

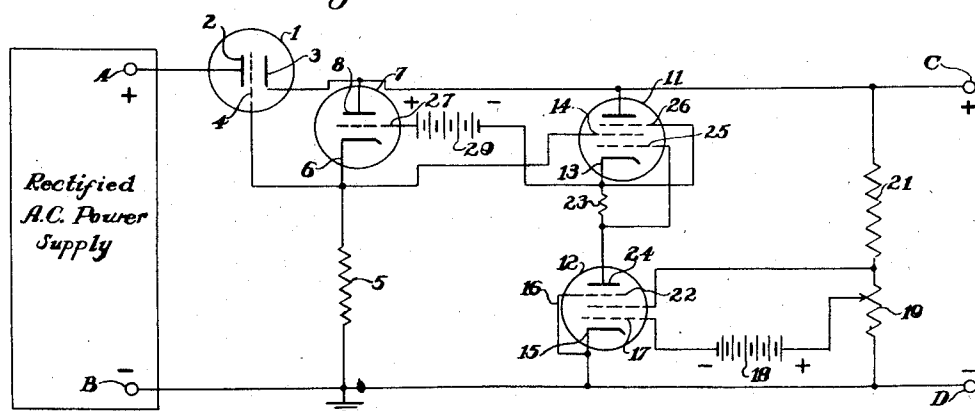
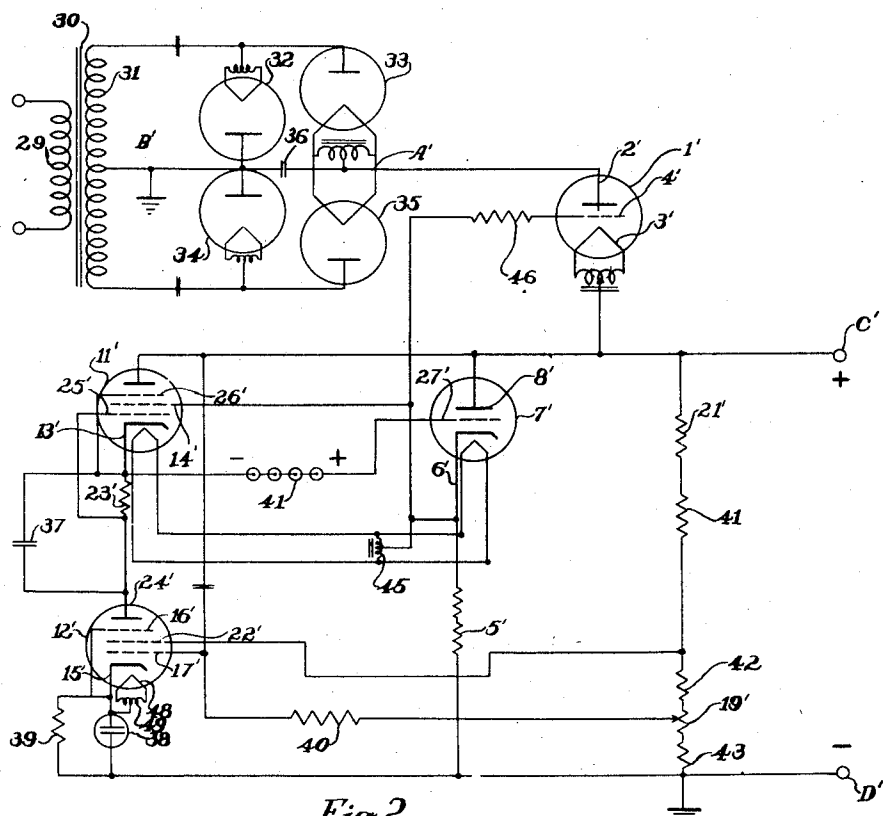
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VOLTAGE REGULATION AND SUPPLY

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WITNESSES.

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Fig. 1

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VOLTAGE REGULATION AND SUPPLY

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5 Claims. (Cl. 323—22)

1

This invention relates to voltage regulating systems and more particularly to power supply circuits delivering a constant potential by means of electronic regulation. Power supplies of the type referred to generally include an electron discharge device placed in series between the supply circuit and the load. The space current conductivity of the discharge device is varied when there is a tendency for a change of voltage at the terminals of the load circuit or in the supply circuit. The conductivity variation is compensative to maintain current flow in the load circuit at such value which provides a substantially constant terminal voltage. The type of control used for the discharge device plays an important part in the overall response of the system. Various electronic control circuits have been developed for effecting regulation of the series connected discharge device.

A particular feature of this invention is that the control circuit permits greater flexibility of regulation as well as stability in the operation of the supply circuit.

Another feature of this invention is that the control circuit incorporates circuit elements heretofore not used, which applied in a specific manner result in a manifold increase in the control effectiveness of the system.

A particular advantage of the control circuit is that small variations in the output voltage of the supply can be effectively compensated. Moreover, use can be made of amplifiers having extremely high amplification.

Another advantage of the invention is that increased stability of operation results from the fact that the control voltage for the controlled tube, derived in part from a vacuum tube as an impedance element, is not affected by terminal voltage variations except in the predetermined and desired manner.

The invention contemplates the use of an electrical network in connection with the control electrode of the controlled tube. At least one impedance element of the network is a vacuum tube. The invention also provides a circuit in which the controlled voltage for the controlled tube is derived from a cathode-follower. The latter is energized from a suitable amplifier and is simultaneously utilized to furnish a constant potential operating voltage for certain electrodes of the vacuum tube in the amplifier.

Other features and advantages will be apparent from the following description of the invention, defined in particularity in the ap-

2

pended claims, and taken in connection with the accompanying drawing in which:

Figure 1 is a simplified circuit diagram of the control circuit and

Figure 2 is a schematic circuit diagram of a complete supply system incorporating the control circuit.

Referring to Figure 1, the input to the control circuit is taken from a power supply indicated by a block diagram marked "Rectified AC Power Supply." The purpose for this is to illustrate the fact that any desired type of supply may be used, including either a full wave or a half wave rectifier and conventional filter networks. The direct current output of this supply is applied between terminals A and B at the indicated polarity. The output side of the supply system is provided with terminals C and D to which a load circuit may be connected. The control circuit maintains across these terminals a substantially constant potential irrespective of changes in the load or fluctuations in the supply circuit within predetermined limits. The vacuum tube 1 is a series connected discharge device having its anode 2 connected to the positive terminal of the supply and the cathode 3 to the positive terminal of the load circuit. The current flow through the tube 1 is regulated by means of the bias voltage applied to the control electrode 4. The latter connects to a junction point between the resistor 5 and the cathode 6 of the vacuum tube 7. The anode 8 thereof connects to the cathode 3 of the tube 1 and thereby also to the positive terminal of the load circuit. The other terminal of the resistor 5 connects to the common negative side of the supply and the load circuit. This side is grounded in the majority of cases and, therefore will be referred to as ground.

Observing this circuit, it will be seen that the vacuum tube 7 and the resistor 5 in series form a voltage divider across the output of the supply system. The space current path of the tube 7 is also directly connected between the control electrode 4 and the cathode 3 of the tube 1. Consequently, this tube replaces the conventional grid resistor and performs the function of a variable impedance path in the grid circuit of the controlled tube 1. Looking at this circuit from another angle, it will be apparent that the vacuum tube 7 with the resistor 5 is essentially a degenerative vacuum tube circuit, known in the art as a cathode-follower. Its high input impedance and low output impedance is advantageously used as a coupling

3

means between the controlled tube and the amplifier control circuit.

By the use of the cathode-follower it is feasible to employ an amplifier of the dynamic load resistance type and benefit from the very high gain that such amplifier possesses. The tube 11 by virtue of its connection in the circuit operates as the dynamic anode load resistance of the amplifying tube 12. In order to perform this function properly, it is essential that a substantially constant potential be maintained between the cathode 13 and the screen grid electrode 14 of this tube. A secondary function of the cathode-follower 7 is to furnish the screen grid potential in the manner described in my copending application Serial No. 558,423 filed October 12, 1944, now Patent No. 2,517,863, issued August 8, 1950.

The amplifying vacuum tube 12 has the cathode 15 as well as the suppressor grid 16 connected to ground. In the input circuit of the amplifier the grid 17 connects through a source of fixed potential, shown here by way of example, by the battery 18 to the variable tap of the potentiometer 19. The latter is in series with a fixed resistance 21 between the output terminals of the load circuit. The screen grid electrode 22 connects to the junction point between potentiometer 19 and the resistor 21. It is to be noted that under certain conditions governed by the value of output voltage it may be necessary to connect other resistance elements in series across the supply circuit in addition to the resistance shown here in order to obtain the required screen grid and control grid potentials.

The output circuit of the amplifier, as mentioned before, has for its anode load resistance the vacuum tube 11. The connection is effected through the resistor 23 which interconnects the cathode 13 and the anode 24. The purpose of this resistor is to supply the minimum bias potential for the grid electrode 25 which return returns to the anode terminal of the resistor 23. The suppressor grid 26 terminates at the cathode 13 in the conventional manner. The screen grid 14 of the tube 11 connects directly to the junction point of the resistor 5 and the cathode 6 of the cathode-follower tube 7. The grid circuit of the latter, including the grid electrode 27 returns to the cathode 13 through a source of fixed potential, shown here by way of example, by the battery 29.

The operating voltages in various portions of the circuit are so chosen that the current flowing in the output circuit through the controlled tube 1 produces the required voltage drop in the load circuit. The static operating potentials maintain this value of current and the conductivity characteristic of the tube 1 is altered only when there is a change which tends to alter the voltage output, for example, when the load increases or decreases, or when the direct current input to the control system fluctuates for any reason at all. The static potential for the grid circuit of the controlled tube 1 is derived from the anode current flow of the cathode-follower tube 7. The anode current of the latter, on the other hand, depends on the grid potential supplied to the grid electrode 27. The purpose of the fixed source shown by the battery 29 is to equalize the potential difference existing between the cathode 13 with respect to the positive side of the output circuit as well as the negative side. In other words, the value of the source is so calculated as to maintain the grid 27 with respect to the cathode 6 at a potential which provides the required

4

current flow to furnish the static bias potential of the grid 4. The value of the battery voltage is approximately that of the required screen grid potential for the vacuum tube 11. In practice, this battery may be replaced by a suitable electronic supply source or by a number of series connected primary cells, of the type known in the art as bias cells.

In the input circuit of the amplifier the battery 18 furnishes a potential known as the reference voltage. This is a constant and variations in the output voltage of the system are applied to the amplifier with respect to this reference voltage. In other words, the battery 18 maintains the required bias potential for the control grid 17 of the amplifier tube 12 so that the potential at the cathode 13 will properly energize the cathode-follower to have the required current conductivity. Once this static condition is established extremely small variations in the output voltage determined by the setting of the potentiometer 19 will be impressed on the control grid 17. These variations in an amplified form appear at the cathode 13 and are impressed, additively or subtractively as to the fixed potential of the battery 29 and cause a change of current in the cathode-follower which will correspondingly change the conductivity of the controlled tube 1. Since the cathode-follower follows the potential variations of the cathode 13, the screen grid potential for the electrode 14 will vary correspondingly inasmuch as it is derived from the output of the cathode-follower 7 across the resistor 5. The screen grid potential therefore varies in phase with the cathode potential and consequently, is maintained substantially constant with respect to the cathode 13. This is instrumental in the function of the vacuum tube 11 as the dynamic load resistance for the vacuum tube 12.

Referring to Figure 2 the voltage regulator is shown applied to a supply system which derives all operating potentials from the supply circuit except the fixed potential of the cathode-follower. The rectifier circuit shown here in the form of a voltage doubler need not be described in detail inasmuch as its operation is well understood in the art and the invention has no bearing on this portion of the system. The filament circuits of the vacuum tubes in the voltage doubler as well as in the control circuit are schematically indicated by center tapped windings. For the sake of simplicity the primary winding which would form a filament transformer with each is not shown here. The control circuit connects to the output circuit of the rectifier effectively across the condenser 36, one terminal of which is grounded and the other connected to the common cathode circuit of rectifier tubes 33 and 35.

The operation of the control system is essentially the same as the one described in connection with Figure 1. Therefore, identical circuit elements appearing here are marked with similar reference characters bearing primary indices. The vacuum tube 1' is placed in series between the load circuit marked by terminals C' and D' and the rectifier output circuit marked by terminals A' and B'. The anode 2' connects to the cathodes of the rectifiers 33 and 35 whereas the cathode 3' connects to the positive side of the load circuit. The cathode-follower comprising the vacuum tube 7' and the resistor 5' is in shunt with the load circuit. The anode 8' is connected to the positive side and the cath-

5

ode 6' to the resistor 5'. The amplifier control circuit for the cathode-follower includes the resistance tube 11' and the amplifying vacuum tube 12'. The cathode 13' connects to the anode 24' through the resistor 23'. The control grid 25' returns to the anode 24' and the suppressor grid 26' to the cathode 13'. A by-pass condenser 37 shunts the resistor 23'. In the input circuit of the amplifier the fixed potential for the bias of the grid 17' is derived from the glow tube 38 and the resistor 39 in parallel therewith. The suppressor grid 16' returns to the cathode 15'. The glow tube 38 is energized by the space current of the amplifying tube 12' and maintains a uniform voltage drop. The grid 17' connects to the potentiometer 19' in series with a grid resistor 40. The potentiometer 19' is a portion of a voltage divider comprising suitable resistance elements indicated by the resistors 21', 41, 42, and 43. The screen grid 22' of the amplifying tube 12' derives operating potentials from the junction point of resistors 41 and 42.

The filaments of vacuum tubes 7' and 11' are energized from a common winding 45 the center tap of which is connected to the cathode 6' of vacuum tube 7'. The cathode 6' is also connected to the grid 4' of the tube 1' as well as to the screen grid 14' of the tube 11' in the same manner as described in connection with Figure 1. Resistor 46 included in this circuit functions as a damping resistor to prevent oscillations under certain operating conditions. It also prevents excessive output voltage when the circuit is first turned on, in which case some tubes warm up to operating condition before others and may give a large output voltage damaging the load. The grid current limiting resistor 46 prevents this. The control grid 27' of the cathode-follower 7' returns to the cathode 13' through a series of bias cells 41 connected in the polarity shown here. The number of cells shown is not intended to be representative of the voltage value used. This will differ widely, depending upon circuit and vacuum tube constants. The filament 48 of the amplifying vacuum tube 12' is energized from the winding 49, the center tap of which connects to the cathode 15'.

The operation of the circuit of Figure 2 does not differ materially from that of Figure 1. Under static conditions the vacuum tube 1' has an internal resistance which permits current flow in the load circuit of a value producing the required output voltage. Very small changes in this voltage appearing across the potentiometer 19' are applied to the input circuit of the amplifier tube 12' and are transmitted in an amplified form as changes of grid bias of the cathode-follower 7'. This in turn changes the operating bias of the grid 4' controlling the internal resistance of the tube 1' in the manner to compensate for the changes which tend to alter the output voltage.

What is claimed is:

1. In a voltage regulating system, a supply circuit, a load circuit, a variable resistance electron discharge device having at least a cathode and control electrode interposed therebetween for controlling the voltage of said load circuit, a second discharge device and a resistance in series connected between terminals of said load circuit, means connecting the junction between said second discharge device and resistance to said control electrode whereby said last-mentioned discharge device operates as a cathode-follower, an electrical connection between the anode of the

6

said cathode-follower and the cathode of said first discharge device, circuit means for varying the resistance of said cathode follower in accordance with voltage variations of said load circuit, whereby the effective resistance of said first discharge device is varied in accordance with the voltage on the cathode of said cathode-follower.

2. In a voltage regulating system, a supply circuit, a load circuit, a variable resistance electron discharge device having at least a cathode, anode, and control electrode and having the interelectrode space thereof electrically connected in series with the supply circuit and the load circuit for controlling the voltage of said load circuit, a second discharge device having anode, cathode, and a control electrode, a connection between the anode of said second device and an electrical terminal of said load circuit and a connection including a resistor between said cathode of said second device and the other terminal of said load circuit, circuit means connecting the junction between the resistance and the cathode of the second discharge device to the control electrode of the first discharge device, circuit means connecting the anode of the second discharge device to the cathode of the first discharge device, whereby said second discharge device operates as a cathode-follower, and whereby the effective resistance of said first discharge device is varied in accordance with the variations of voltage output of said cathode-follower, circuit means for controlling the voltage of the cathode with respect to the anode of said cathode-follower in accordance with voltage variations of said load circuit including an amplifier having input and output circuits, circuit means for impressing the voltage output of said output circuit on the control electrode of said cathode-follower, and circuit means for impressing voltage variations in said load circuit on the input circuit of said amplifier.

3. In a voltage regulating system including a source of energy and a load circuit, a variable resistance electron discharge device having at least a cathode and control electrode interposed therebetween for controlling the voltage of said load circuit, an amplifier having an input and output circuit, an amplifying vacuum tube and a second vacuum tube electrically connected to the first tube so as to operate as the dynamic load resistance of said first tube, a second electron discharge device and a resistance connected in series therewith connected between terminals of said load circuit, circuit means connecting said second device as a cathode-follower with respect to the control electrode of said first device and as a cathode-follower with respect to the screen grid electrode of said second tube to supply a predetermined potential thereto, circuit means for impressing voltage changes in said load circuit on the input circuit of said amplifier, circuit means including a source of bias potential connecting the output circuit of said amplifier with the control electrode of said cathode-follower and with the cathode of said second tube.

4. In a voltage regulating system, a supply circuit, a load circuit, a variable resistance electron discharge device having at least a cathode, anode, and control electrode and being electrically connected in series with the supply circuit and the load circuit for controlling the voltage of said load circuit, a second discharge device having anode, cathode, and a control electrode, a connection between the anode of said second

device and a terminal of said load circuit, and a connection between the cathode of said second device and the other terminal of said load circuit including a resistance, an electrical connection between the junction of the resistance and the cathode of the second discharge device and the control electrode of the first discharge device, an electrical connection between the anode of the second discharge device and the cathode of the first discharge device, whereby said second discharge device operates as a cathode-follower, and whereby the effective resistance of said first discharge device is varied in accordance with the variations of voltage developed between the cathode and anode of said cathode-follower, circuit means for controlling the voltage across said cathode-follower in accordance with voltage variations of said load circuit, including an amplifier comprising an input and output circuit, an amplifying vacuum tube and a second vacuum tube adapted to operate as the dynamic load resistance of said amplifying tube, a circuit including a bias source connecting the control electrode of said cathode-follower and the cathode of said second vacuum tube, a connection between the cathode of the cathode-follower and the screen grid electrode of said second tube, and circuit means for impressing voltage variations in said load circuit on the input circuit of said amplifier.

5. In a voltage regulating system, a supply circuit, a load circuit, a variable resistance electron discharge device having at least a cathode, anode, and control electrode, said discharge device being connected in series with the supply circuit and the load circuit for controlling the voltage of said load circuit, a second discharge device having anode, cathode, and a control electrode, a connection between said anode of said second device and a terminal of said load circuit and a connection between said cathode of said second device and the other terminal of said load circuit including a resistance, circuit means connecting the junction between the re-

sistance and the cathode of the second discharge device to the control electrode of the first discharge device, and circuit means connecting the anode of the second discharge device to the cathode of the first discharge device, whereby said second discharge device operates as a cathode-follower, and whereby the effective resistance of said first discharge device is varied in accordance with the variations of voltage developed between the anode and cathode of said cathode-follower, circuit means for controlling the voltage across said cathode-follower in accordance with voltage variations of said load circuit, including an amplifier comprising an input and output circuit, an amplifying vacuum tube and a second vacuum tube adapted to operate as the dynamic load resistance of said amplifying tube, a circuit including a bias source connecting the control electrode of said cathode-follower and the cathode of said second vacuum tube, said bias source supplying a potential at the value of which said cathode-follower is controlled in accordance with variations of the potential of the cathode of said second tube, a connection between the cathode of the cathode-follower and the screen grid electrode of said second tube, and circuit means for impressing voltage variations in said load circuit on the input circuit of said amplifier.

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