Aug. 29, 1939. A. F. PRICE 2,170,873

ELECTRICAL SYSTEM

Filed May 5, 1936

FIG. 1

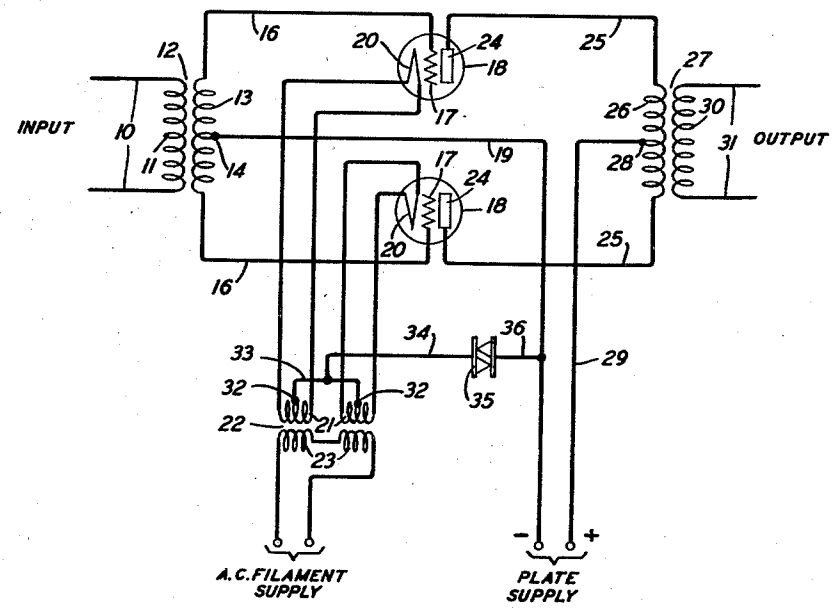
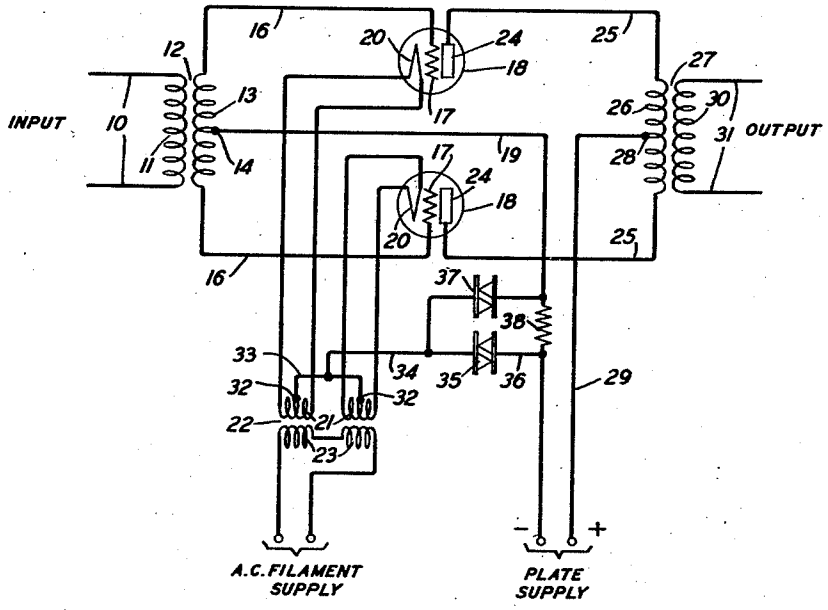


FIG. 2



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Patented Aug. 29, 1939 2,170,873

UNITED STATES PATENT OFFICE

2,170,873

ELECTRICAL SYSTEM

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Application May 5, 1936, Serial No. 77,986

6 Claims. (Cl. 179—171)

This invention relates to electrical systems employing space discharge devices, and, more particularly, to such systems in which it is desired to maintain a substantially constant potential on the control electrode of such devices.

An object of the invention is to simplify and reduce the cost of such systems.

A feature of this invention comprises the combination of a space discharge device having a control electrode and a resistor with a symmetric non-linear voltage-current characteristic associated with it and traversed by a variable unidirectional current for maintaining substantially constant the bias on the control electrode.

Another feature comprises the combination of such a device and resistor in which the latter is of a material having a substantially instantaneously-acting negative resistance-current characteristic substantially independent of temperature.

Still another feature comprises the combination of such a device and resistor, the potential drop across the latter for wide variations in current flow therethrough being substantially constant.

A further feature comprises the combination of such a device and resistor in which the resistor is located in the common path for the circuits provided by the main electrodes and the control electrode.

Other and further features will be apparent from the detailed description which follows hereinafter.

A more complete understanding of this invention will be obtained from the detailed description which follows in conjunction with the appended drawing wherein:

Fig. 1 shows an electrical system, more specifically, an audio-frequency amplifier of the push-pull type, embodying the invention; and

Fig. 2 shows another electrical system embodying a modification of the invention.

Referring to Fig. 1, incoming line 10 is connected to the primary winding 11 of a transformer 12 having a secondary winding 13 inductively coupled to the primary and provided with a center tap 14. Each end of the secondary is connected through a conductor 16 to the control electrode or grid 17 of an electrical discharge device or vacuum tube 18. The center tap 14 is connected through conductor 19 with the negative terminal of the plate voltage supply, which may be a battery or other source of direct current voltage. The filaments or cathodes 20 of the tubes are connected with secondary windings 21 of a transformer 22, the primary windings 23 being serially connected and connected to a source of alternating current. Each plate or anode 24 is connected through conductors 25 with an end of the primary winding 26 of output transformer 27, the winding having a center tap 28 connected through conductor 29 with the positive terminal of the plate supply. A secondary winding 30 is inductively coupled to the winding 26 and its ends are connected with outgoing line 31. Connected to the mid-points 32 of cathode transformer windings 21 through conductors 33, 34, is a resistor or variable resistance device 35 of a material known commercially as "thyrite". "Thyrite" is a composition of silicon carbide, graphite and clay, is described in K. McEachron Patent 1,822,742, issued September 8, 1931, and has a substantially instantaneously acting negative resistance-current characteristic, the voltage-current characteristic being symmetric and non-linear and substantially independent of temperature. The resistor is connected through conductor 36 with conductor 19. It is apparent that the resistor is connected in the common return path for the control electrode-cathode circuit and the anode-cathode circuit and that the variable unidirectional plate current traverses it.

In amplifiers in which the grids are biased almost down to "cut-off" to obtain more power from a given size vacuum tube than can otherwise be obtained, a separate source of grid bias potential has been employed, usually, a rectifier. This has been considered necessary because the ratio of full load to no load plate current in such amplifiers is approximately 3 to 1 and, consequently, a sufficiently constant grid bias could not be obtained from the voltage drop across a resistance in the cathode return circuit as is the common practice in Class "A" amplifiers.

If, however, such a grid bias resistance is replaced by a resistor whose resistance varies with current flow therethrough such that the voltage drop across it remains substantially constant with a 3 to 1 change in current therethrough, the grid bias potential may be obtained from that source and the separate source of grid potential eliminated. This is made possible by the use of the resistor 35, the drop across it being substantially constant for load current fluctuations of the stated range.

The current-voltage characteristic of "thyrite" is expressed by the equation:

$$I=kV^n$$

where

I=current.

k= a constant.

V=voltage.

n is an exponent which depends upon the mixture and manufacturing process.

This variable resistance material is obtainable commercially with an exponent n equal to 4 and similar material can be made having an exponent n equal to 5+. For a 3 to 1 current change, therefore, it is apparent that, with $n=4$, the cor-

responding voltage change will be only 1.32 to 1, and with an exponent of $n=5$, only 1.25 to 1.

By putting more than one resistor in cascade, the voltage variation may be reduced even more. The electrical system of Fig. 2 is substantially the same as that of Fig. 1, like parts having corresponding identifying numerals. In addition to the member **35**, however, there is provided a second variable resistance device or resistor **37** and a linear current-voltage characteristic or ohmic resistance **38** in the common return circuit, the conductor **19** being connected at a point intermediate the members **37, 38**, the resistance of the resistor **35** being small compared to the combined resistance of the members **37, 38**.

If each of members **35, 37** has the characteristic $I=kV^4$ and the current varies in the ratio of 3 to 1, the voltage drop across the member **35** will vary in the ratio of 1.32 to 1. If the resistance of member **38** is large compared to that of member **37**, the current variation through members **37, 38** will approach 1.32 to 1 and the voltage variation across member **37** will aproach 1.073 to 1 as a maximum. A substantial saving in the cost of high power amplifier equipment is made possible by the described arrangements.

While this invention has been disclosed with reference to a specific embodiment, it is to be understood that it is not limited thereto but by the scope of the appended claims only.

What is claimed is:

1. The combination of a space discharge device comprising a cathode, an anode and a control electrode, a cathode-anode circuit, a cathode-control electrode circuit, non-ohmic resistance means common to said circuits across which the potential drop increases only slightly between no load and full load current, and additional resistance means common to said circuits and comprising an ohmic and a non-ohmic resistance portion for reducing the effects on the control electrode of such increases in potential drop across said first-mentioned means, said non-ohmic resistances each having a negative resistance-current characteristic.

2. In combination, a space discharge device comprising a cathode, an anode and a control electrode, a cathode-anode circuit, a cathode-control electrode circuit, and means common to said circuits for applying a substantially constant potential on said control electrode for wide variations in current flow in the cathode-anode circuit, said means including members of a substantially instantaneously-acting negative resistance-current characteristic resistance material, one of said members being in parallel with a series combination of the other member and an ohmic resistance.

3. In combination, a space discharge device comprising a cathode, an anode and a control electrode, a cathode-anode circuit, a cathode-control electrode circuit, and means common to said circuits for applying a substantially constant potential on said control electrode for wide variations in current flow in the cathode-anode circuit, said means including members of a substantially instantaneously-acting negative resistance-current characteristic resistance material, one of said members being in parallel with a series combination of the other member and an ohmic resistance, the resistance of the combination being relatively great compared to that of said one member.

4. In combination, a space discharge device comprising a cathode, an anode and a control electrode, a cathode-anode circuit, a cathode-control electrode circuit, and means common to said circuits for applying a substantially constant potential on said control electrode for wide variations in current flow in the cathode-anode circuit, said means including members of a substantially instantaneously-acting negative resistance-current characteristic resistance material, one of said members being in parallel with a series combination of the other member and an ohmic resistance, the resistance of the combination being relatively great compared to that of said one member, connection to the control electrode being made through a conductor in the cathode-control electrode circuit that is connected intermediate the member and the resistance of the series combination.

5. In combination a space-discharge device comprising a cathode, an anode and a control electrode, a cathode-anode circuit, a cathode-control electrode circuit, non-ohmic resistance means common to said circuits, and additional means, a part only of which comprises non-ohmic resistance means in shunt with said first-mentioned means for maintaining said biasing potential substantially constant with said cathode-anode current variation, the non-ohmic resistance means each having a negative resistance-current characteristic.

6. The combination of a space discharge device comprising a cathode, an anode and a control electrode, a cathode-anode circuit, a cathode-control electrode circuit, negative resistance-current characteristic resistance means common to said circuits capable of supplying a potential varying only slightly with cathode-anode current variations, and additional means, a part only of which includes negative resistance-current characteristic resistance means, in shunt with said first-mentioned means, said additional means applying to said control electrode a biasing potential that remains substantially constant with variation in value of current flow between no load and full load current in said cathode-anode circuit.

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