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L. H. CRANDON ET AL

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LOW VOLTAGE REGULATED POWER SUPPLY

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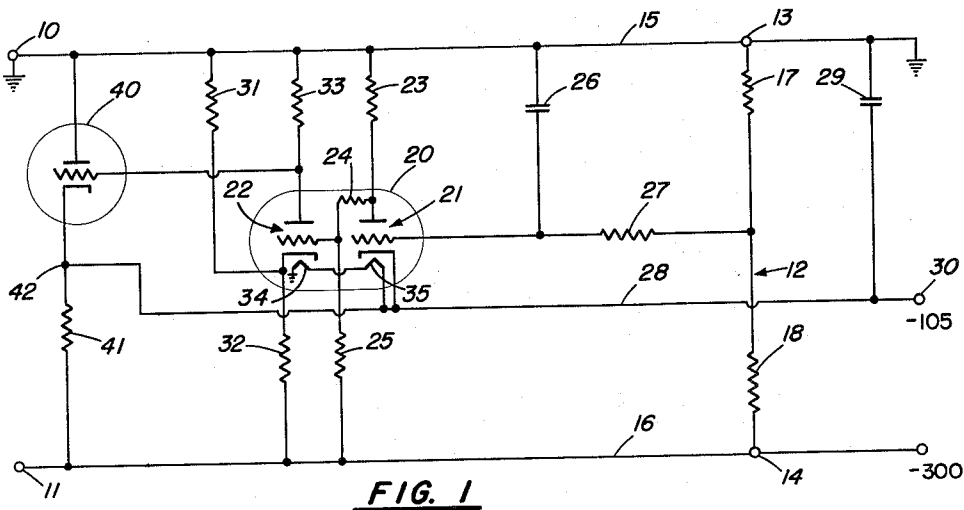


FIG. 1

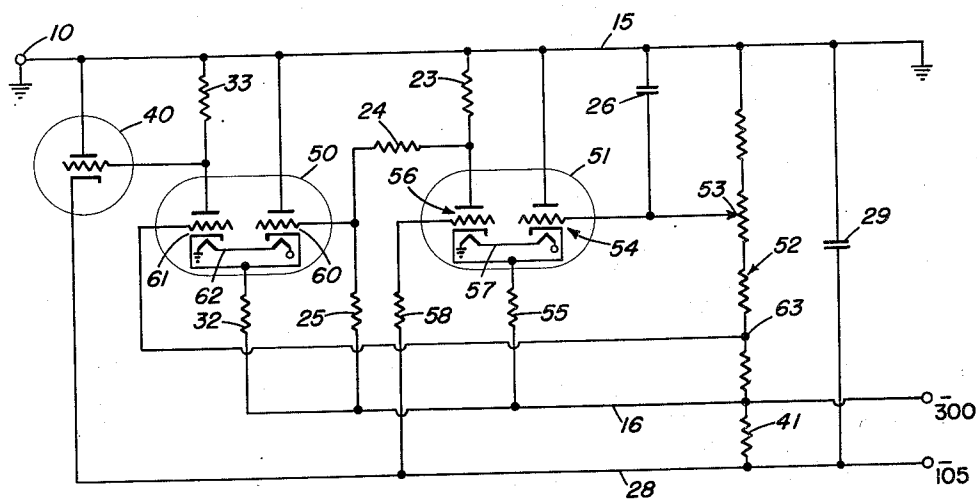


FIG. 2

INVENTORS
LAWRENCE H. CRANDON
GORDON S. LEY
THOMAS C. PRIDMORE

BY

H. Schmitt
Walter S. Paul.
ATTORNEYS

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LOW VOLTAGE REGULATED POWER SUPPLY

Lawrence H. Crandon, Los Angeles, Calif., and Gordon S. Ley, Elmira, and Thomas C. Pridmore, Bath, N. Y., assignors, by mesne assignments, to the United States of America as represented by the Secretary of the Navy

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5 Claims. (Cl. 323—22)

This invention relates to voltage regulation with particular application to regulation of voltages below 110 volts.

In ordinary voltage regulatory systems there is no important difficulty in securing satisfactory regulation above 110 volts. However, below this voltage, as, for example, around 105 volts, difficulties arise and it is usually necessary to build another regulated supply to serve as a reference voltage. Gaseous-discharge voltage-regulator tubes have been used to some extent for reduced voltages but stability and regulation have not been found satisfactory.

In brief, the regulatory system proposed is a multistage amplifier, with the last stage connected as a cathode follower with 100% negative feedback from the last stage to the first stage.

The objects of the invention are to secure adequate regulation of a low voltage power output, to reduce output ripple and to compensate for cathode emission changes in the control circuit.

Other objects and many of the attendant advantages of this invention will appear on reference to the following detailed description and the accompanying drawings wherein:

Fig. 1 is a circuit diagram illustrating one form of the invention; and

Fig. 2 is a circuit diagram illustrating a modified form of the invention.

In Fig. 1 the power input terminals are indicated at 10 and 11, across which there is impressed 300 volts as received from an alternating current rectifier or other source. This voltage is closely controlled so that the voltage divider 12 between terminals 13 and 14 on main power lines 15 and 16 and including resistors 17 and 18, serves as a reference voltage for the system.

Tube 20 is a direct coupled high gain twin triode amplifier (12Ax7), having an input grounded-grid triode unit 21 and output direct-coupled triode unit 22. The anode of unit 21 is connected to power main 15 via resistor 23 and to main line 16 through resistors 24 and 25. The grid of input unit 21 is connected through a capacitor 26 to main line 15 and through resistor 27 to a point on the divider 12 between resistors 17 and 18. The cathode of unit 21 is connected by conductor 28 directly to the low potential output terminal 30. Capacitor 29 is connected between main line 15 and output line 23.

The grid of output unit 22 of tube 20 is connected to the output of unit 21 between resistors 24 and 25, and the cathode of unit 22 is connected through resistor 31 to main line 15 and through resistor 32 to main line 16. The anode of unit 22 joins the main line 15 through resistor 33. Cathode heaters 34 and 35 of unit cathodes are series connected, the input triode heater 35 having a connection with the associated cathode and the output heater being grounded.

The amplifier tube 40 is a triode (6As7) with the anode connected to the main line 15, the cathode connected

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through resistor 41 to main line 16 and the grid connected to the anode of the outlet unit of tube 20. The cathode is also connected from point 42 to the low potential output terminal 30, and thus, also, to the cathode of the inlet unit of tube 20, this being the well-known cathode follower arrangement.

The operation of the circuit as set out in Fig. 1 will now be described, assuming application of a constant voltage of —300 volts to main line 16, line 15 being grounded. The capacitor and resistor constants are so chosen that a reduced voltage of around —105 is secured at terminal 30. Should there now be a reduction in voltage between terminal 30 and ground due to load variation, the change will be impressed on the cathode of the input unit 21 of tube 20, increasing the effective resistance of the unit and thus reducing the voltage on the grid of the output unit. The current in the output unit 22 is therefore increased, increasing the output voltage as applied to the grid of tube 40 and thereby decreasing the current flow in tube 40 and increasing the negative voltage at point 42 and at output terminal 30. Thus, there is voltage compensation for the output voltage drop. Tests have shown that within a range variation of 5 to 50 milliamperes the load voltage is stabilized within a range of ± 0.01 volt. Also, ripple change is compensated to within 2.5 millivolts.

If the filament voltage on the tubes changes, thus changing the emission of the cathodes, or if the cathode emission changes with age, the tubes act as if a small voltage had been injected in series with the cathodes. In the case of the input unit 21 of tube 20, this injected voltage will be uncompensated and will cause an equal error voltage in the output which may exceed 0.1 volt. Where it is desirable to compensate for this error the circuit diagram of Fig. 2 may be employed. In this circuit the same general arrangement of Fig. 1 is used with main lines 15, 16 and amplifier tube 40 connected as a cathode follower to the load. However, in place of tube 20, a pair of twin triodes 50 and 51 are used and the divider and tube connecting circuits are modified.

Tube 51 is substituted for the input unit 21 of tube 20, the grid of the input grounded-grid section 54 having connection to a slider 53 or the divider 52, the anode having connection to main line 15 and the cathode having connection through resistor 55 to main line 16. The cathode of the output section 56 of this tube is connected to the input section cathode and resistor 55 and both cathodes are provided with a common heater 57 having line connection at one end and ground connection at the other end. The output section grid is connected through resistor 58 to the load line 28, and the anode is connected to the main line 15 through resistor 23, to the grid of input cathode follower section 60 of tube 50 through resistor 24 and to main line 16 through resistors 24 and 25.

The anode of the input section of tube 50 is connected directly to the main line 15, and the cathode is connected through resistor 32 to main line 16 and to the cathode of output grounded-grid section 61 of this tube. A heater 62 is provided for the joined cathodes, one end being connected to a line junction and the other to ground. The grid of the output section is joined to a fixed point 63 on the divider at a voltage point lower than slider 53; and the anode is joined through resistor 33 to main line 15 and to the grid of tube 40.

Examination of the circuit of Fig. 2 will show that it has a compensatory action similar to the circuit of Fig. 1 for all load voltage variations, the load voltage change being impressed on the grid of the output section 56 of tube 51 and then being transmitted through tube 50 to tube 40 to produce a compensation for the initial load variation. In addition, any change in the cathode emission, is countered by a voltage due to the twin triode ar-

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rangement, thus cancelling the effect of the emission change. Thus, in tube 54 a reduction in cathode emission results in a reduction in current flow through the tube and an increase in plate voltage, thereby cancelling the effect of the drop in cathode emission. For example, in a load variation of 3 to 20 milliamperes the load voltage is stabilized within 20 millivolts, a 10 percent voltage variation is held within 30 millivolts and the ripple is reduced to 1.0 millivolt.

It should be pointed out that in tubes 50 and 51 the values of amplification and plate resistance (r_p) for the tube units are alike and hence it amplifies the grid difference voltage like a tube with the same resistance (r_k) and, twice the internal plate resistance of a single section. Therefore, any voltage injected in series with the cathode, such as may in effect be due to heater current variation or diminution in cathode emission, is reduced by the factor

$$\frac{r_p}{(\mu+1)r_k+r_p}$$

where r_k is the common cathode resistor.

In effect, the circuit is a super cathode follower, the amplifier units being the "control grid" and tube 40 being the "cathode." The effective " μ " and " gm " of this super-cathode follower is high due to the amplification of the cascaded triodes inserted between the "control grid" and "cathode." The fluctuations of the supply voltage are accordingly reduced by " μ " times and the internal resistance becomes $1/gm$.

Modifications and variations of the present invention are possible in the light of the above teachings; and it is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A voltage regulating system comprising: a source of D. C. voltage; a first amplifying element having a first cathode, a first grid, and a first plate; an output terminal; voltage dividing means for producing a bias voltage which is a portion of said D. C. voltage; means for connecting said bias voltage to said first grid; impedance means for connecting said first plate to the positive terminal of said source of D. C. voltage; means for connecting said first cathode to said output terminal; a second amplifying element having a second cathode, a second grid, and a second plate; impedance means for connecting said first plate to said second grid; impedance means for connecting said second grid to the negative terminal of said source of D. C. voltage; impedance means for connecting said second cathode to the positive terminal of said source of D. C. voltage; impedance means for connecting said second cathode to the negative terminal of said source of D. C. voltage; impedance means for joining said second plate to the positive terminal of said source of D. C. voltage; a third amplifying element having a third cathode, a third grid, and a third plate; leads for connecting said third cathode to said output terminal; impedance means for connecting said third cathode to the negative terminal of said source of D. C. voltage; leads for connecting said third grid to said second plate; and leads for connecting said third plate to the positive terminal of said source of D. C. voltage.

2. A voltage regulating system comprising: a source of D. C. voltage, a first amplifying unit having a first positive element and a first negative element, means for biasing said first amplifying element with a portion of said D. C. voltage, an output terminal; means for connecting said first negative element to said output terminal, impedance means for connecting said first positive element to the positive terminal of said source of D. C. voltage, a second amplifying unit having a second positive element and a second negative element, means for connecting the output of said first amplifying unit to the input to said second amplifying unit, impedance means

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for connecting said second positive element to the positive terminal of said source of D. C. voltage, impedance means for connecting said second negative element to the negative terminal and to the positive terminal of said source of D. C. voltage, a third amplifying unit having a third positive element and a third negative element, means for connecting the output of said second amplifying unit to the input to said third amplifying unit, leads for connecting said third positive element to the positive terminal of said source of D. C. voltage, leads for connecting said negative element to said output terminal, and impedance means for connecting said third negative element to the negative terminal of said source of D. C. voltage.

3. A voltage regulating system comprising: a source of D. C. voltage, a voltage divider connected across said source of D. C. voltage, a first amplifying unit having a first positive element and a first negative element, leads for connecting said first positive element to the positive terminal of said source of D. C. voltage, impedance means for connecting said first negative element to the negative terminal of said source of D. C. voltage, leads for connecting a first bias voltage from said voltage divider to said first amplifying unit, a second amplifying unit having a second positive element and a second negative element, leads for connecting said second negative element to said first negative element, impedance means for joining said second positive element to the positive terminal of said source of D. C. voltage, an output terminal, impedance means for connecting any voltage on said output terminal to bias said second amplifying unit, a third amplifying unit having a third positive element and a third negative element, means for connecting the output of said second amplifying unit to the input of said third amplifying unit, leads for connecting said third positive element to the positive terminal of said source of D. C. voltage, impedance means for joining said third negative element to the negative terminal of said source of D. C. voltage, a fourth amplifying unit having a fourth positive element and a fourth negative element, leads for connecting said fourth negative element to said third negative element, impedance means for connecting said fourth positive element to the positive terminal of said source of D. C. voltage, leads for connecting a second bias voltage from said voltage divider to said fourth amplifying unit which bias is less positive than said first bias voltage, a fifth amplifying unit having a fifth positive element and a fifth negative element, means for connecting the output of said fourth amplifying unit to the input of said fifth amplifying unit, leads for connecting said fifth positive element to the positive terminal of said source of D. C. voltage, leads for connecting said fifth negative element to said output terminal, and impedance means connecting said output terminal to the negative terminal of said source of D. C. voltage.

4. A regulator for maintaining a load voltage that is substantially independent of changes in the load, said regulator comprising: a first output terminal and a second output terminal, a ground connection for said second output terminal, a grounded-grid amplifier having a cathode directly joined to said first output terminals for producing a plate voltage that is a function of the voltage changes of the potential between said first and second output terminals, a direct-coupled amplifier connected to amplify the plate voltage of said grounded-grid amplifier, a cathode follower circuit having a triode with a cathode directly connected to said first output terminal and a plate directly connected to said second output terminal, and leads for directly connecting the output of said direct-coupled amplifier to the grid of said triode.

5. A regulator for maintaining a load voltage that is substantially independent of changes in the load and of changes in the cathode emission in the tubes of the regulator, said regulator comprising: two output terminals, a first tube section comprising a cathode follower circuit supplied with fixed plate and grid voltages, a second tube

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section similar in physical characteristics to said first tube section and having a common cathode resistor with said first tube section and having a grid direct-coupled to one of said two output terminals for producing an output in response to the voltage difference between grid and cathode, a third tube section comprising a cathode follower circuit direct-coupled to be energized by the output of said second tube section, a fourth tube section having physical characteristics similar to said third tube section and comprising a grounded-grid amplifier having a common cathode resistor with said third tube section for producing an output in response to the voltage difference between grid and cathode, a cathode follower circuit having

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a cathode directly connected to said one output terminal and a plate directly connected to the other of said two output terminals, and leads for directly conducting the output of said fourth tube section to the grid of said cathode follower circuit.

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