May 11, 1954 L. S. LAPPIN 2,678,391

PROTECTIVE CIRCUIT

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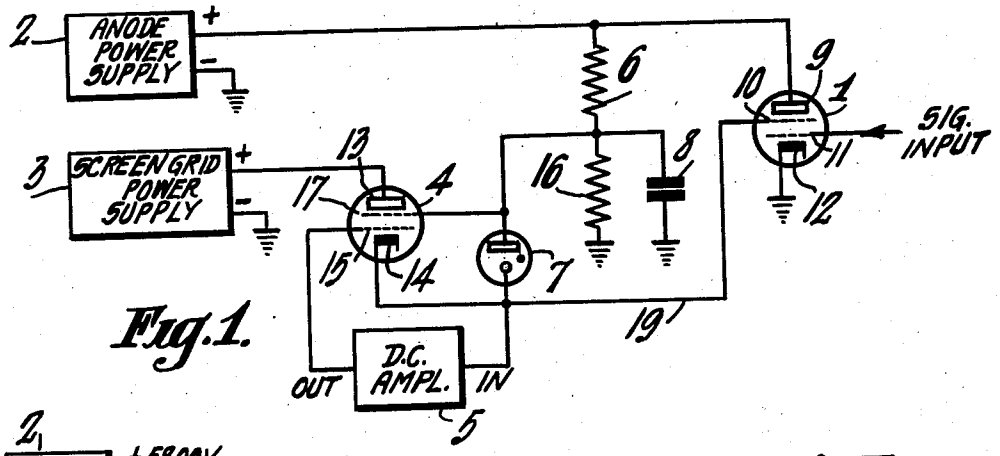


Fig. 1.

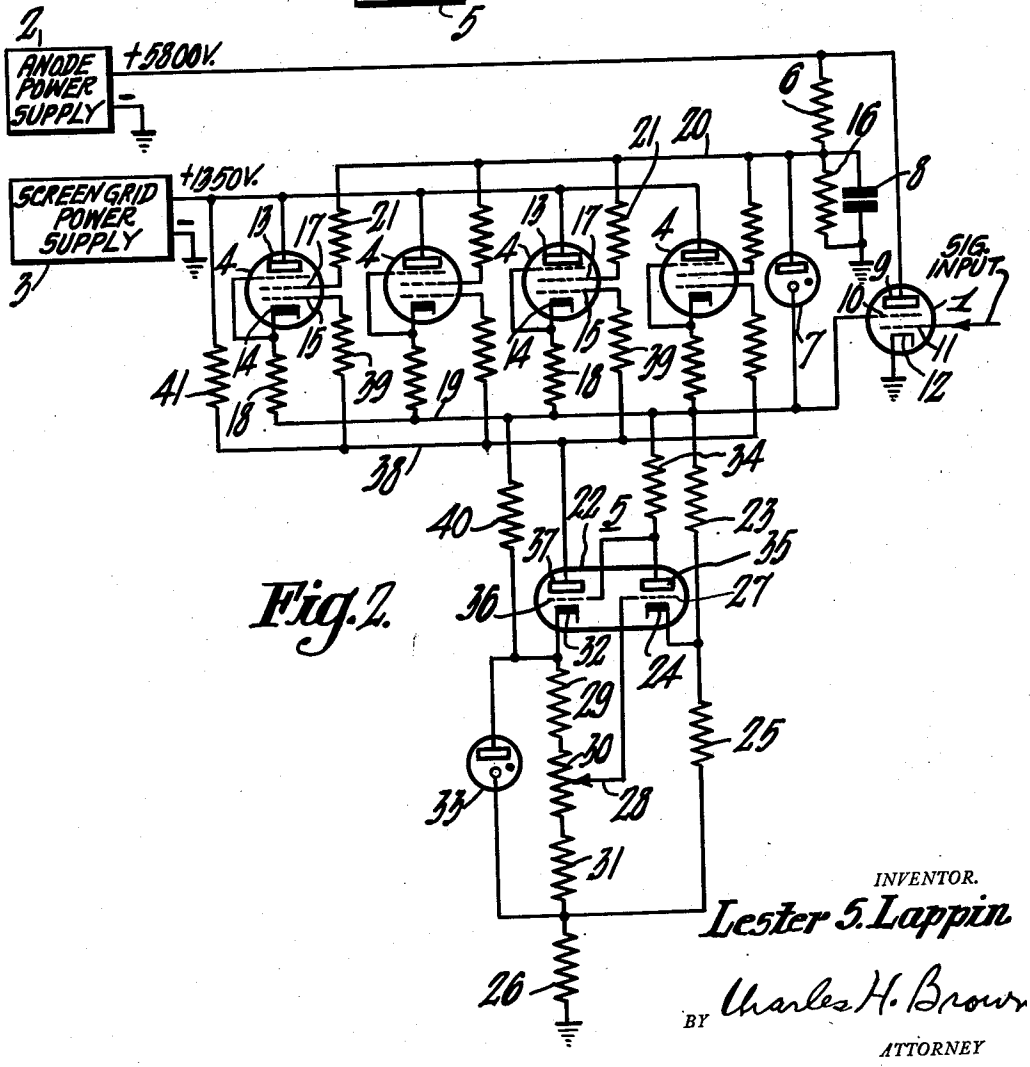


Fig. 2.

INVENTOR.
Lester S. Lappin

BY Charles H. Brown

ATTORNEY

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PROTECTIVE CIRCUIT

Lester S. Lappin, Merchantville, N. J., assignor to Radio Corporation of America, a corporation of Delaware

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This invention relates to protective circuits, and more particularly to a combined screen grid power supply and protective circuit for screen-grid-type tubes. This invention has particular application in transmitters, wherein the screen-grid-type tubes used (for example, tetrodes) are rather large and have high power-handling capabilities.

Certain advantages are obtained through the use of electron tubes containing screen grids. However, these tubes are easily damaged by the application of screen grid voltage thereto in the absence of anode voltage, since in this case the screen grid current usually becomes excessive due to the fact that the electron flow is entirely to the screen grid, rather than only partly to such grid. When the screen grid current becomes excessive, damage to the tube will result. If the cost of the tube is high, it is quite desirable to provide some means for protecting the tube against such damage.

An object of the present invention is to devise a novel screen grid power supply circuit for screen grid vacuum tubes.

Another object is to devise a screen grid power supply circuit which operates to protect screen grid tubes against damage which occurs when voltage is applied to the screen grid of such tubes in the absence of anode voltage.

A further object is to provide a screen grid power supply circuit which prevents application of screen grid voltage to a screen grid tube in the absence of anode voltage on such tube.

Yet another object is to devise a screen grid power supply circuit which operates to delay the application of screen voltage to a tube for any predetermined time after the application of anode voltage to such tube.

The foregoing and other objects of the invention are accomplished, briefly, in the following manner: The screen grid tube being protected is supplied with anode potential from an anode power supply and is supplied with screen grid potential through a series regulator tube from a separate screen grid power supply. The regulator tube is of the screen grid type, the screen grid of this tube being supplied with potential from the main anode power supply through a voltage divider network provided with a time delay feature. Regulation of the screen grid potential supplied to the protected tube is effected by means of a direct current amplifier suitably coupled to the series regulator tube.

The foregoing and other objects of the invention will be best understood from the following description of an exemplification thereof, reference being had to the accompanying drawing, wherein:

Fig. 1 is a simplified schematic of a circuit according to this invention; and

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Fig. 2 is a detailed schematic of a practical embodiment of this invention, such as might be used in a television transmitter.

Now referring to Fig. 1, the evacuated electron discharge device 1, which is a screen grid tube of the tetrode or pentode type, is the tube being protected by the circuit of this invention. Tube 1 has at least four electrodes including an anode 9, a screen grid 10, a control grid 11, and a cathode 12. Tube 1 is illustrated as a tetrode, but it may be a pentode or other type tube having four or more electrodes, including a screen grid. Tube 1 may be, for example, the final or output tube of a radio frequency power amplifier in a transmitter, and may have high power-handling capabilities. Such a tube is likely to be rather costly and it is therefore desirable to protect such tube against appreciable damage to its screen grid arising from excessive screen current, when the anode potential on this tube goes off for any reason.

Anode potential is applied to tube 1 from an anode power supply 2 by connecting the anode 9 to the positive anode power supply lead and the cathode 12 to ground, the negative power supply lead being grounded as shown.

Screen grid potential for tube 1 is obtained from a separate screen grid power supply 3 through the anode-cathode path of a series regulator vacuum tube 4. The positive screen power supply lead is connected to the anode 13 of tube 4, while screen grid 10 of tube 1 is connected to the cathode 14 of tube 4. The negative screen power supply lead is grounded. Thus, the screen current of tube 1 flows through tube 4 and the potential on screen 10 is the same as that of cathode 14 of tube 4.

A direct current amplifier 5, having a voltage gain on the order of 5,000 times, has its input connected to cathode 14 of the regulator tube and its output connected to the control grid 15 of this tube. This amplifier operates in a manner to be further detailed hereinafter, in such a way that when the potential of cathode 14 (and of screen grid 10) tends to fall, the voltage applied to regulator control grid 15 changes in such a direction as to cause the potential of cathode 14 to rise. The converse action occurs when the potential of cathode 14 tends to rise. In other words, the D. C. amplifier 5 in conjunction with the regulator tube 4 causes the potential on screen grid 10 of tube 1 to be constant, within the range of regulation of tube 4. This of course assumes that tube 4 is conducting and that the circuit is otherwise in normal operating condition.

Tube 4 is a screen grid tube the screen potential for which is obtained through a voltage divider from the anode power supply 2. Thus, a pair of resistors 6 and 16 are connected in

series between the positive anode power supply lead and ground, and the screen grid 17 of tube 4 is connected to the junction of these two resistors. The voltage divider 6, 16 reduces the potential of power supply 2 to a suitable value for application to screen grid 17. A capacitor 8, which is connected from the junction of resistors 6 and 16 to ground, serves to delay the build-up of screen potential on screen 17.

A gaseous voltage regulator tube 7 is connected from screen grid 17 to cathode 14 of regulator tube 4 and serves to maintain the screen potential of tube 4 constant after the voltage across tube 7 has increased sufficiently to cause breakdown of this gaseous discharge tube. After tube 7 breaks down, its anode-to-cathode potential is constant. In this way, variations in the voltage of anode power supply 2 are prevented from causing any variations in the output voltage (screen supply for tube 1) of tube 4. Also, the screen potential of tube 4 is maintained at the correct value for proper operation of this tube.

To describe the operation of the Fig. 1 circuit, let us assume that the screen power supply 3 is energized before the anode power supply 2. It should be apparent that, if the opposite is the case, no screen voltage can possibly be supplied to screen grid 10 until power supply 3 is energized, since until this occurs there cannot be any appreciable potential at cathode 14 of regulator tube 4 (which tube is in series between power supply 3 and screen 10). If screen supply 3 is energized before anode supply 2, voltage is applied to the anode 13 of tube 4. However, the screen grid 17 is at zero potential, so no current can flow through tube 4 at this time. Now, if anode power supply 2 is energized, a positive potential is applied to anode 9 and to the voltage divider 6, 16. Initially, the potential of screen 17 with respect to cathode 14 is zero, due to the presence of capacitor 8. Therefore, tube 4 is non-conductive. As capacitor 8 charges at a rate determined by the time constant of the voltage divider 6, 16 and capacitor 8, the potential on screen grid 17 gradually increases and the anode current of tube 4 and screen current of tube 1 gradually increase (the screen current of tube 1 flowing through the anode circuit of tube 4, as will be recalled) until the output voltage of the regulator tube 4 (potential at cathode 14) reaches its normal value, at which time the regulator action prevents any further increase in voltage, due to the action of amplifier 5 in the regulator circuit previously described. After the discharge in tube 7 is initiated, its anode-to-cathode potential is constant, so that the potential on screen grid 17 is then constant. Normal operating conditions have now been reached. Thus, the application of screen voltage to tube 1 via lead 19 is delayed by any predetermined time after the application of anode voltage thereto.

If the anode supply voltage goes off for some reason after operating conditions have been reached, the potential on screen grid 17 of series tube 4 falls to zero almost instantly, since such screen grid potential is obtained from anode power supply 2. This cuts off tube 4, so that the potential on screen grid 10 of tube 1 drops immediately. Thus, the application of screen voltage to tube 1 is prevented, the absence of anode supply voltage keeping tube 4 from conducting. Since the screen potential of tube 1 is thus dropped, the screen current of this tube is greatly reduced, to a value much less than the normal operating screen current. The screen current of tube 1 does not necessarily go to zero, but it is reduced to a value far below the normal screen current. This action is in marked contrast to a conventional screen power supply circuit, which does not effect any protective action and in which, the anode voltage goes off, the screen potential remains high and the screen current becomes excessive. Since by the circuit of this invention the screen current of tube 1 is markedly reduced when the anode voltage goes off, damage to tube 1 which might result if this were not done, is effectively prevented.

Fig. 2 is a schematic diagram of a practical embodiment of this invention, such as might be used in a television transmitter. In Fig. 2, parts similar to those of Fig. 1 are denoted by the same reference numerals.

As in Fig. 1, the evacuated screen grid tube 1 (shown as a tetrode) is the tube to be protected, and the anode 9 and cathode 12 of this tube are connected across the anode power supply 2. In Fig. 2, four series regulator vacuum tubes 4 in electrically parallel relation are used between the screen grid power supply 3 and the screen grid 10 of tube 1. The anode 13 of each tube 4 is connected directly to the positive output lead of screen power supply 3, while the cathode 14 of each tube 4 is connected through a separate balancing resistor numbered 18 to the common screen grid potential output lead 19 which is connected to screen grid 10 of tube 1.

In order to supply screen grid potential to the regulator tubes 4, a supply lead 20 is connected to the junction of resistors 6 and 16 (the voltage divider which is connected across anode power supply 2) and a separate parasitic suppressing resistor 21 is connected from this lead to each respective regulator tube screen grid 17. The screen potential of tubes 4 is maintained constant by a gaseous voltage regulator tube 7 connected between leads 20 and 19.

The D. C. amplifier 5 consists of a twin triode vacuum tube 22 and its circuit connections, now to be described. The input to this amplifier is taken from the regulator tube cathode lead 19 through a voltage divider comprising resistors 23 and 25. Cathode 24 is connected to the junction of resistors 23 and 25 at which point the voltage is proportional to the potential on the screen grid 10. Any variation in screen grid potential thus appears at the input of the D. C. amplifier (cathode 24). A substantially constant bias is provided on the right-hand control grid 27 of tube 22 by means of a potentiometric tap connected to said grid and movable on the central one 30 of three series-connected resistors 29, 30, and 31 arranged between the left-hand cathode 32 of tube 22 and the upper, ungrounded end of resistor 26. The voltage across the series combination 29—31 is maintained constant by means of a gaseous voltage regulator tube 33.

The tube 22 is arranged as a two-stage D. C. amplifier, with its input at the cathode 24. An anode load resistor 34 is connected between the right-hand anode 35 of tube 22 and lead 19. Anode 35 is directly coupled to the left-hand control grid 36 of tube 22, while the output of D. C. amplifier 5 is taken off by means of a connection between the left-hand anode 37 of tube 22 and a lead 38. The control grid 15 of each regulator tube 4 is connected through a respective parasitic suppressing resistor 39 to lead 38.

The D. C. amplifier 5 operates, in conjunction with regulator tubes 4, to maintain the screen potential on screen grid 10 of tube 1 substan-

tially constant, when the circuit is in normal operating condition. Any incipient change of voltage on screen grid potential output lead 19 is applied to the cathode 24 input of D. C. amplifier 5. The bias voltage on control grid 27 is held substantially fixed by means of voltage regulator tube 33 connected across resistor network 29—31, the lower electrode of tube 33 being connected to the ungrounded end of resistor 26 and the upper electrode of this tube being connected through a resistor 40 to lead 19. The voltage change across the first stage anode load resistor 34 is applied to the grid 36 of the second stage amplifier, and the voltage change across the second stage anode load resistor 41 (connected between anode 37 and the positive lead of power supply 3) is applied to the control grids 15 of the respective regulator tubes 4. The connections are such that if the potential of lead 19 tends to increase, the voltage applied to grids 15 by way of amplifier 5 will be of such a polarity as to decrease this lead potential, while if the potential of lead 19 tends to decrease, the voltage applied to grids 15 by way of amplifier 5 will be of such a polarity as to increase this lead potential. Thus, the series regulator tubes 4 operate in conjunction with the D. C. amplifier 5 to maintain the screen potential of tube 1 quite constant.

The operation of the Fig. 2 circuit, to protect tube 1 from the possibility of damage due to excessive screen currents when the anode voltage goes off this tube, is exactly like that of Fig. 1, previously explained, so the description will not be repeated at this point. The Fig. 2 circuit is in all essential details exactly the same as that of Fig. 1. Suffice it to say at this point that when the anode voltage goes off tube 1 for any reason whatever, the screen voltage is also removed from tube 1. Also, the application of screen voltage to tube 1 is delayed for any predetermined time after the application of anode voltage to this same tube.

The following values for certain of the components are given by way of example only, for a circuit according to Fig. 2 which was actually built and successfully tested. The circuit of Fig. 2 was actually embodied in a television transmitter designed to have a power output of 10 kilowatts and operating in the VHF television band.

Tube 1	6166
Tubes 4	4–6146's
Tube 7	OA3
Tube 22	6SL7–GT
Tube 33	OA2
Resistor 6	94,000 ohms
Resistor 16	150,000 ohms
Resistor 23	20,000 ohms
Resistor 25	2,700 ohms
Resistor 26	20,000 ohms
Resistor 29	470,000 ohms
Resistor 30	100,000 ohms
Resistor 31	220,000 ohms
Resistor 34	1 megohm
Resistor 40	10,000 ohms
Resistor 41	470,000 ohms
Capacitor 8	2 mfd.

What is claimed is:

1. A power supply circuit for a tube of the screen grid type comprising an anode power supply, a separate screen grid power supply, means coupling the anode of said tube to the positive terminal of said anode power supply, an electron discharge device of the screen grid type having at least an anode electrode, a cathode electrode and a screen grid electrode, means connecting said anode electrode to the positive terminal of said screen grid power supply, means connecting said cathode electrode to the screen grid of said tube, and means for applying a positive bias potential derived from said anode power supply to said screen grid electrode.

2. A circuit in accordance with claim 1, wherein the positive bias potential applied to the device screen grid is derived from a voltage divider connected across the anode power supply.

3. A circuit in accordance with claim 1, wherein voltage regulating means is connected between the device screen grid and the said cathode, to maintain substantially constant the bias potential applied to such screen grid.

4. A power supply circuit for a tube of the screen grid type comprising an anode power supply, a separate screen grid power supply, means coupling the anode of said tube to said anode power supply, an electron discharge device having an anode electrode, a cathode electrode and two control electrodes, means connecting the anode-cathode path of said device in series between said screen grid power supply and the screen grid of said tube, connections for applying bias potential to a first one of said control electrodes from said anode power supply, and a voltage amplifier having its input coupled to said cathode electrode and its output coupled to the second one of said control electrodes to maintain the voltage applied to the screen grid of said tube substantially constant.

5. A circuit in accordance with claim 4, wherein the electron discharge device is a device of the screen grid type and wherein the first one of said control electrodes is the screen grid thereof.

6. A circuit in accordance with claim 4, wherein the electron discharge device is a device of the screen grid type, wherein the first one of said control electrodes is the screen grid thereof, and wherein voltage regulating means is connected between the device screen grid and the said cathode, to maintain substantially constant the bias potential applied to such screen grid.

7. A power supply circuit for a tube of the screen grid type comprising an anode power supply, a separate screen grid power supply, means coupling the anode of said tube to said anode power supply, an electron discharge device having an anode electrode, a cathode electrode and two control electrodes, means connecting the anode-cathode path of said device in series between said screen grid power supply and the screen grid of said tube, connections for applying bias potential to a first one of said control electrodes from said anode power supply, means in said connections for preventing the application of bias potential to said first control electrode for a predetermined interval following energization of said anode power supply, and a voltage amplifier having its input coupled to said cathode electrode and its output coupled to the second one of said control electrodes to maintain the voltage applied to the screen grid of said tube substantially constant.

8. A circuit in accordance with claim 7, wherein the electron discharge device is a device of the screen grid type and wherein the first one of said control electrodes is the screen grid thereof.

9. A circuit in accordance with claim 7, wherein the electron discharge device is a device of the screen grid type, wherein the first

one of said control electrodes is the screen grid thereof, and wherein voltage regulating means is connected between the device screen grid and the said cathode, to maintain substantially constant the bias potential applied to such screen grid.

10. A circuit in accordance with claim 7, wherein the means for preventing the application of bias potential comprises a capacitor arranged to be charged from the anode power supply and to which the first one of said control electrodes is coupled.

11. A circuit in accordance with claim 7, wherein the electron discharge device is a device of the screen grid type, wherein the first one of said control electrodes is the screen grid thereof, and wherein the means for preventing the application of bias potential comprises a capacitor arranged to be charged from the anode power supply and to which the screen grid of said device is coupled.

12. A circuit in accordance with claim 7, wherein the electron discharge device is a device of the screen grid type, wherein the first one of said control electrodes is the screen grid thereof, wherein the means for preventing the application of bias potential comprises a capacitor arranged to be charged from the anode power supply and to which the screen grid of said device is coupled, and wherein voltage regulating means is connected between the device screen grid and the said cathode, to maintain substantially constant the bias potential applied to such screen grid.

13. A power supply circuit for a tube of the screen grid type comprising an anode power supply, a separate screen grid power supply, means coupling the anode of said tube to said anode power supply, an electron discharge device of the screen grid type having at least an anode electrode, a cathode electrode and a screen grid electrode, means connecting the anode-cathode path of said device in series between said screen grid power supply and the screen grid of said tube, connections for applying bias potential to said screen grid electrode from said anode power supply, and means in said connections for preventing the application of bias potential to said screen grid electrode for a predetermined interval following energization of said anode power supply.

14. A power supply circuit for a tube of the screen grid type comprising an anode power supply, a separate screen grid power supply, means coupling the anode of said tube to said anode power supply, an electron discharge device having an anode electrode, a cathode electrode and at least one control electrode, means connecting the anode-cathode path of said device in series between said screen grid power supply and the screen grid of said tube, connections for applying bias potential to said control electrode from said anode power supply, and a capacitor in said connections arranged to be charged from the anode power supply, said capacitor being coupled to said control electrode and serving to prevent the application of bias potential to said control electrode for a predetermined interval following energization of said anode power supply.

15. A power supply circuit for a tube of the screen grid type comprising an anode power supply, a separate screen grid power supply, means coupling the anode of said tube to said anode power supply, an electron discharge device of the screen grid type having at least an anode electrode, a cathode electrode and a screen grid electrode, means connecting the anode-cathode path of said device in series between said screen grid power supply and the screen grid of said tube, connections for applying bias potential to said screen grid electrode from said anode power supply, and a capacitor in said connections arranged to be charged from the anode power supply, said capacitor being coupled to said control electrode and serving to prevent the application of bias potential to said control electrode for a predetermined interval following energization of said anode power supply.

16. A power supply circuit for a tube of the screen grid type comprising an anode power supply, a separate screen grid power supply, means coupling the anode of said tube to said anode power supply, a plurality of electron discharge devices of the screen grid type each having an anode electrode, a cathode electrode, a control electrode and a screen grid electrode, means connecting the anodes of all of said devices together, means connecting the cathodes of all of said devices together, means connecting the paralleled anode-cathode paths of all of said devices in series between said screen grid power supply and the screen grid of said tube, means connecting the screen grids of all of said devices together, connections for applying bias potential to all of said device screen grids from said anode power supply, a capacitor in said connections arranged to be charged from the anode power supply, said capacitor being coupled to all of said device screen grids and serving to prevent the application of bias potential to said device screen grids for a predetermined interval following energization of said anode power supply, means connecting the control electrodes of all of said devices together, a voltage amplifier having its input coupled to all of said cathode electrodes and its output coupled to all of said control electrodes to maintain the voltage applied to the screen grid of said tube substantially constant, and voltage regulating means connected between the device screen grids and the device cathodes, to maintain substantially constant the bias potential applied to said device screen grids.

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