May 10, 1960 C. F. SIMONE 2,936,404

CURRENT SUPPLY APPARATUS

Filed Aug. 14, 1957

FIG. 1

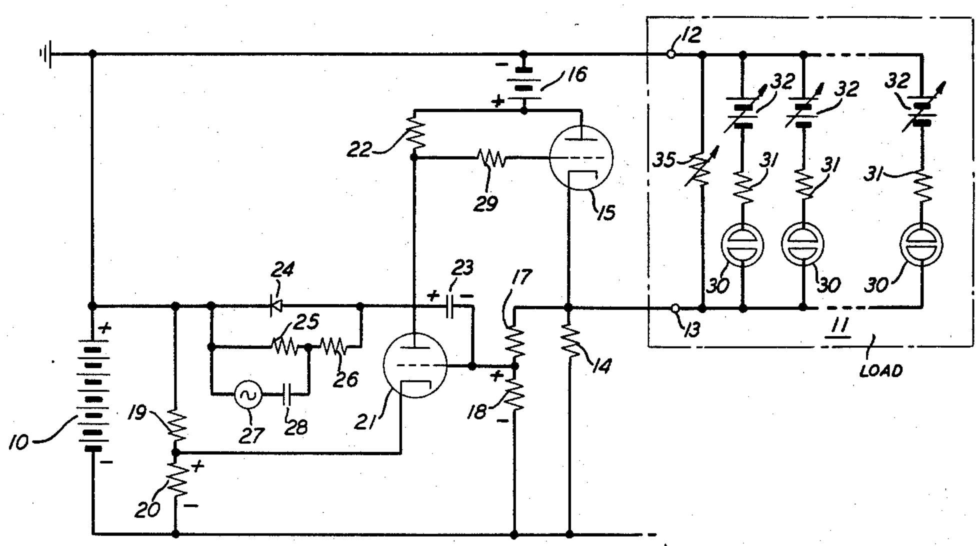
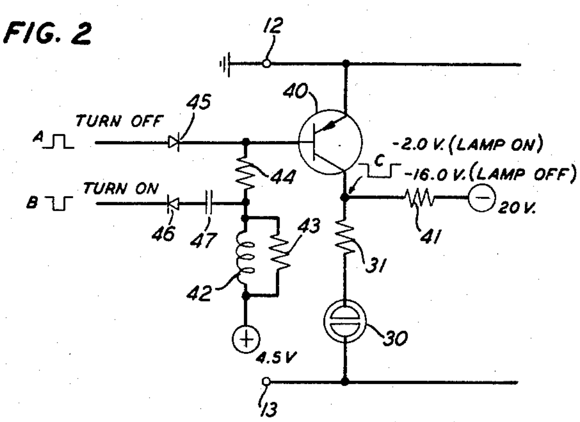


FIG. 2



INVENTOR
C. F. SIMONE
BY G. F. Heuerman
ATTORNEY

United States Patent Office

2,936,404

Patented May 10, 1960

2,936,404

CURRENT SUPPLY APPARATUS

Carl F. Simone, Florham Park, N.J., assignor to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

Application August 14, 1957, Serial No. 678,218

7 Claims. (Cl. 315—130)

This invention relates to current supply apparatus and particularly to a current supply apparatus for selectively energizing indicating lamps of the cold cathode, gas-filled type.

An object of the invention is to provide apparatus for supplying a regulated, periodically varying voltage wave to a varying load.

There are known switching circuits, sometimes called flip-flop or bistable circuits, in which a transistor, for example, is made conducting in response to a control pulse of one polarity and nonconducting in response to a control pulse of opposite polarity. For testing and locating faults in circuits of this type, it is desirable to employ neon or other cold cathode, gaseous lamps to produce an indication of the conducting and nonconducting states of each of a plurality of transistors. The use of such lamps is desirable because of their small size and relatively low power consumption. However, the potential change produced at an electrode of a transistor when conduction is started or stopped is in many cases less than the difference between the firing voltage and the extinguishing voltage of a neon lamp. For example, the firing voltage of a neon lamp may be 75 volts and its extinguishing voltage may be 60 volts while a typical bistable transistor circuit may have a collector potential of minus 2 volts when conducting and a collector potential of minus 16 volts when nonconducting.

In accordance with a specific embodiment of the invention, herein shown and described for the purpose of illustration, there is provided for energizing a varying load comprising a plurality of neon lamps in parallel current paths, a regulated current supply circuit for impressing across the load a periodically varying regulated voltage wave. The current supply circuit comprises a resistor in series with a direct-current supply source and the load and the space current path of a first space current device in a shunt path across the load. The resistance of the space current path of the first space current device is controlled from the output of an amplifier comprising a second space current device upon the control electrode-cathode circuit of which a control voltage is impressed. The control voltage comprises an average voltage component upon which an alternating voltage wave is superposed. The alternating voltage wave is derived from a source of rectified alternating voltage and comprises a sinusoidal pulse produced during alternate half-cycle periods of the alternating voltage and a substantially uniform voltage produced during the remaining half-cycle periods. There is thus set up across the load a periodically varying unidirectional voltage wave having portions of substantially uniform amplitude during intermittent periods and sinusoidal pulses during intervals separating the intermittent periods. The circuit comprising the series resistor and the space current devices functions to minimize changes of both the uniform voltage portions and the sinusoidal pulses of the load voltage irrespective of changes of load.

The invention will now be described in greater detail with reference to the accompanying drawing of which:

Fig. 1 is a schematic view of a current supply circuit embodying the invention; and

Fig. 2 is a schematic view of a modification of a portion of the circuit shown in Fig. 1.

Referring now to the drawing, there is shown a circuit for supplying current from a direct-current supply source **10**, a battery, for example, to a variable load **11** having a pair of load terminals **12** and **13**. The grounded positive terminal of battery **10** is connected to load terminal **12** and the negative battery terminal is connected through a resistor **14** to the load terminal **13**. The anode-cathode or space current path of a triode space current device **15** is connected in a shunt current path across the load **11**, the cathode of tube **15** being directly connected to load terminal **13** and the anode being connected through an auxiliary direct voltage source or battery **16** to the load terminal **12**.

A voltage divider comprising resistors **17** and **18** in series is connected across the resistor **14** and a second voltage divider comprising resistors **19** and **20** in series is connected across the battery **10**. There is provided a second space current device **21** having a control electrode connected to the common terminal of resistors **17** and **18** and having a cathode connected to the common terminal of resistors **19** and **20**. The anode of the tube **21** is connected to ground through a resistor **22** and the auxiliary battery **16** in series. The anode of tube **21** is also connected through a resistor **29** to the control electrode of tube **15**. The control electrode of tube **21** is connected through a condenser **23** and a rectifier element **24** in its forward or low resistance direction to ground. Resistors **25** and **26** in series are connected across the rectifier element **24**. There is provided an alternating current supply source **27** having one of its terminals connected to ground and its other terminal connected through a condenser **28** to the common terminal of resistors **25** and **26**. Resistors **14**, **17**, **18**, **19** and **20** may have resistance values of 6,000; 160,000; 270,000; 50,000 and 39,000 ohms, respectively. The capacitance of condenser **23** may be 20 microfarads.

The load **11**, as shown in Fig. 1, comprises a variable resistance **35** and a plurality of current paths each connected across the load terminals **12** and **13**. Each of the current paths comprises in series a neon lamp **30**, a resistor **31** and a source of variable voltage **32** the polarity of which is in opposition to the polarity of battery **10** in the circuit for supplying current to the current path. The variable batteries **32** and the variable resistance **35** are shown in Fig. 1 for the purpose of simplicity. Instead of the variable resistance **35** and each of the batteries **32** there may be employed, as shown in Fig. 2, a p-n-p type transistor **40** having its emitter connected to the grounded load terminal **12** and having its collector connected through resistor **31** and neon lamp **30** to the load terminal **13**. The collector is connected through a resistor **41** to a potential source which is 20 volts negative with respect to ground. A positive 4.5 volt potential source is connected through an inductor **42** and a resistor **43** in parallel and, in series therewith, a resistor **44** to the base of transistor **40**. Positive pulses A may be supplied to the base of the transistor through a rectifying element **45**. Negative pulses B may be supplied to the base through rectifying element **46** and a condenser **47** in series. When pulse A is applied, the transistor **40** is substantially nonconducting, the voltage drop across resistor **41** is relatively small and the potential at the common terminal of resistor **31** and the collector of transistor **40** may be minus 16 volts with respect to ground, for example. The potential at terminal **13** may vary from minus 51 volts to minus 81 volts so that the voltage across the lamp **30** and resistor **31** in series will vary from 35 to 65 volts. The voltage required for firing a lamp **30** may be from 72 to 78 volts and the extinguishing voltage may be from 55 to 65 volts, for example. Therefore, when pulse A is applied the lamp **30** will be extinguished and will not refire. When pulse B is supplied to the transistor circuit, the transistor **40** is made conducting, the voltage drop across resistor **41** is relatively large and the potential at the collector of transistor **40** becomes minus 2 volts with respect to ground, for example. The voltage across the lamp **30** and resistor **31** in series will, therefore, vary from 49 to 79 volts causing the lamp to be extinguished during alternate half-cycle periods and to be refired during each of the remaining half-cycle periods. The frequency of the alternating-current supply source **27** may be 60 cycles per second, for example. Because of the persistence of vision, the illumination produced by lamp **30** will appear to be continuous as long as the transistor **40** associated with the lamp is conducting. The potential at the collector of transistor **40** is shown at C, Fig. 2.

The number of transistors **40** and lamps **30** which are simultaneously conducting current may vary considerably. The load current may vary from zero to 15 milliamperes, for example. In considering the operation of the circuit, let it be assumed initially that the voltage of the alternating-current supply source **27** is zero. Condenser **23** is initially charged by current from battery **10** through a circuit comprising resistors **25** and **26**, condenser **23** and resistor **18**, all in series, to make the control electrode of tube **21** negative with respect to ground. It is seen that the current flowing through resistor **14** is substantially equal to the current flowing through the load **11** plus the current flowing through the anode-cathode path of tube **15**. If the load current should increase, for example, to cause the current through resistor **14** to increase, the control grid of tube **21** becomes relatively more positive or less negative with respect to its cathode potential. As a result, the control electrode of tube **15** becomes relatively more negative with respect to its cathode to cause the resistance of the space current path of tube **15** to increase. The space current flowing through the tube **15** thus decreases. The increase of current through resistor **14** and of the voltage drop across resistor **14** are thus minimized. The load voltage is equal to the voltage of battery **10** minus the voltage drop across resistor **14**. Therefore, when the voltage of the source **10** is substantially constant, the load voltage will also be maintained substantially constant irrespective of changes of load.

When the voltage of alternating-current source **27** is increased to a suitable operating value, during a half-cycle period of one polarity of the alternating voltage, current will flow through the series circuit comprising condenser **28**, resistor **26** and rectifying element **24**, all in series, to make the rectifier **24** conductive. During this half cycle period, the rectifying element **24** will maintain the common terminal of resistor **26** and condenser **23** substantially at ground potential. Subsequent to the initial charging of condenser **23**, the potential of the control grid of tube **21** and, therefore, the potential of the control grid of tube **15**, each with respect to its cathode, will be substantially fixed during each half cycle period of this polarity. During the next half cycle period of opposite polarity, the rectifying element **24** is non-conducting and the potential of the common terminal of resistor **26** and condenser **23** with respect to ground will vary sinusoidally from zero to a negative peak amplitude and then back to zero as the voltage of the alternating current supply source increases from zero to a peak amplitude and then decreases to zero. The impedance of condenser **23** to the sine wave pulse is sufficiently low that the changes of potential at the common terminal of condenser **23** and resistor **26** will be impressed upon the control grid of tube **21**. The half cycle sine wave pulse will make the control grid of tube **21** relatively more negative with respect to its cathode, thereby causing to be impressed upon the control electrode-cathode circuit of tube **15** a half cycle sine wave pulse making its control grid relatively more positive with respect to its cathode. This positive half cycle pulse impressed upon the control circuit of tube **15** causes an increase of voltage drop across resistor **14** and therefore a reduction of load voltage, the reduction of load voltage being proportional to the instantaneous amplitudes of the sine wave pulse.

There is thus set up across the load terminals **12, 13** a periodically varying unidirectional voltage wave comprising a substantially steady average voltage component upon which an alternating voltage component is superposed. During half-cycle periods when rectifying element **24** is conducting, the voltage across load terminals **12, 13** has a substantially uniform amplitude larger than the average voltage. During half-cycle periods when rectifying element **24** is nonconducting, the load voltage is substantially a half-cycle sine wave pulse having a peak voltage less than the average voltage.

The regulating circuit operates not only to maintain the average voltage substantially constant but also to minimize amplitude changes of the superposed alternate flat top and sinusoidal pulses. Suppose, for example, that the voltage of the alternating-current supply source **27** increases. As a result, the resistance of the anode-cathode path of tube **15** decreases to cause a decrease of the load voltage across terminals **12, 13** and an increase of voltage across resistor **14**. The increase of voltage across resistor **14** makes the control electrode of tube **21** relatively more positive and the control electrode of tube **15** relatively more negative, thereby opposing the decrease of resistance of the anode-cathode path of tube **15** and minimizing the decrease of load voltage. By thus minimizing the amplitude changes of the average load voltage component and of the flat top and sinusoidal pulses which are superposed on the average component, both the magnitude and shape of the periodically varying load voltage wave are maintained substantially fixed.

What is claimed is:

1. Apparatus for supplying current from a direct-current supply source to a varying load comprising a resistor in series with said supply source and said load, variable impedance means in a shunt path across said load, means for increasing the impedance of said impedance means in response to an increase in current flowing through said resistor and for decreasing the impedance of said impedance means in response to a decrease of current through said resistor and means for alternately increasing and decreasing the impedance of said impedance means.

2. Apparatus for supplying current from a direct-current supply source to a varying load having a pair of terminals comprising a resistor in series with said supply source and said load, a current regulating device having a pair of principal electrodes and a control electrode upon which may be impressed a potential with respect to the potential of one of said principal electrodes for controlling the current flowing through said device, direct-current conducting means for connecting said principal electrodes to said load terminals respectively, means for controlling the potential of said control electrode to cause the current through said device to increase in response to a decrease of current through said resistor and to decrease in response to an increase of current through said resistor and means for further controlling the potential of said control electrode to cause the current through said device to increase intermittently.

3. Apparatus for supplying current from a direct-current supply source to a varying load comprising vari-

able resistance means connected in a shunt direct-current path across said load, a resistor in series with said supply source and said load, said variable resistance means, said resistor and said load having a common terminal, means responsive to the current flow through said resistor for controlling the resistance of said variable resistance means to minimize changes of current flowing through said resistor, and means for intermittently further controlling the resistance of said variable resistance means to transiently change the current through said resistor.

4. Apparatus for supplying current from a direct-current supply source to a load which may vary comprising a variable resistance means connected in a shunt direct-current path across said load, a resistor in series with said supply source and said load, said variable resistance means, said resistor and said load having a common terminal, means responsive to the current flowing through said resistor for controlling the resistance of said variable resistance means to minimize voltage changes across said load and means for further controlling the resistance of said variable resistance means for causing said load voltage to change during intermittent periods only.

5. A current supply circuit for supplying current from a direct-current supply source to a load which may vary, said load having a first and a second terminal, a first and a second space current device each having an anode, a cathode and a control electrode, means for connecting said anode of said first space current device to said first terminal, means for connecting said cathode of said first space current device to said second terminal, a resistor connected in series with said supply source and said load, a terminal of said resistor being connected to said second load terminal, a circuit connecting the control electrode and cathode of said second space current device, means for impressing upon said control electrode-cathode circuit a portion at least of the voltage across said resistor, an increase of current through said resistor making the control electrode of said second space current device relatively more positive with respect to its cathode, means for connecting the anode of said second space current device to the control electrode of said first space current device and means for deriving from an alternating-current supply source and impressing upon the control electrode with respect to the cathode of said second space current device intermittent unidirectional pulses.

6. In combination, a plurality of similar indicating devices each requiring a firing voltage for initiating current conduction therethrough which is higher than the extinguishing voltage required for causing interruption of current conduction therethrough, a load comprising a plurality of current paths connected in parallel to a pair of load terminals, said current paths comprising said indicating devices respectively, a plurality of sources of varying direct voltage in said current paths respectively, each of said sources having a maximum and a minimum voltage such that the difference of said maximum and minimum voltages is less than the difference between said firing voltage and said extinguishing voltage, and means for impressing across said load terminals a second unidirectional voltage opposed to the voltage in each of said current paths and larger than said maximum voltage, said second voltage comprising portions of relatively high amplitude during intermittent periods for initiating current conduction only in the current paths in which the direct voltage is relatively low and portions of relatively low amplitude during intervals separating said intermittent periods for causing interruption of the current flow in said current paths which are conducting.

7. In combination, a plurality of similar gaseous lamps requiring a firing voltage for initiating current conduction therethrough which is higher than the extinguishing voltage required for causing interruption of current conduction therethrough, a load comprising a plurality of current paths connected in parallel to a pair of load terminals, a plurality of transistors each having a collector, an emitter and a base, said current paths comprising the emitter-collector paths of said transistors respectively and said lamps respectively in series, means for setting up a varying voltage drop across said emitter-collector paths respectively, the maximum variation of said voltage drop being less than the difference between said firing voltage and said extinguishing voltage, and means for impressing across said load terminals a voltage having portions of relatively high amplitude during intermittent periods for initiating current conduction only in the current paths in which said voltage drop is relatively low and portions of relatively low amplitude during intervals separating said intermittent periods for causing interruption of the current flow in said current paths which are conducting.

References Cited in the file of this patent

UNITED STATES PATENTS

2,407,458	Spielman	Sept. 10, 1946
2,697,201	Harder	Dec. 14, 1954
2,749,512	Blair	June 5, 1956
2,790,132	Gilbert	Apr. 23, 1957
2,791,719	Bliss	May 7, 1957

FOREIGN PATENTS

472,326	Great Britain	Sept. 22, 1937