voltage V_h produced. This is undesirable. More particularly, in colour-television receivers, such variation in the high voltage V_h results in color distortion because the convergence circuits, which are always present in a colour-television receiver, no longer operate satisfactorily.

It is known, in order to stabilize the high voltage V_h, to connect a ballast tube **13** in parallel with the picture tube **9** and to control this tube so that upon an increase in beam current, the current through the ballast tube decreases, and conversely, so that the sum of the two currents remains substantially unchanged under all conditions. Consequently, the voltage drop across the internal resistance of the voltage source V_h also remains unchanged despite the variations in beam current.

The ballast tube **13** may be controlled, for example, by means of a network comprising a resistor **14** and a capacitor **15** connected between the primary winding **4** and the secondary winding **5**. The resistor **14** is then traversed by the direct current I_h from the high voltage circuit so that the voltage drop across the resistor **14** is a measure of the said direct current or load current I_h.

The capacitor **15** serves to pass the pulses to the secondary winding **5**.

The cathode of the ballast tube **13** is connected to the junction of winding **4** and capacitor **7** and the control grid is connected, through a smoothing resistor **16**, to the junction point of resistor **14** and winding **5** and, through a smoothing capacitor **17**, to the cathode.

As previously mentioned, a positive direct voltage is set up across the capacitor **7** and the resistor **14** must therefore be so proportioned that the voltage drop across it is higher than that across the capacitor **7** so that the control grid is, under all conditions, negative relative to the cathode.

FIGURE 1 also shows a stabilizing circuit **18** which is controlled from a tapping **19** on the primary winding **4** and which develops a negative control-voltage which is applied through a resistor **20** to the control grid of the line-output tube **1**. The stabilizing circuit **18** serves to stabilize the sawtooth current through the deflection coil **8** and the voltage across the capacitor **7** in the event of variation in the supply voltage V_b, or in case of ageing of the tubes **1** and **6**, and in case of temperature variations. If the load on the high-voltage circuit would not vary, the high voltage V_h would thus also remain constant. The purpose of ballast tube **13** is to stabilize the voltage V_h against load current variations.

If the ballast tube **13** were connected directly between the cathode of the rectifier diode **10** and the positive terminal of the supply voltage source, substantially the full high voltage would be set up across the ballast tube **13**. In fact, V_b is many times smaller than V_h, so that V_b is negligible relative to V_h.

Assuming, for example, that $V_h=25$ kilovolts, a voltage of 25 kilovolts would be set up across the ballast tube which would thus have to be rated for a breakdown voltage higher than this value. This is a very stringent requirement and, in addition, this requirement must be made irrespective of the current traversing the ballast tube **13**.

In addition, the ballast tube **13** must be capable of dissipating the power supplied by the high-voltage circuit when the beam current through the picture tube **9** is cut off (black level). Assuming that the current then flowing through the ballast tube **13** is about 1 ma., it is necessary for the tube to dissipate 25 watts. This requirement also is high.

The foregoing implies that a very large tube would be required which is difficult to construct. In addition, because of its large bulb, such a tube differs from the kind of tubes normally employed so that such bulbs would have to be manufactured either by hand, or on a special machine. As a matter of fact, the electrodes, too, differ from those of the tubes normally employed so that it will be evident that the manufacture of such a ballast tube would become extremely expensive.

A first improvement may be obtained by including a series-impedance in series with the ballast tube **13**. Maintaining a constant load current as such is not influenced thereby since control of the ballast tube **13** ensures that the direct current delivered by the high-voltage circuit remains substantially unchanged irrespective of the intensity of the beam current through the picture tube **9**.

If, for example, an ohmic resistor R of 22 megohms is chosen as the series impedance, it follows from Table I that the maximum dissipation of the ballast tube **13** is reduced from 25 watts to 7.1 watts. This maximum dissipation occurs for a current of about 0.56 ma.

Table I

[With a series-resistor R of 22 megohms]

I ballast, ma.	V_{tube}, kv.	V_r, kv.	W_{tube}, watts
1.00	3.0	22.0	3.0
0.56	12.5	12.5	7.1
0.50	14.0	11.0	7.0
0.25	19.5	5.5	4.9
0.10	22.8	2.2	2.3
0.00	25.0	0.00	0.0

A considerable improvement however is obtained if, according to the invention, instead of an ordinary linear resistor, a voltage-dependent resistor **21** (a so-called V.D.R. resistor) is connected in series with the ballast tube **13**, as shown in FIGURE 1.

Table II

[With V.D.R. connected in series $\rightarrow V_{VDR}=CI^{\beta}_{ballast} \rightarrow C=82.10^3\Omega^{-1}$, $\beta=0.19$]

$I_{VDR}=I_{ballast}$, ma.	V_{tube}, kv.	V_{VDR}, kv.	W_{tube}, watts
1.00	3.0	22	3.00
0.96	4.0	21	3.84
0.50	6.5	19.5	3.25
0.25	7.7	17.3	1.90
0.10	10.0	15.0	1.00
0.00	25.0	00.0	0.00

In fact, from Table II it appears that the maximum dissipation of the ballast tube **13**, which now occurs for a current of about 0.96 ma., is reduced to 3.84 watts, which is again much less than the 7.1 watts for which the ballast tube must be rated when using a linear or ohmic resistor.

According to the invention, a further improvement may be obtained if the current through the ballast tube is controlled back to a predetermined minimum value of I_0 amp. instead of a value zero for the maximum beam current. Assuming that $I_0=0.1$ ma., it follows from Table I that the maximum voltage set up across the ballast tube **13** is about 22.8 kilovolts when using an ohmic resistor of 22 megohms, and from Table II that this maximum voltage drops to 10 kilovolts when using a voltage-dependent resistor **21**.

From the above it follows that by using the two steps, that is to say:

(1) Connecting in series a votlage-dependent resistor **21**

(2) Preventing the current through the ballast tube **13** from decreasing below a value of I_0 amp.

the dissipation requirement is reduced from 25 watts to about 3.84 watts and the breakdown-voltage requirement from 25 kilovolts to 10 kilovolts.

It has thus become possible considerably to reduce the dimensions of the ballast tube **13** to the size which is common practice for ordinary television receiver tubes.

In the present example, in which a triode is chosen as the ballast tube **13**, the voltage drop across the voltage-dependent resistor **21** is set to 22 kilovolts for a current of 1 ma. through the ballast tube **13**.

This is obtained in that the voltage-dependent resistor **21**, the properties of which may be written by the formula

$$V=CI^{\beta} \quad (1)$$

is proportioned so that the constants C and β are given by

$$C=82(10^3)\Omega^{-1} \text{ and } \beta=0.19$$

By increasing C, it is possible to reduce the maximum dissipation of the tube **13**, which may be calculated with the aid of the formula

$$W_{\text{tube max.}}=\frac{\beta}{\beta+1}\cdot V_h\left(\frac{V_h}{C(\beta+1)}\right)^{1/\beta} \quad (2)$$

The voltage across the ballast tube **13** is given by

$$V_{\text{tube}}=V_h-CI^{\beta} \quad (3)$$

If I becomes smaller, it follows from Formula 3 that the voltage across the tube increases. Consequently, the maximum voltage across the tube **13** occurs for the minimum permissible current I_0 so that it will be evident that this maximum voltage may be decreased by increasing the constant C of VDR **21**.

Both the maximum dissipation and the breakdown voltage for which the ballast tube must be rated may be decreased by increasing C. However, in this case, the anode voltage is also smaller during the occurrence of the maximum current. A further increase of the constant C may therefore give rise to a situation in which the maximum anode current can no longer flow due to the reaction of the anode voltage upon the anode current (penetration factor), unless the negative grid-bias is exceptionally decreased, thus involving a risk of unwanted grid current.

The foregoing may be avoided by using a screen-grid tube instead of a triode as the ballast tube so that the current control is solely determined by the voltage at the control grid despite the high value of the voltage-dependent resistor **21**. In fact, as is well-known, the anode current of such a screen-grid tube is much less dependent upon the anode voltage than in the case of a triode. (The screen-grid tube used may be, for example, a tetrode or a pentode.) If the cathode of the ballast tube **13** is connected to the lower side of the capacitor **7**, then the screen grid may be connected to the junction point of the primary winding **4** and the capacitor **7**, as illustrated in FIG. 1, for obtaining the desired supply voltage. As an alternative, it would be possible to connect the cathode of the ballast tube to earth and to connect the screen grid to the ordinary supply voltage of V_b volts.

It will also be evident that if the current through the ballast tube must not drop below I_0 ampere, the maximum current traversing it must also be slightly increased with respect to the case in which the ballast tube **13** is completely cut off when the beam current through the picture tube **9** is at maximum.

In the example shown, this implies that I_{max} must be raised from 1 ma. to 1.1 ma., if $I_0=0.1$ ma. From this it follows that if the beam current through the picture tube **9** is 1ma., the current through the ballast tube **13** assumes a value $I_0=0.1$ ma., and if the beam current is cut off, the current through the ballast tube **13** is about 1.1 ma. It is therefore ensured that the sum of the two currents is, under all conditions, about 1.1 ma. so that the voltage drop across the internal resistance of the high voltage circuit always remains constant and hence the value of the high voltage V_h produced does not substantially vary despite variations in the beam current.

The following step may be taken to prevent the current through the ballast tube **13** from decreasing below the value I_0.

The resistor **14** may be so proportioned that the voltage at the control grid of the ballast tube **13** never decreases below the cut-off voltage even for the maximum beam current possible through the picture tube **9**.

However, it is preferable for the ballast tube **13** itself to be constructed so that the anode current I_a cannot decrease below a value I_0 irrespective of the extent of the increase in negative grid-bias V_g at the control grid of this tube. This is illustrated in FIGURE 2, which shows a desired I_a-V_g characteristic of the ballast tube **13**. As can be seen from this figure, the mutual conductance of tube **13** becomes substantially zero when the control-grid voltage reaches the value $-V_{g0}$ by which an anode current of I_0 ampere keeps flowing.

Such a characteristic may be obtained, for example, by providing the control grid with one or more additional apertures. For this purpose, one or more turns may be omitted in winding the grid wire so that, as it were, a diode which continuously conveys a current I_0 is connected in parallel with the ballast tube proper. The same result could be obtained, for example, by connecting a fixed resistor **25** in parallel with the ballast tube **13**. When the ballast tube is completely cut off, this resistor is traversed by the current I_0.

In the example shown, the control grid is wound so that the grid voltage indicated in FIGURE 2 is

$$V_{g0}=-3 \text{ volts}$$

This affords the advantage that I_0 is determined by the tube itself so that with a correct choice of the associated voltage-dependent resistor **21** the requirement for the maximum permissible breakdown voltage is fulfilled, otherwise the choice of the resistor **14** would also play a part.

In conclusion, it is mentioned that the stabilizing circuit **18** is not strictly necessary. If it is desired to take only the variations in beam current into account, a control circuit with the ballast tube **13** alone suffices.

In addition, the use of the circuit arrangement need not be limited to television receivers. The inventive concept may be used in all those cases where a voltage is produced which is stabilized by means of a ballast tube. In fact, such circuit arrangements may also be used for stabilizing the high voltage in X-ray equipment and radar installations.

What is claimed is:

1. A voltage regulating circuit comprising a source of voltage having first and second terminals, load circuit means connected between said terminals, a ballast device having at least output, common and control electrodes, a voltage-dependent resistor, means serially connecting said resistor and the output-common electrode path of said device between said terminals, and means connected to said control electrode for controlling the current through said path in the opposite sense with respect to current in said load circuit means.

2. A voltage regulating circuit comprising a source of voltage having first and second terminals, load circuit means connected between said terminals, an electron discharge device having at least cathode, anode and control grid electrodes, a voltage-dependent resistor, means serially connecting the cathode-anode path of said discharge device and said voltage-dependent resistor between said first and second terminals, means for deriving a voltage dependent upon current through said load circuit means, and means applying said dependent voltage to said control grid electrode whereby current through said discharge device varies in the opposite sense with respect to current in said load circuit means.

3. A voltage regulating circuit comprising a source of voltage of high impedance, a load circuit connected to said source, an electron discharge device having at least cathode, control grid and anode electrodes, a voltage-dependent resistor, means serially connecting said resistor and the anode-cathode path of said device in parallel with said load circuit, means for deriving a voltage dependent upon current flow in said source, and means for applying said dependent voltage to said control electrode whereby current variations in said load circuit produce current variations in the opposite sense in said device.

4. A voltage regulating circuit comprising a source of voltage of high impedance, a load circuit connected to said source, an electron discharge device having at least cathode, control grid and anode electrodes, a voltage-dependent resistor, means serially connecting said resistor and the anode-cathode path of said device in parallel with said load circuit, means for deriving a voltage dependent upon current flow in said source, means for applying said dependent voltage to said control electrode whereby current variations in said load circuit produce current variations in the opposite sense in said device, and means for maintaining a predetermined minimum current flow in said resistor.

5. The circuit of claim **4**, in which said means for maintaining a predetermined minimum current comprises resistor means connected between said anode and cathode electrodes.

6. The circuit of claim **4**, in which said means for maintaining a predetermined minimum current comprises aperture means in said control grid electrode whereby anode current flow in said tube is maintained when said control grid electrode has a sufficiently low potential to reduce the transconductance of said device to zero.

7. A high voltage regulating circuit comprising a transformer having a primary and a secondary winding, means for providing a periodic current flow in said primary winding, a first series circuit comprising said primary winding, resistance means, and said secondary winding in that order, a second series circuit comprising serially-connected rectifier means and load means, means connecting said first and second series circuits in parallel, an electron discharge device having at least cathode, control grid and anode electrodes, a third series circuit comprising a voltage-dependent resistor and the cathode-anode path of said device, means connecting said third series circuit in parallel with said load means, and means connecting the junction of said resistance means and secondary winding to said control grid electrode, whereby current in said cathode-anode path varies in the opposite sense with respect to current flow in said load means.

8. A high voltage regulating circuit comprising a transformer having a primary and secondary winding, means for providing a periodic current flow in said primary winding, a first series circuit comprising said primary winding, resistance means, and said secondary winding in that order, a second series circuit comprising serially-connected rectifier means and load means, means connecting said first and second series circuits in parallel, an electron discharge device having at least cathode, control grid and anode electrodes, a third series circuit comprising a voltage-dependent resistor and the cathode-anode path of said device, means connecting said third series circuit in parallel with said load means, means connecting the junction of said resistance means and secondary winding to said control grid electrode, whereby current in said cathode-anode path varies in the opposite sense with respect to current flow in said load means, and means for maintaining a predetermined minimum current flow in said third series circuit.

9. The circuit of claim **8**, in which said device is a screen grid tube.

10. A voltage regulating circuit comprising a source of voltage having first and second terminals, load circuit means connected between said terminals, a ballast device comprising first and second electrodes defining a current path through said device and a control electrode, a non-linear voltage-dependent resistor, means serially connecting said device current path and said voltage-dependent resistor between said first and second terminals, means for deriving a control voltage which varies with the magnitude of the current flow in said load circuit means, means for applying said control voltage to said control electrode in a sense to control the current through said path in the opposite sense with respect to current in said load circuit means, and means for maintaining a predetermined minimum current flow in said resistor.

11. A voltage regulating circuit for a high impedance source of high direct voltage, said source including a pair

of terminals, comprising a load circuit connected across said terminals, an electron discharge device having a control electrode and an anode and a cathode which define a current path through said device, a bidirectional non-linear voltage-dependent resistor, means serially connecting the anode-cathode path of said discharge device and said voltage dependent resistor across said terminals, means for deriving a direct voltage which varies with the total load current supplied by said source, means for applying said direct voltage to said control electrode in a sense such that current variations in said load circuit produce current variations in the opposite sense in said device, and means serially connected with said voltage-dependent resistor for maintaining a predetermined minimum current flow in said resistor.

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LLOYD McCOLLUM, *Primary Examiner.*

ARTHUR GAUSS, MILTON O. HIRSHFIELD, *Examiners.*