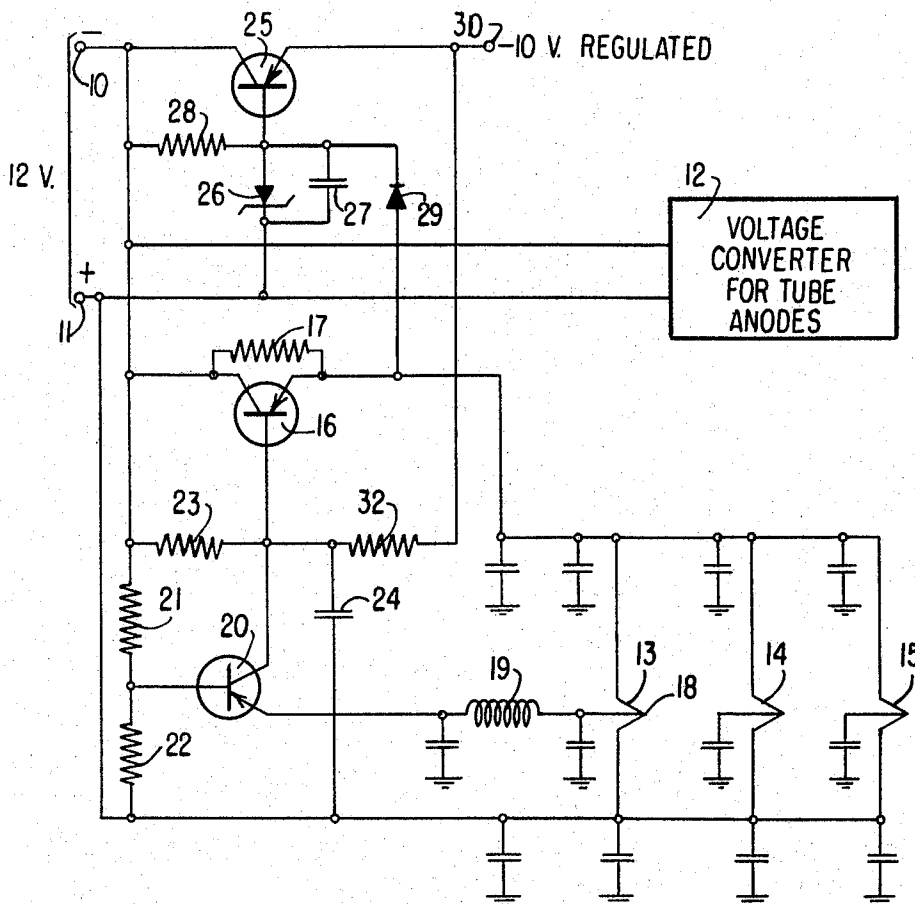


July 25, 1967

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REGULATED POWER SUPPLY WITH PLURAL OUTPUTS FOR TUBE
FILAMENTS AND TRANSISTORS
Filed Nov. 15, 1963

3,333,151



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REGULATED POWER SUPPLY WITH PLURAL OUTPUTS FOR TUBE FILAMENTS AND TRANSISTORS

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Filed Nov. 15, 1963, Ser. No. 324,090
8 Claims. (Cl. 315-107)

This invention relates generally to electrical regulating systems, and more particularly to a system for providing a regulated voltage output and for controlling the current applied to a heating element, the resistance of which increases with temperature.

Vacuum as used in electronic equipment normally include filaments or heater elements for causing electron emission from the cathodes of the tubes. These heater elements normally have a temperature coefficient such that the resistance increases with temperature, commonly referred to as a positive temperature coefficient. Accordingly, when the heater is first energized and the temperature is relatively low, the resistance will be low and a surge of current will flow through the heater. This has a detrimental effect on the life of the heater. The supply voltage may also vary over such a wide range that excessive current is produced in the heaters to damage the same.

Systems have been provided for controlling energization of tube heaters so that the current is applied thereto gradually. Some of these systems have included mechanical switch devices which are objectionable for various reasons. Further, circuits for controlling the initial heater current and the steady state current in the presence of wide variations of supply voltage so that the heater current is held within the desired limits, have been complex and expensive. These circuits have not provided complete regulation of voltages and currents, as desired.

It is therefore an object of the present invention to provide an improved circuit for applying current to heater elements, the resistance of which increases with temperature, so that excessive current surges are prevented.

A further object of the invention is to provide a regulator circuit which applies current in steps to elements having resistance with a positive temperature coefficient, and which provides a regulated voltage output when the last step of current is applied.

Another object of the invention is to provide a regulator circuit which furnishes a regulated voltage output from an unregulated supply, and which also controls the voltage in an auxiliary circuit energized from the unregulated supply.

A feature of the invention is the provision of a regulator circuit for energizing tube heaters or filaments from a vehicle battery, wherein the initial current is applied through a resistor to reduce the applied voltage, with a bridge across the resistor to increase the voltage after the filaments heat up, and with the bridge controlling the voltage during operation to compensate for variation in the battery voltage.

Another feature of the invention is the provision of a first circuit for providing a regulated voltage output from an unregulated supply, which circuit is coupled to a second circuit for controlling filament current and operates to delay the regulated output until full filament current is applied, and with the regulated output from the first circuit controlling the supply of current in the second circuit. The circuits include transistors for controlling the voltage and current, and a Zener diode which forms the reference for the regulated voltage.

The invention is illustrated in the single figure of the drawing which is a circuit diagram of the system for

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providing regulated voltage output and controlled current in a heater element.

In practicing the invention, a power supply is provided for connecting electronic equipment to a varying source voltage, such as that provided by the battery of a vehicle. Present automobiles include a nominal 12 volt battery, but the voltage of the battery may vary from 10 to 16 volts or more depending upon the condition of charge of the battery. The regulator includes a circuit having a transistor and a Zener diode for providing a regulated direct current output. The regulator also includes a transistor circuit for controlling the current supplied to heater elements having resistance with a positive temperature coefficient, such as filaments or heaters of vacuum tubes. The current supplied to the filaments is initially supplied through a resistor to drop the voltage, with a transistor shunting the resistor to apply full voltage. The transistor is connected in a Schmitt trigger circuit with a control transistor which senses a voltage at the heater element. The voltage sensed varies with the resistance of the heater element, and when the resistance increases to a predetermined value, the trigger operates to shunt the resistor to apply full voltage to the heater element. The voltage regulator circuit is coupled to the current supplying circuit so that the regulated voltage output is not developed until full current is applied to the filaments. The regulated voltage output further controls the current supply circuit to reduce the current when the supply voltage becomes objectionably high.

Referring now to the drawing, the power supply control circuit is shown in the single figure. Terminals 10 and 11 are connected to the supply voltage which may be the voltage of a battery in a vehicle. This has a nominal voltage of 12 volts, but varies from 10 volts to 16 volts depending upon the condition of charge of the battery. The circuit may be used for energizing both tubes and transistors and controls the current applied to the tube heaters or filaments, and provides a regulated output voltage for operating transistors and the like. The voltage converter 12 for providing high voltage for tube anodes may be a standard unit, and is shown as a block.

Considering first the filament supply, the tube filaments 13, 14 and 15 are energized in parallel from the voltage supply, being connected through resistor 17, across which is bridged transistor 16. The filaments are of the type having a center tap, and the center tap and the end terminals of each filament are bypassed for radio frequency by capacitors. The transistor 16 is controlled by transistor 20, the two transistors being connected in a Schmitt trigger circuit. The base electrode of transistor 20 is connected to the junction of resistors 21 and 22 which form a voltage divider connected across the supply voltage. Resistor 23 and capacitor 24 are also connected across the supply voltage, and when the circuit is initially energized capacitor 24 charges so that current flows through resistor 23. The voltage developed across resistor 23 by this charging current renders transistor 20 conducting and holds the transistor 16 cut off. With transistor 16 cut off, the current is applied to the filaments through register 17 and this has a value to drop the voltage so that the current through the filaments exceeds the rated value by only a limited amount.

As the filaments warm up and the resistance thereof increases, the current therethrough is reduced. Increase in resistance of the filaments increases the voltage at the center point 18 of filament 13. This point is coupled through choke coil 19 to the emitter electrode of transistor 20. Resistors 21 and 22 are selected to provide a bias voltage at the base electrode of transistor 20 so that this transistor is cut off when the voltage on the emitter rises to a predetermined value. This may be set so that the

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transistor 20 will start to cut off when the current through the filaments drops to or below the rated value. Although this is a gradual action, since transistors 16 and 20 are connected in a Schmitt trigger circuit the cut off of transistor 20 will cause transistor 16 to conduct and this will shunt the resistor 17 to effectively apply a higher voltage to the filaments. This will cause the voltage at point 18 to further increase so that the transistor 20 is cut off more and transistor 16 conducts more.

The Schmitt trigger action will provide fast switching so that transistor 16 is fully conducting to shunt out the resistor 17. This will increase the voltage supplied to the filaments so that the current therethrough will increase to a controlled value which may be greater than the rated value. However, further heating of the filaments by the increased current will increase the resistance of the filaments so that a steady state is reached at which the current is reduced to the rated value, provided the nominal filament voltage is not exceeded.

It is therefore seen that the circuit provides application of current to the filaments in two stages. While the current may be above rated value at starting and again at the beginning of the second stage, the increase above rated values may be held within safe limits so that the filaments are not damaged thereby and filament life is greatly increased.

Considering now the circuit for providing a regulated 10 volt supply, this is provided by transistor 25 connected as an emitter follower stage with Zener diode 26 bridged by capacitor 27 connected to control the conduction of the transistor. The base electrode of transistor 25 is connected to the junction between resistor 28 and diode 29, which are connected from the negative supply terminal 10 to the emitter electrode of transistor 16. This circuit holds the transistor 25 partially cut off when transistor 16 is not conducting, during the filament warm up period. This takes place because the drop in voltage through resistor 17, which is applied through diode 29 to the base of transistor 25, holds the transistor 25 in a partially cut off state. When transistor 16 conducts, the voltage on its base electrode appears at its emitter and acts to reverse bias diode 29. Zener diode 26 then takes over to regulate the voltage applied to the base electrode of transistor 25, which in turn controls the voltage applied from the emitter electrode thereof to the regulated terminal 30.

It is therefore seen that the circuit for providing the regulated 10 volt output is controlled by the circuit for energizing the filaments, so that the regulated output voltage is not applied until after the warm up period.

The 10 volt regulated output is also utilized for controlling the filament energizing circuit. This action takes place because of resistor 32 connected from the 10 volt regulated output to the base electrode of transistor 16. This acts to prevent excessive voltage to the filaments in the event the battery voltage is at a high value, as for example 16 volts. Resistor 32 cooperates with resistor 23 to form a voltage divider to control the voltage applied to the base electrode of transistor 16. When the battery voltage is at a low value, as for example 10 volts, it will be seen that the voltage at both ends of the divider is 10 volts, and therefore the voltage at the junction connected to the base electrode is also 10 volts. This will cause the transistor 16 to be fully conductive so that the supply voltage is not dropped at all, and the full 10 volts supply voltage is applied to the filaments.

In the event the supply voltage rises to a value such as 16 volts, this voltage applied to resistor 23 will operate against the regulated 10 volts applied by resistor 32 to provide a voltage of the order of 13 volts at the base electrode of transistor 16. This will cause the emitter voltage to be of the order of 13 volts, and the voltage which is applied to the filaments will be only 13 volts rather than the full 16 volts. This reduction in overvoltage is effective in prolonging the life of the filaments and renders the tubes more stable in operation. To provide the desired dividing action, the resistor 23 will have a

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value somewhat less than the resistor 32, because the base-emitter path of transistor 16 is effectively in parallel with resistor 32 to reduce its effective value.

The invention therefore provides a power supply circuit which has a plurality of functions as may be required for energizing equipment having both tubes and transistors. By providing combined operation the circuit is greatly simplified. The voltage regulator portion not only provides a regulated output voltage but also controls the current supply circuit to prevent excess current in the presence of high voltage at the supply. Also the voltage regulator portion delays the output voltage until the current controlling circuit has applied full current to the heater elements. The overall circuit has been found to be very effective in providing the required voltage and current.

I claim:

1. A power supply circuit for providing from a supply voltage which varies a regulated output voltage and controlled current in a heating element, said circuit including in combination, regulator means for energization from the supply voltage for providing a substantially constant output voltage, resistor means connecting the heating element to the supply voltage for reducing the voltage applied thereto, switching means for selectively bridging said resistor means, sensing means coupled to the heating element for controlling the conduction of said switching means, and means responsive to said output voltage for controlling the conduction of said switching means.

2. A power supply circuit for energizing tubes and transistors from a supply voltage which varies and which provides a regulated voltage for energizing transistors and controlled current in heating elements of tubes the resistance of which increases with temperature, said circuit including in combination, regulator means for energization from the supply voltage for providing a regulated output voltage, resistor means connecting the heating elements to the supply voltage for reducing the voltage applied thereto, switching means for selectively bridging said resistor means, sensing means coupled to the heating elements for controlling the conduction of said switching means, and means responsive to said output voltage for controlling the conduction of said switching means, whereby the current in the heating elements is compensated for the characteristics of the heating elements and for variations in supply voltage.

3. A power supply circuit adapted to be energized from a supply voltage which varies, and for controlling an output voltage and the current applied to a heating element, said circuit including in combination, resistor means connecting the heating element to the supply voltage for reducing the voltage applied thereto, switching means for selectively shorting said resistor means, sensing means coupled to the heating element and operative after a predetermined time to cause conduction of said switching means and thereby increase the voltage applied to the heating element, regulator means coupled to said switching means and operative after said switching means is rendered conductive for providing from the supply voltage a substantially constant output voltage, and means responsive to said output voltage for controlling the conduction of said switching means to control the voltage applied to the heating element.

4. A power supply circuit adapted to be energized from a supply voltage which varies, and for controlling an output voltage and the current applied to a heating element having a resistance which increases with temperature, said circuit including in combination, resistor means connecting the heating element to the supply voltage for reducing the voltage applied thereto, switching means for selectively shorting said resistor means, sensing means coupled to the heating element and operative when the voltage across at least a portion of the heating element reaches a predetermined value to cause conduction of said switching means and thereby increase the voltage applied

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to the heating element, regulator means coupled to said switching means and operative after said switching means is rendered conductive for providing from the supply voltage a substantially constant output voltage, and means responsive to said output voltage for controlling the conduction of said switching means to control the voltage applied to the heating element.

5. A power supply circuit for energizing tubes and transistors from a supply voltage which varies, and which controls an output voltage for energizing transistors and the current applied to the heating elements of tubes, said circuit including in combination, resistor means connecting the heating elements to the supply voltage for reducing the voltage applied thereto, switching means for selectively shorting said resistor means, sensing means coupled to the heating elements and operative in response to a predetermined voltage to cause conduction of said switching means so that increased voltage is applied to the heating elements, regulator means coupled to said switching means and operative after said switching means is rendered conductive for providing from the supply voltage a regulated voltage to the transistors, so that said transistors are energized after increased voltage is applied to the heating elements of the tubes.

6. A power supply circuit adapted to be energized from a supply voltage which varies for controlling the current applied to a heating element which has a resistance which increases with temperature, said circuit including in combination, resistor means connecting the heating element to the supply voltage for reducing the voltage applied thereto, a Schmitt trigger circuit including first and second transistors, said first transistor being normally non-conductive and having a control electrode and output electrodes connected across said resistor means for selectively shorting the same, said second transistor having a control electrode coupled to the heating element and output electrodes coupled to said control electrode of said first transistor and operative when the voltage across at least a portion of said heating element reaches a predetermined value to cause conduction of said first transistor and thereby increase the voltage applied to the heating element, whereby the current through the heat-

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ing element is reduced by action of said resistor means and heating of the heating element increases the resistance thereof and the voltage thereacross to cause operation of said Schmitt trigger circuit to short said resistor means and increase the voltage applied to the heating element.

7. A power supply circuit in accordance with claim 4 wherein said switching means includes a first transistor having a control electrode and output electrodes connected across said resistor means, and said sensing means includes a second transistor having output electrodes connected to said control electrode of said first transistor and a control electrode connected to the heating element and responsive to a voltage therefrom so that said second transistor starts to cut off when the current through the heating element reaches a given value to apply a voltage to said first transistor to render the same conducting for increasing the current supplied to the heating element, and wherein said means responsive to said output voltage is connected to said control electrode of said first transistor for controlling the conduction thereof.

8. A power supply circuit in accordance with claim 4 wherein said regulator means includes a series transistor having a control electrode and output electrodes connected between the supply voltage and the regulated output voltage, and a zener diode connected to said control electrode for providing a reference voltage thereto, with said control electrode being further coupled to said switching means so that said transistor is rendered conducting in response to operation of said switching means.

References Cited

UNITED STATES PATENTS

1,252,502	1/1918	Shreeve	323—9
2,337,911	12/1943	Mayer et al.	323—38 X
2,776,382	1/1957	Jensen	307—97
2,940,010	6/1960	Kenny	315—107
2,992,385	7/1961	Lingle.	
3,066,241	11/1962	Palmer	315—99

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