

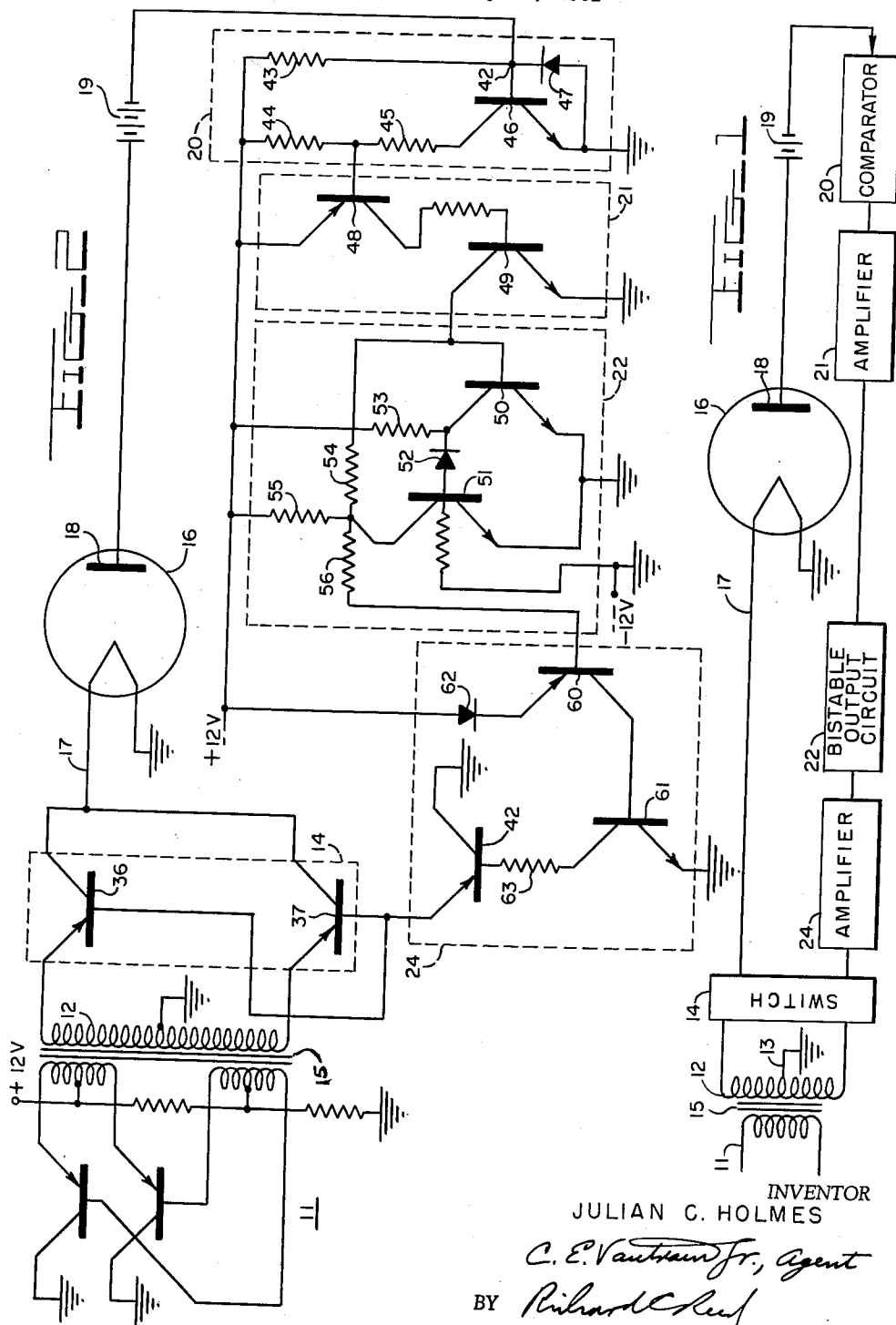
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# EMISSION CURRENT REGULATOR

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## EMISSION CURRENT REGULATOR

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates generally to current regulation and/or particularly to emission current regulation.

The regulation of current by vacuum tubes as well as by transistors is well known, however, such regulation is accomplished conventionally by placing a controllable voltage dropping device in series with the filament thereby providing a system which is by nature inefficient. Such operation has been acceptable in certain applications, but it is often desired to regulate current without the loss of excessive power, and existing devices providing such regulation are both expensive and bulky. With increasing miniaturization it becomes more and more necessary to have a compact device which will provide close control of current. It is often a requirement that such a compact control device be relatively inexpensive, and that it be applicable for use in systems other than solid state, that is, where weight and size are not as important considerations.

Accordingly, it is an object of the present invention to provide an efficient emission current regulator.

It is another object of the present invention to provide an efficient emission current regulator which is made of solid state components.

It is a further object of this invention to provide an emission current regulator which is light in weight, compact, and yet able to withstand excessive shock and vibration without affecting its operation.

It is still another object of the present invention to provide a current regulator which furnishes a fine degree of control such that current lag and advance is reduced to a minimum.

It is a further object of the present invention to provide an emission current regulator in which semi-conductor devices are used as combination switch-rectifiers.

It is still a further object of the present invention to provide a solid state current emission regulator which will eliminate or substantially eliminate the large power waste found in conventional regulators.

Various other objects and advantages will appear from the following description of an embodiment of the invention, and the novel features will be particularly pointed out hereinafter in connection with the appended claims.

In the drawings:

FIG. 1 is a diagram, partly block and partly circuit, of one embodiment of the invention.

FIG. 2 is a circuit diagram of the embodiment of the invention illustrated in FIG. 1.

Referring to FIG. 1, a rectangular A.C. power input is introduced through coil 11 and is converted to rectangular A.C. of the proper amplitude by iron core 15 and center-grounded coil 12. Switch 14 acts as a control rectifier in supplying power to filament 17. The power thus introduced for heating filament 17 is in the form of elongated pulses whose time of duration is controlled by on-off operation of bi-stable circuit 22. The pulsed energy causes a flow of electrons from filament 17 to anode 18 of an electron discharge device such as a vacuum or gas filled tube 16, which anode is maintained positive by battery 19. Current emission regulation is accom-

plished by comparing the electron flow with a standard current in comparator 20. Amplifier 21 amplifies the current differential arising in comparator 20 an amount sufficient to actuate bi-stable circuit 22, which circuit's output is in turn amplified by amplifier 24 to stop or start the control rectifier in switch 14. Thus, when there is an excess flow of electrons to anode 18 a signal from comparator 20 to bi-stable circuit 22 causes the bi-stable circuit to cut off which in turn causes a cessation of current to filament 17. When there is a deficiency of electrons flowing in the comparator, a signal to the bi-stable circuit causes that circuit to cut in thereby re-establishing the flow of current to filament 17. There results a filament current of the order of amperes which is actuated by fluctuations in current of the order of milliamperes.

FIG. 2 illustrates in greater detail the elements of the emission current regulator. In FIG. 2, a rectangular A.C. input is obtained through circuit 11 which includes a D.C. power source supplying, in this embodiment, a potential of 12 volts with the supply connected to coils 33 and 34 at corresponding points. The circuit 11 shown is known as a Royer oscillator, however, any similar circuit may be used within the concept of this invention which includes a transformer having a core of a material possessing a rectangular hysteresis loop characteristic. Iron core 15 converts the A.C. input to a level proper to run filament 17, and the rectangular A.C. is reconverted to D.C. by alternate action of amplifiers 36 and 37. Amplifiers 36 and 37 are, in the present embodiment, transistors having their bases connected in parallel with transistor amplifier 42 by means of which on-off control of conduction by transistors 36 and 37 is obtained. By such control, the flow of energy through 17, and therefore the heat of that filament, is regulated to conform to the desired rate of electron flow through tube 16 to anode 18. The thermal inertia of filament 17 is utilized to alter the sharp on-off action of bi-stable circuit 22 into an undulating heating of the filament, with the time interval between pulses establishing a mean temperature of the filament.

The comparator 20 senses whether there is an excess or a deficiency of electrons flowing into it from anode 18. A potential of 12 volts D.C. exists across resistor 43 which biases the base electrode of transistor 46 with respect to the grounded emitter of that transistor. When the bias voltage is at or above a predetermined value the transistor conducts causing a voltage drop across resistor 45 which in turn biases the base of transistor 48 causing that transistor to conduct. When the bias of transistor 46 is below the predetermined value, it ceases to conduct thereby cutting off current through resistor 45 and stopping transistor 48 from conducting. The current  $i_1$  flowing through resistor 43 is essentially fixed since it is determined by the three components which in turn are fixed, namely, the 12-volt D.C. supply source, the voltage at junction 42 and the resistance of resistor 43. Diode 47 is inserted to establish an upper limit to the voltage at junction 42. Assuming that current  $i_1$  is flowing through resistor 43, a predetermined electron flow from anode 18 will establish a point of equilibrium such that transistor 46 will not conduct and there will be no output signal from the comparator. With the comparator cut off, there is no current flow in filament 17 and it gradually cools thereby reducing electron emission therefrom. A reduction in electron flow reduces current  $i_1$  reducing the voltage drop across resistor 43 and increasing the bias of the base electrode of transistor 46 with respect to the emitter thereof. The foregoing action causes transistor 46 to conduct permitting current to flow through resistors 44 and 45 providing an output signal which is amplified by transistors 48 and 49. This output signal, after amplification, is introduced into bi-stable circuit 22 which is in effect a Schmitt circuit operating between predetermined voltage

limits. In the embodiment shown, circuit 22 operates between 3 volts and 5 volts, that is, at 5 volts the circuit is sharply cut-off and remains off until its voltage has been reduced to 3 volts at which event the circuit is cut full on remaining on until its voltage again reaches 5 volts. The bi-stable, or Schmitt, circuit comprises transistors 50 and 51, diode 52, and resistors 53, 54, 55 and 56. The output of circuit 22 is a series of square pulses spaced according to signals received from comparator 20. The pulses are amplified by transistors 60, 61 and 42 with diode 62 providing emitter bias for transistor 60 and resistor 63 providing base bias for transistor 42.

The emission current regulator described provides close regulation of filament emission current and may be used in any device requiring closely controlled emission current—with such regulation obtained at negligible loss in circuit power. The use of solid state switch 14 in place of the conventional variable resistance in series with a filament virtually eliminates power consumption in all components of the present invention except filament 17 where it is essential for electron emission. The heat capacity of the filament acts as a smoothing device to maintain low emission current ripple. The use of a solid state switch also eliminates any requirement for high current rectifiers which are conventionally essential to feed D.-C. to a filament. Solid state switches operate at a lower voltage drop than do D.-C. rectifiers, thereby avoiding an additional source of power loss.

An example of the use to which the invention may be put is in connection with a mass spectrometer. In such application, tube 16 is a gas-filled tube and is positioned in the entrance of the mass spectrometer. The regulated emission current provides a constant current ionization source for gas passing through tube 16 into the mass spectrometer.

The foregoing description is illustrative of but one embodiment of this invention, it being within the scope of the invention to substitute proportional control in lieu of on-off control, among other embodiments. That is, instead of using the transistors of switch 14 as combination switch-rectifiers, these transistors could be used as controlled rectifiers by merely eliminating bi-stable circuit 22.

It will be understood that various changes in the details and arrangements of parts and circuits, and in the selection of component elements, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

What is claimed is:

1. An emission current regulator for an electron discharge device having a thermionic filament comprising a first power source for supplying rectangular A.-C. power of a selected amplitude, rectifying means connected between said power source and said filament, switching means connected between said first power source and said filament for providing controlled interruption of power to said filament, a second power source for supplying D.-C. power of a selected amplitude, and comparator means connected in parallel with said second power source and in series with said electron discharge device and said switching means for establishing a standard current and comparing said current with the current through said electron discharge device.

2. The device claimed in claim 1 wherein said switching means and said rectifying means are combined in a switch-rectifier which includes at least a pair of parallel-controlled semiconductors, one or the other of said semiconductors always conducting.

3. An emission current regulator for an electron discharge device having a thermionic filament comprising a

D.-C. power source for supplying D.-C. power of a selected amplitude, converter means connected in parallel with said power source for converting said D.-C. power into rectangular A.-C. power of a selected amplitude, rectifying means connected between said converter means and said filament, switching means connected between said converter means and said filament for providing proportional control of power to said filament, and comparator means connected in parallel with said D.-C. power source and in series with said electron discharge device and said switching means for establishing a standard current and comparing said current with the current through said electron discharge device.

4. The device claimed in claim 3 wherein said switching means and said rectifying means are combined in a switch-rectifier which includes at least a pair of parallel-controlled semiconductors, one or the other of said conductors always conducting.

5. An emission current regulator for an electron discharge device having a thermionic filament comprising a first power source for supplying rectangular A.-C. power of a selected amplitude, rectifying means connected between said power source and said filament, switching means connected between said first power source and said filament for providing controlled interruption of power to said filament, a second power source for supplying D.-C. power of a selected amplitude, comparator means connected in parallel with said second power source and in series with said electron discharge device for establishing a standard current and comparing said current with the current through said electron discharge device, and bi-stable output means connected in parallel with said second power source and in series with said switching means and said comparator for on-off control of said switching means in response to the current flow through said electron discharge device.

6. The device claimed in claim 5 wherein said switching means and said rectifying means are combined in a switch-rectifier which includes at least a pair of parallel-controlled semiconductors, one or the other of said semiconductors always conducting.

7. An emission current regulator for an electron discharge device having a thermionic filament supplying D.-C. power of a selected amplitude, converter means connected in parallel with said power source for converting some of said D.-C. power into rectangular A.-C. power of a selected amplitude, rectifying means connected between said converter means and said filament, switching means connected between said converter means and said filament for providing controlled interruption of power to said filament, comparator means connected in parallel with said D.-C. power source and in series with said electron discharge device and said switching means for establishing a standard current and comparing said current with the current through said electron discharge device, and bi-stable output means connected in parallel with said D.-C. power source and in series with said switching means and said comparator for on-off control of said switching means in response to the current flow through said electron discharge device.

8. The device claimed in claim 7 wherein said switching means and said rectifying means are combined in a switch-rectifier which includes at least a pair of parallel-controlled semiconductors, one or the other of said semiconductors always conducting.

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