

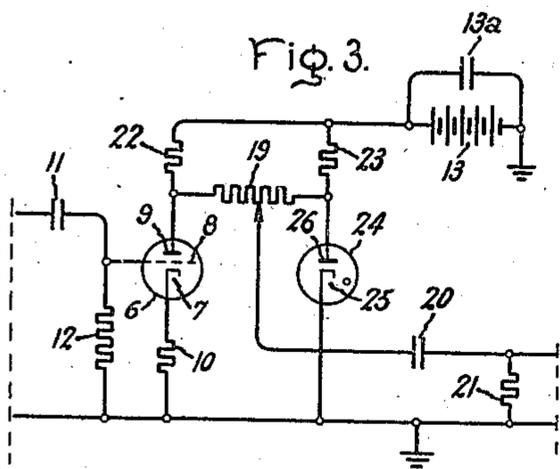
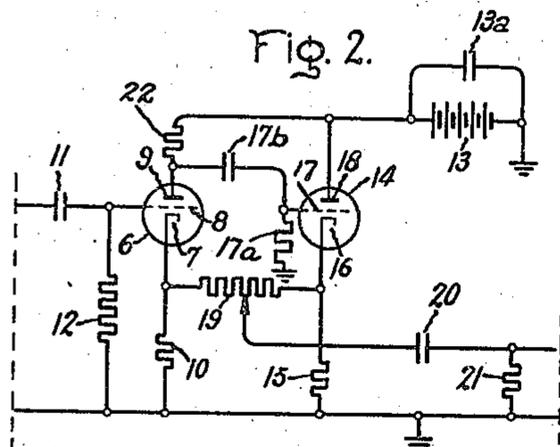
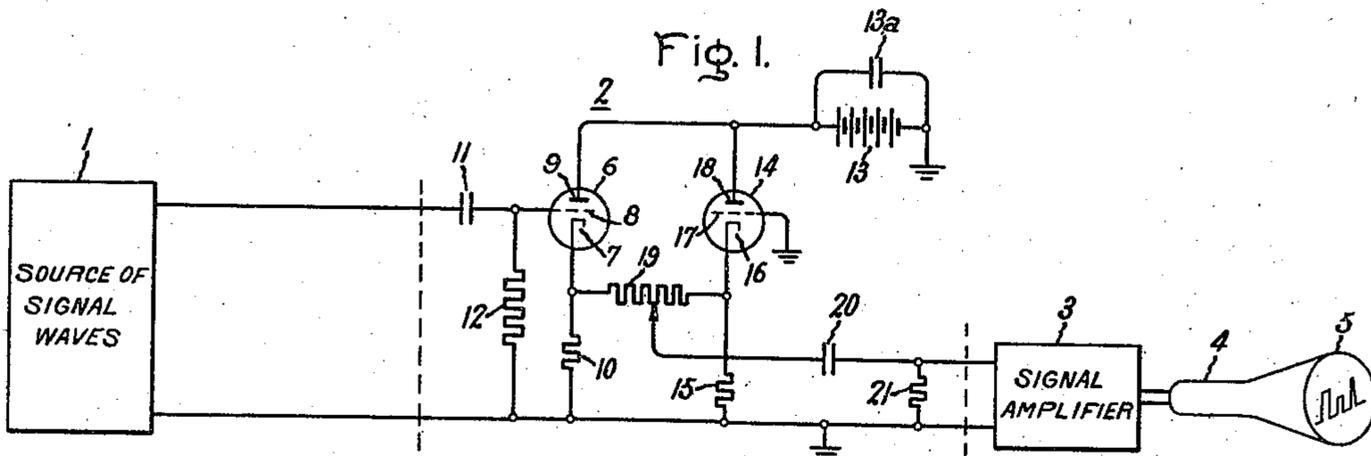
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S. BERKOFF

2,430,699

AMPLIFIER GAIN CONTROL

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# UNITED STATES PATENT OFFICE

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## AMPLIFIER GAIN CONTROL

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Application December 28, 1944, Serial No. 570,173

12 Claims. (Cl. 179—171)

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My invention relates to gain control apparatus, and more particularly to signal amplifier gain control circuits for audio and video signal frequencies, such as are commonly used in television, radio detection and range finding apparatus, and the like.

Signal sources of a wide band of frequencies, such as are used to supply test oscilloscopes in radio detection and range finding apparatus or to supply picture tubes in television apparatus, present special problems in amplitude control not adequately solved by gain control apparatus heretofore known. The usual high resistance gain control potentiometer is not suitable for the high frequency portion of the wide band, because the capacitance of the circuits following the potentiometer and the stray capacitance of the potentiometer itself, in combination with the high resistance, undesirably attenuate the high frequencies. On the other hand, a low resistance potentiometer connected across the signal source does not provide a feasible general solution, because the high frequency signal source frequently includes high resistance circuits which would be effectively shunted by such a low resistance potentiometer. Accordingly, it is desirable to provide a low resistance control potentiometer located after the first signal amplifying device in order to prevent short circuiting of a high impedance signal source.

Gain control in the output of a signal amplifier is commonly accomplished by controlling either the cathode biasing resistor or an anode resistor, or a low resistance potentiometer connected in series with a blocking capacitor to the output circuit of the amplifier. Control by a cathode or anode resistor is effective, but has the disadvantage that it produces a direct current fluctuations upon manual rotation of the control by reason of the fact that the control resistor is in a direct current circuit. Ordinarily, this fluctuation results in a slow drift of the signal level to its final value, rather than a prompt response to the movement of the control, while transient voltages appear in the signal circuits, resulting in noisy operation when the control is rotated. Control by means of a low resistance potentiometer connected in series with a blocking capacitor has the advantage that it does not produce transients or direct current fluctuations. This has been found impractical in many cases, however, by reason of the large size of the capacitor required to secure adequate low frequency response in wide band circuits, since the capacitive reactance must be small at low fre-

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quencies compared to the low resistance potentiometer.

It will be evident, therefore, that in a wide band gain control apparatus it is desirable to provide a low resistance control which does not require a blocking capacitor, but none the less carries no direct current. Such a control is described and claimed in a copending application, Serial No. 570,172 of Charles S. Root, filed December 28, 1944, and assigned to the same assignee as the instant application. In accordance with the disclosure of that application a gain control potentiometer is connected across the load resistor in the output circuit of a signal amplifier and unidirectional potential across the load resistor is rendered ineffective to cause unidirectional current in the potentiometer by connecting the potentiometer across the load resistor in series with a source of unidirectional potential substantially equal in magnitude and opposite in polarity to the unidirectional potential drop across the load resistor. As described in the foregoing copending application, this opposing source of unidirectional potential may be either a resistance voltage divider connected across the battery, or a source of negative unidirectional potential such as a separate battery.

While high gain ratios may be obtained by using the negative potential source above described, it is difficult to obtain a high gain ratio by using the bleeder resistor, because of the large bleeder currents required. According to my invention high gain ratios are attainable in gain control circuits of the above general character without the use of a source of negative unidirectional potential supply and without the use of a heavy bleeder current.

Accordingly, it is a general object of my invention to provide a new and improved signal amplifier gain control apparatus for high signal frequencies.

It is a further object of my invention to provide a new and improved wide band signal amplifier gain control apparatus.

It is still another object of my invention to provide a new and improved low resistance gain control apparatus having a high maximum gain ratio.

It is a still further object of my invention to provide new and novel means for dynamically balancing a gain control apparatus for unidirectional current without limiting its alternating current gain control ratio.

Briefly, my invention comprises an electron discharge signal wave amplifier connected in series

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circuit relation with a load impedance across the terminals of a source of unidirectional current supply, a second discharge device connected in series circuit relation with a resistor as a direct current bleeder across the supply source, and a variable voltage divider connected between points of like unidirectional potential on the impedance and resistor. The advantage of such an arrangement is that the second electron discharge device is effectively connected in parallel circuit relation with the resistor for alternating currents. As will be shown hereinafter the second discharge device behaves like a very small alternating current resistor at the low signal end of the potentiometer without affecting the direct current resistance at this point. Accordingly, therefore, the second discharge device and resistor provide the required unidirectional bias for direct current balance across the potentiometer, without presenting a correspondingly high impedance to the alternating current in the gain control circuit. The low alternating current impedance permits a high gain ratio.

My invention will be more fully understood and its objects and advantages further appreciated by referring now to the following detailed specification taken in conjunction with the accompanying drawing, in which Fig. 1 is a schematic circuit diagram of an oscilloscope apparatus including a gain control circuit embodying my invention, and Figs. 2 and 3 are schematic circuit diagrams of gain control circuits suitable for application to the oscilloscope apparatus of Fig. 1 and illustrating other embodiments of my invention.

Referring now to the drawing and particularly to Fig. 1, the oscilloscope apparatus there shown comprises a source of signal waves 1, a gain control circuit 2, a desired number of succeeding stages of signal amplification 3, and a cathode ray discharge device 4 having a viewing screen 5. The gain control circuit 2 comprises an electron discharge signal amplifier 6 having a cathode 7, a control electrode 8, and an anode 9. The cathode 7 is connected to ground through a cathode load resistor 10, while the control electrode 8 is coupled to the source of signal waves 1 through a coupling capacitor 11 and connected to ground through a grid leak resistor 12. Negative bias for grid 8 is supplied by the unidirectional voltage drop across cathode resistor 10. The anode 9 is connected directly to the positive terminal of a suitable source of unidirectional current supply, such as a battery 13, having its negative terminal grounded. The current source 13 is such that it provides substantially zero impedance for alternating currents, as indicated by a by-pass capacitor 13a connected across the battery. The alternating current output circuit for the discharge device 6 thus comprises the resistor 10 and the capacitor 13a.

Direct current from the battery 13 is bled through a second electron discharge device 14 and a resistor 15 connected in series circuit relation for direct current between the positive battery terminal and ground. The discharge device 14 includes a cathode 16, a control electrode 17, and an anode 18. The cathode 16 is connected to the resistor 15 and the anode 18 is connected to the positive terminal of the battery 13. The control electrode 17 of the discharge device 14 is connected directly to ground. Negative bias for the grid 17 is provided by the unidirectional voltage drop across the cathode resistor 15. A gain control potentiometer 19 is connected directly between the

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cathodes 7 and 16, and these cathodes are maintained at substantially the same unidirectional potential by current bled from the battery 13 through the discharge devices 14 and 9 into cathode resistors 15 and 10 respectively. The movable slider of the potentiometer 19 is connected through a coupling circuit, comprising a condenser 20 and resistor 21, to the control electrode (not shown) of the following stage of signal amplification.

The resistor 15 is so adjusted that the unidirectional current through the discharge device 14 and the resistor 15 produces across the resistor 15 a direct current voltage drop substantially equal to the unidirectional potential component across the cathode resistor 10 in the output circuit of the amplifier 6. In this way the opposite terminals of the potentiometer 19 are maintained at substantially the same unidirectional potential, so that only signal frequency potentials appear across the potentiometer. For signal frequency currents, the potentiometer 19 is connected in series circuit relation with the resistor 15 as a voltage divider across the cathode load resistor 10. Thus, a portion of the signal frequency potential across the resistor 10 appears across the resistor 15 and, unless the effective resistance of the resistor 15 is reduced for alternating currents, the fixed signal frequency potential across the resistor 15 unduly limits the maximum attainable gain ratio.

In accordance with my invention, the effective impedance of the resistor 15 for alternating or signal frequency currents is appreciably reduced without reducing the resistance to direct current between the cathode 16 and ground by including in the direct current bleeder circuit the discharge device 14. As previously stated, the discharge device 14 is connected in series circuit relation with the resistor 15 for direct current. However, by reason of the fact that the battery 13 presents substantially zero impedance to alternating or signal frequency currents, the anode 18 of the discharge device 14 is maintained substantially at ground potential for signal frequency currents. Accordingly, therefore, the discharge device 14 may be regarded as connected effectively in parallel circuit relation with the resistor 15 for signal frequencies. Since the effective resistance of the discharge device 14 in the alternating current circuit is

$$\frac{1}{g_m}$$

in the "cathode follower" connection shown, where  $g_m$  is the transconductance of the device 14, the total effective impedance  $r_e$ , connected in series circuit relation with the potentiometer 19 across the cathode resistor 10 is

$$r_e = \frac{\frac{1}{g_m} \times r_{15}}{\frac{1}{g_m} + r_{15}}$$

where  $r_{15}$  is the resistance of the resistor 15. This total effective impedance is considerably less than  $r_{15}$  alone. On the other hand, the total resistance between the cathode 16 and ground for unidirectional current is  $r_{15}$ . Accordingly, therefore, the cathode 16 may be maintained at an appreciable unidirectional potential without developing an appreciable portion of the signal voltage across the resistor 15. The gain ratio of the circuit described is expressed as

$$\frac{r_{10} + r_e}{r_e}$$

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It will now be evident that, by my invention, I am able to obtain a very high gain ratio, while maintaining in the resistor 15 sufficient resistance to direct current to limit the bleeder current through discharge device 14 to an acceptable low value.

It will be observed from the foregoing description that the discharge device 14 in the circuit of Fig. 1 is operated in the alternating current circuit as a cathode follower driven in the cathode discharge circuit. Qualitatively, this means that the discharge device 14 acts as a low shunt resistance in the alternating current circuit, because the cathode follower action tends to resist the imposition of any alternating or signal frequency voltage across the resistor 15. That is, as the cathode 16 tends to swing in the positive direction with signal oscillations, the effective negative grid bias of the device 14 is increased because of the fixed ground connection to the control electrode 17. Therefore, the device 14 conducts less current and tends to lessen the instantaneous potential rise across the resistor 15. Conversely, when the alternating potential of the cathode 16 swings in the negative direction, the discharge device 14 becomes more conductive thereby to oppose a decrease in instantaneous potential across resistor 15. In this manner the device 14 resists the imposition of alternating or signal frequency currents across the resistor 15 from the load resistor 10.

The low effective alternating current resistance characteristic of the discharge device 14, resulting from the above-described tendency to resist the imposition of signal frequency potential across the resistor 15, may be utilized in accordance with Fig. 2 of the drawing to obtain an even greater gain ratio by reducing the effective resistance between the cathode 16 and ground to substantially zero for alternating currents. The gain control circuit shown in Fig. 2 is generally similar to that shown at Fig. 1, and like parts have been assigned the same reference numerals. The embodiment of the invention shown at Fig. 2 differs, however, from that shown at Fig. 1 in that the control electrode 17 of the discharge device 14 is connected to ground through a resistor 17a and coupled to the anode 9 of the discharge device 6 through a capacitor 17b, while a load resistor 22 is connected between the anode 9 and the positive terminal of the battery 13.

In the operation of the circuit shown in Fig. 2, the cathode follower operation of the discharge device 14 in resisting the imposition of alternating potential across the resistor 15 is enhanced by coupling to the grid 17 from the anode 9 a signal frequency potential in opposite phase relation to that across the resistor 15. It will be evident that the voltage coupled to the grid 17 is in opposite phase relation to that impressed on the resistor 15 from the cathode resistor 10 with respect to a point of fixed potential, by reason of the fact that it is derived from the anode of the discharge device 6. Relative to the voltage applied to cathode 16, the voltage applied to grid 17 is in the correct direction to further resist a change in instantaneous potential at the cathode 16, and by proper adjustment of the resistor 22, the cathode follower action of the discharge device 14 may be so exaggerated that it is impossible to impress any alternating potential across the resistor 15. This, of course, means that alternating or signal frequency currents encounter zero impedance between the cathode 16 of the discharge device 14 and ground.

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It is also possible, by increasing the value of the resistor 22 and thereby raising the alternating voltage at the grid 17, to render the alternating current resistance between the cathode 16 and ground effectively negative to a signal impressed on cathode 16 from cathode 7. With such an adjustment, the signal voltage at the cathode 16 will be of opposite polarity with respect to that of the cathode 7 so that, as the gain control is turned down, the output will pass through zero and then reverse in polarity and increase in magnitude. The circuit of Fig. 2, therefore, may be used as a combination gain control and phase reversing control, if desired.

As explained in the foregoing copending application of Charles S. Root, the amplifier load resistor across which the gain control potentiometer is connected may be located in the anode circuit of the amplifier 6. My invention is applicable also to this form of the circuit in the manner illustrated at Fig. 3. In this figure, the amplifier 6, the battery 13, and the coupling circuit 20, 21 are similar to like parts shown at Figs. 1 and 2 and have been assigned the same reference numerals. At Fig. 3, however, the potentiometer 19 is connected across the anode load resistor 22 in series circuit relation with a resistor 23. The resistor 23 is connected also as a unidirectional voltage divider across the battery 13 in series with a gas-filled electric discharge device 24. The device 24 may suitably be a neon lamp, mercury vapor tube, or the like, and is provided with a cathode 25 connected directly to ground and an anode 26 connected to the common terminal of the resistor 23 and potentiometer 19. As explained above in connection with Fig. 1, the discharge device 24 is effectively connected in parallel circuit relation with the resistor 23 for alternating currents impressed thereon from the anode load resistor 22, thereby to decrease the effective alternating current resistance in series with the potentiometer 19. For direct currents the discharge device 24 is connected in series with the resistor 23 across the battery 13, so that a sufficient unidirectional balancing bias may be maintained across the resistor 23. The alternating current resistance at the juncture of resistor 23 and control 19 is kept low by the gas filled discharge device 24. It will be noted, however, that in Fig. 3, as distinguished from Figs. 1 and 2, the discharge device 24 is connected with its cathode, rather than its anode, grounded for signal frequency currents.

In operation, the discharge device 24 of Fig. 3 decreases the effective alternating current resistance between the anode 26 and ground by reason of its voltage regulating action. As is well known to those skilled in the art, it is characteristic of a gas tube that the voltage between its anode and cathode is substantially constant over a wide range of currents. Since the current through the discharge device 24 comprises both unidirectional and alternating components, and since the voltage drop across the device is substantially constant, it will be evident that the maximum alternating potential which may be impressed across the device is limited to a very low value. The gas tube 24, therefore, acts as a low resistance connected in parallel circuit relation with the resistor 23 for alternating currents.

While I have described only certain preferred embodiments of my invention by way of illustration, many modifications will occur to those skilled in the art and I, therefore, wish to have it understood that I intend in the appended claims

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to cover all such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A signal wave amplifier comprising an electron discharge device, an output circuit for said discharge device including a load impedance connected to conduct unidirectional and signal frequency current components, a voltage divider, impedance means connected in series circuit relation with said voltage divider across said load impedance, a source of unidirectional current supply having no appreciable impedance for signal frequency currents, and an electric discharge device connected across said supply source in series with said impedance means thereby to maintain opposite terminals of said voltage divider at substantially the same unidirectional potential.

2. A signal wave amplifier comprising an electric discharge device, an output circuit for said discharge device including a load impedance connected to conduct unidirectional and signal frequency current components, a voltage divider, impedance means connected in series circuit relation with said voltage divider across said load impedance, means including an electric discharge device connected in series circuit relation with said impedance means for supplying unidirectional current to said impedance means thereby to maintain opposite terminals of said voltage divider at substantially the same unidirectional potential, and means for effectively connecting said electric discharge device in parallel circuit relation with said impedance means for signal frequency currents.

3. A signal wave amplifier comprising an electron discharge device, a source of unidirectional current supply having substantially no impedance for alternating currents, an output circuit for said discharge device including a load resistor connected between said discharge device and said source to conduct unidirectional and signal frequency current components, a voltage divider, impedance means connected in series circuit relation with said voltage divider across said load resistor, and an electric discharge device connected in series circuit relation with said impedance means across said supply source to provide across said impedance means a unidirectional voltage drop substantially equal to the unidirectional voltage component across said load resistor.

4. A signal wave amplifier comprising an electron discharge device, an output circuit for said discharge device including a load resistor connected to conduct unidirectional and signal frequency current components, a voltage divider, a resistor connected in series with said voltage divider across said load resistor, a source of unidirectional current supply, and an electric discharge device connected to conduct direct current from said supply source through said resistor and to decrease the effective resistance of said resistor for alternating currents.

5. A signal wave amplifier comprising an electron discharge device, an output circuit for said discharge device including a load resistor connected to conduct unidirectional and signal frequency current components, a variable voltage divider, a second resistor connected in series circuit relation with said voltage divider across said load resistor, a source of unidirectional current supply having no appreciable impedance for signal frequency currents, and a second electron discharge device having a cathode circuit

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including said second resistor and connected to derive current from said supply source.

6. A signal wave amplifier comprising an electron discharge device, an output circuit for said discharge device including a load resistor connected to conduct unidirectional and signal frequency current components, a variable voltage divider, a second resistor connected in series circuit relation with said voltage divider across said load resistor, a source of unidirectional current supply having no appreciable impedance for signal frequency currents, and a second electron discharge device having a control electrode and connected to derive current from said supply source in cathode following relation with said second resistor.

7. A signal wave amplifier comprising an electron discharge device, an output circuit for said discharge device including a load resistor, a source of unidirectional current supply having no appreciable impedance for signal frequency currents and connected to supply said output circuit, said load resistor conducting unidirectional and signal frequency current components, a variable voltage divider, a second resistor connected in series circuit relation with said voltage divider across said load resistor, and a second electron discharge device coupled to said supply source with said second resistor in its cathode circuit and having a control electrode connected to a point of substantially fixed potential, whereby unidirectional current through said second resistor maintains opposite terminals of said voltage divider at substantially equal unidirectional potentials and said second discharge device effectively shunts said second resistor for signal frequency currents.

8. A signal wave amplifier comprising a first electron discharge device having an anode and a cathode, an output circuit for said discharge device including a cathode load resistor connected to conduct unidirectional and signal frequency current components, a variable voltage divider, a second resistor connected in series circuit relation with said voltage divider across said load resistor, a source of unidirectional current supply having no appreciable impedance for signal frequency currents, and a second electron discharge device connected to derive current from said source in cathode following relation with said second resistor and including a control electrode coupled to the anode of said first discharge device.

9. A signal wave amplifier comprising an electron discharge device having an anode and a cathode, an output circuit for said discharge device including a cathode load resistor connected to conduct unidirectional and signal frequency current components, a variable voltage divider, a second resistor connected in series circuit relation with said voltage divider across said load resistor, a source of unidirectional current supply having no appreciable impedance for signal frequency currents, a second electron discharge device connected to derive current from said supply source in cathode following relation with said resistor and including a control electrode, means for biasing the control electrode of said second discharge device negatively with respect to the cathode thereof, and means for coupling said control electrode to the anode of said first discharge device.

10. A signal wave amplifier comprising an electron discharge device, an output circuit for said discharge device including a load resistor

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connected to conduct unidirectional and signal frequency current components, a variable voltage divider, a second resistor connected in series circuit relation with said voltage divider across said load resistor, a source of unidirectional current supply having no appreciable impedance for signal frequency currents, and a substantially constant voltage electric discharge device connected in series circuit relation with said second resistor across said supply source.

11. A signal wave amplifier comprising an electron discharge device, an output circuit for said discharge device including a load resistor connected to conduct unidirectional and signal frequency current components, a variable voltage divider, a second resistor connected in series circuit relation with said voltage divider across said load resistor, a source of unidirectional current supply having no appreciable impedance for signal frequency currents, and a gas-filled electric discharge device connected to derive current from said supply source and having an anode circuit including said second resistor.

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12. A signal wave amplifier comprising an electron discharge device, an output circuit for said discharge device including a load resistor connected in the anode circuit of said device to conduct unidirectional and signal frequency current components, a variable voltage divider, a second resistor connected in series circuit relation with said voltage divider across said load resistor, a source of unidirectional current supply having no appreciable impedance for signal frequency currents, and a gas-filled electron discharge device connected to derive current from said supply source and having an anode circuit including said second resistor, whereby unidirectional current through said second resistor maintains opposite terminals of said voltage divider at substantially equal unidirectional potentials and said gas-filled discharge device effectively shunts said second resistor for signal frequency currents.

SEYMOUR BERKOFF.