United States Patent [19]

Miller

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[54] PROCESS AND APPARATUS FOR PROVIDING IMAGE BRIGHTNESS OVER A WIDE RANGE OF DISCHARGE REPETITION RATES

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[52] **U.S. Cl.** ....**321/15,** 315/241 P, 315/241 S

[51] **Int. Cl.** **H02m 7/00**

[58] **Field of Search** ....315/200, 227, 241 P, 315/241 S, 272, 273, 352, 353; 321/15

[56] **References Cited**

UNITED STATES PATENTS

3,412,311 11/1968 Siedband ....321/15 X
3,329,247 7/1967 Jaeschke........................321/15 X

FOREIGN PATENTS OR APPLICATIONS

367,785 2/1932 Great Britain..........................321/15

OTHER PUBLICATIONS

IBM Technical Disclosure Bulletin, "Self–Regulated Pulse Power Supply," Vol. 9, No. 11, April, 196, p. 1,666

Electronics, "Multiplier Phototube," July 8, 1960 Vol. 33 No. 28 P. 51

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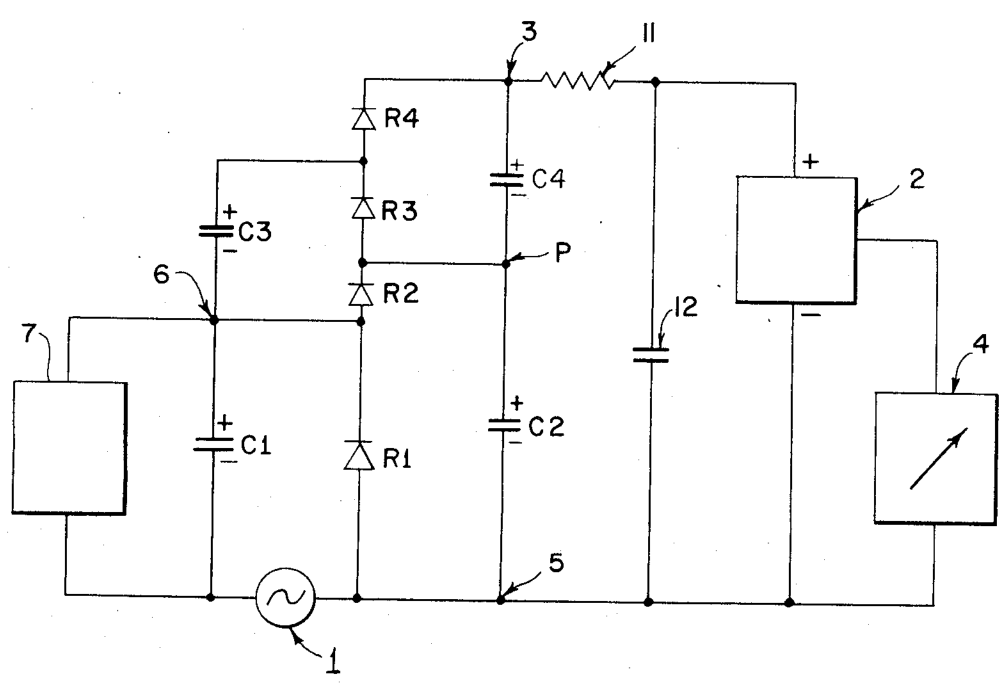
[57] **ABSTRACT**

This disclosure deals with a novel voltage-multiplying power supply process ad apparatus particularly adapted, through the use of a reactive voltage drop within the supply circuit, to produce substantially constant power in repetitive discharges of stored energy, irrespective of the variation in repetition rate of the discharges, within wide limits.

3 Claims, 5 Drawing Figures



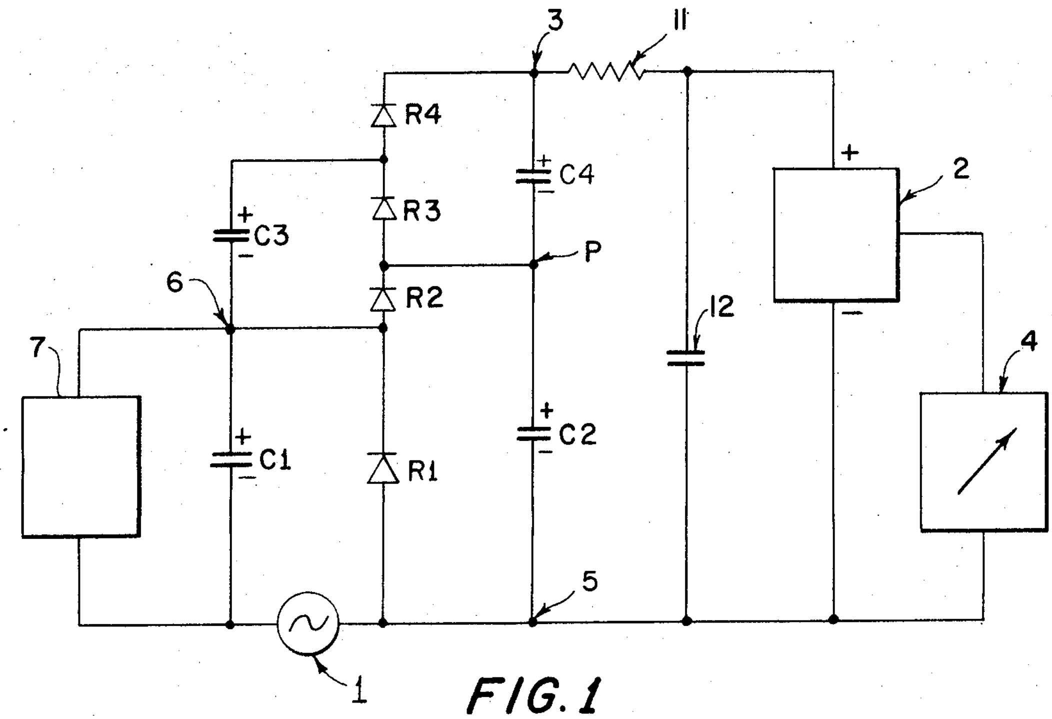


FIG. 1

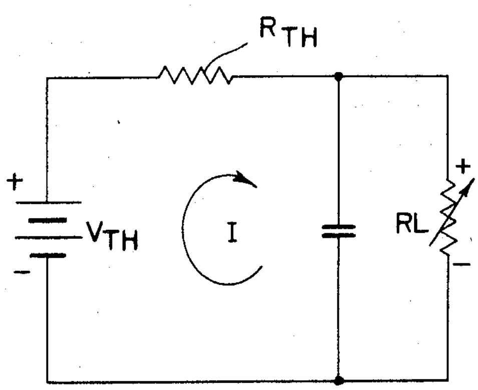


FIG. 2a

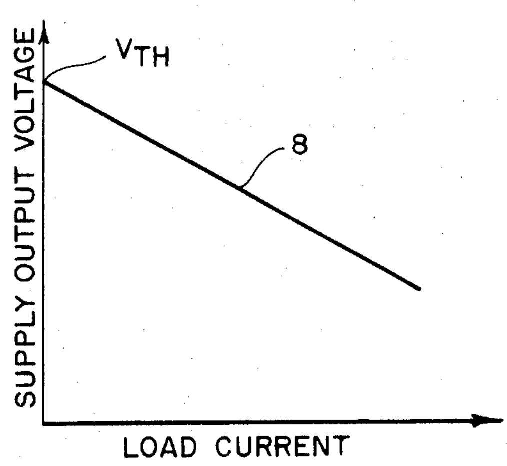


FIG. 2b

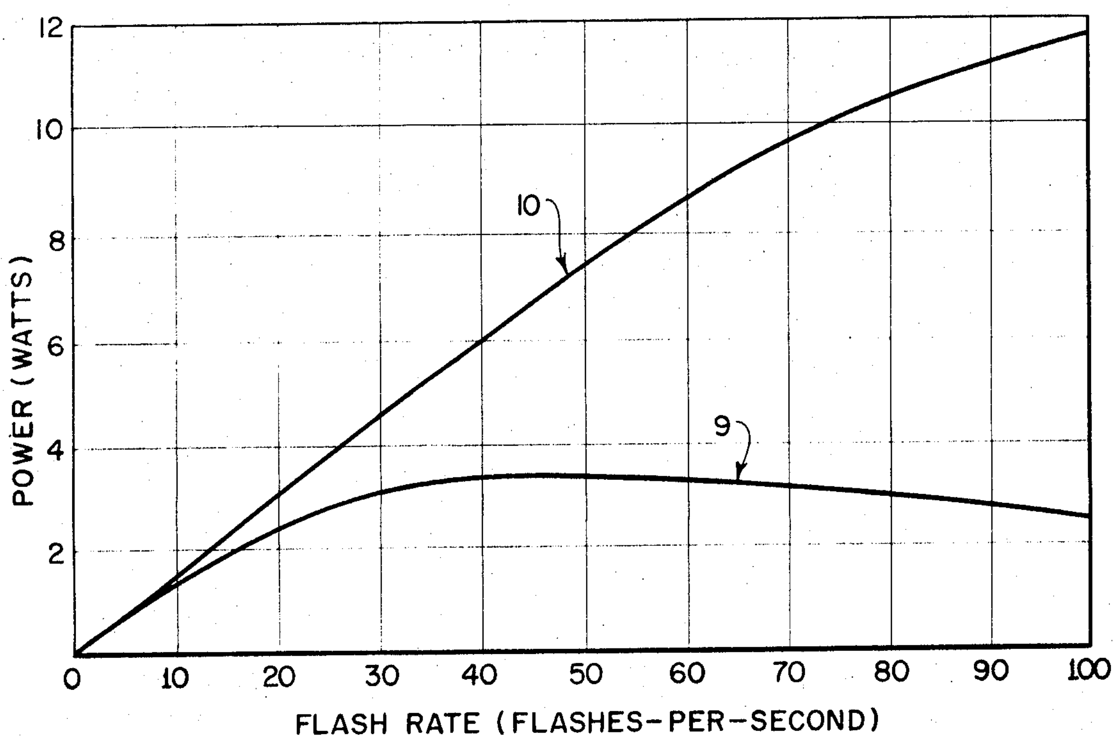

POWER (WATTS)
12
10
8
6
4
2
0
10
20
30
40
50
60
70
80
90
100
10
9
FLASH RATE (FLASHES-PER-SECOND)

FIG. 3

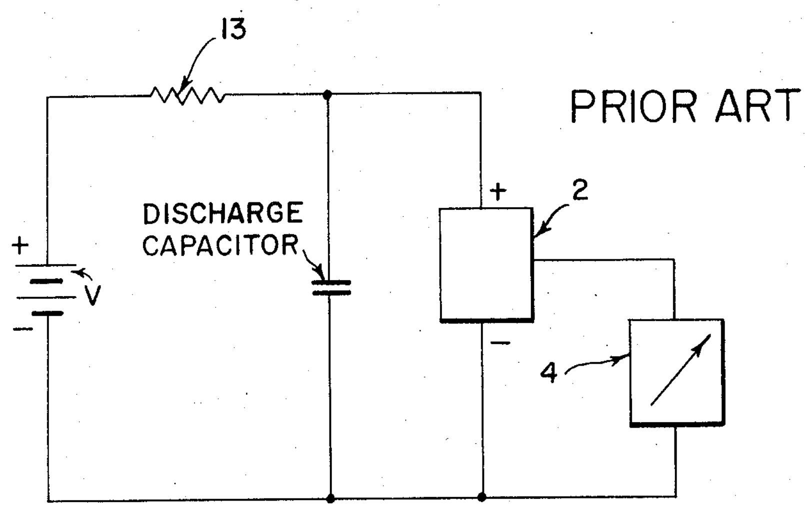

13
PRIOR ART
+
2
DISCHARGE
CAPACITOR
+
V
−
−
4

FIG. 4

PROCESS AND APPARATUS FOR PROVIDING IMAGE BRIGHTNESS OVER A WIDE RANGE OF DISCHARGE REPETITION RATES

The present invention relates to processes and apparatus for supplying energy discharges to a load, such as a flashtube and the like, that is to be repetitively energized by voltage supplied by a voltage-multiplying power supply.

The invention will be particularly described in connection with its preferred application to repetitively discharged loads, such as flashtubes, discharge gaps and similar devices, as for such applications as stroboscopy and the like, though it is to be understood that the basic features thereof are equally applicable to the supplying of voltage to loads from voltage-multiplying power supplies of this character in other applications, as well.

Turning, however, to the application to stroboscopy and the like, the art is replete with all kinds of resonant charging power supply circuits and other voltage-multiplying circuits, such as doublers, quadruplers, etc., which have been adapted to deliver voltage to flashtube discharge circuits and similar loads for the production of high energy flashes of light and other energy.

Voltage multiplier power supplies are particularly well suited for use in small portable equipments, having the advantages that, in practice, they are typically smaller, lighter weight and less expensive than equivalent transformer-operated supplies. Among such systems are those described in, for example, U.S. letters Pat. Nos. 2,342,257; 2,478,901; 2,965,807; 3,115,594; 3,267,328; 3,286,128; 3,340,426; 3,354,379; 3,463,992; 3,513,376; and RE 24,823. Unfortunately, none of these techniques sufficiently accommodates for the desirable variation in energy from the power supply discharged into the flash lamp or similar load when the rate of repetition of the charging and discharging or flashing varies over wide limits. While attempts have been made to try to render more uniform the energy per flash over a wide range of repetition rates, these efforts have not proven adequately satisfactory and they have been accompanied by several disadvantages hereinafter explained.

The subjective image brightness to an observer using the stroboscope is proportional to flash lamp power, with the power in the lamp being also proportional to the energy per flash times the flash repetition rate. A flash lamp has a maximum power limit, however, that cannot be exceeded without damage. It is thus common practice to design a stroboscope circuit to produce the greatest possible light output commensurate with the limitations dictated by the components, allowable heat rise, etc.

In wide-range stroboscope circuits of this character, for example, the charging resistor or resistance in the flash lamp anode circuit is of such value that the storage or discharge capacitor normally recharges completely between flashes, producing a constant illumination each flash. Maximum power to the lamp and maximum subjective image brightness thus occurs at or near the maximum flash repetition rate, and the subjective image brightness decreases approximately in proportion to the decrease in flash repetition rate. Following each flash, the discharge capacitor is recharged to the power supply output voltage by current flowing through the charging resistor, with a consequent dissipation of power by the resistor in the form of heat equal to the power in the lamp at the particular flash repetition rate.

The value of the charging resistor may be adjusted with relation to the discharge capacitor to increase the time required to charge the capacitor with respect to the shortest interflash period. By suitable selection of voltage, resistance and capacitance values, the capacitor does not recharge completely at higher flash repetition rates. This can compensate somewhat for the loss of light at lower flash rates by providing an increasing anode voltage at decreasing frequencies; but this is subject to the principal disadvantage that such resistive compensation causes heat to be lost in the resistor in excess of the power dissipated in the lamp at high repetition rates. This is especially disadvantageous in small instruments or in instruments employing plastic enclosures the integrity of which might be jeopardized at elevated temperatures.

Other suggestions have involved range-changing circuits that introduce different-size capacitors; but these are not only relatively complicated and costly, but they disadvantageously involve an exponential factor as the flash rate is varied or have practical effectiveness only over a narrow maximum-minimum flash rate ratio for each range if relatively constant subjective image brightness is desired.

An object of the present invention, accordingly, is to provide a new and improved process and apparatus for supplying voltage to a load, such as a repetitively discharged flash lamp and the like, that shall not be subject to the above-described disadvantages, but that, to the contrary, enables substantially constant power automatically to be produced in the load irrespective of variation in the discharge repetition rate over wide ranges thereof and without excess heat losses or complex range-changing circuits.

In summary, this result is attained by providing a substantially pure reactive voltage drop within the power supply circuit itself that enables a substantially linear variation of stored voltage with current produced thereby through the load as the result of discharge, thus enabling substantially constant power to be produced in the load for a wide variation in the discharge repetition rate.

A further object of the invention is to provide a novel voltage-multiplier power supply apparatus and process of more general applicability, as well.

Other and further objects will be described hereinafter and will be more particularly pointed out in connection with the appended claims.

The invention will now be described with reference to the accompanying drawing,

FIG. 1 of which is a schematic circuit diagram illustrating a preferred form of the invention, operating in accordance with the process thereof, and illustratively shown adapted to the triggering of flashtubes or other lamps, as in the stroboscope and similar applications:

FIG. 2 (a) is an equivalent circuit diagram of the circuit of FIG. 1, designed in accordance with the invention;

FIG. 2 (b) is a graph illustrating the phenomenon underlying the operation of the invention and plotting load current along the abscissa.

FIG. 3 is a graph illustrating the performance of the circuits of FIG. 1 and hereinafter described FIG. 4, plotting the lamp and charging resistor power for the preferred form of the invention of FIG. 1, and the resistor power in the conventional prior art stroboscope circuit of FIG. 4; and

FIG. 4 is an equivalent circuit diagram of such a typical prior art conventional stroboscope circuit.

Referring to FIG. 1, a quadrupler power supply (at first blush of conventional configuration) is shown comprising a source 1 of, for example, alternating-current input voltage, (or any similar input voltage source), connected to enable the storing or charging of direct-current voltage in capacitors C1, C2, C3 and C4, with the aid of rectifiers R_1, R_2, R_3 and R_4. In this circuit, the rectifiers are connected in series and in closed charging loops containing capacitors C_2 and C_4, also connected in series. The rectifier R_1 is disposed in a first closed charging and storing loop circuit with the capacitor C_1, and rectifiers R_2 and R_3 are similarly connected in a loop containing capacitor C_3. Capacitors C_1 and C_3 are connected in series with rectifiers R_1, R_2 and R_3 and the input from the source 1, with the point of series connection 6 between the capacitors C_1 and C_3 being connected between the rectifiers R_1 and R_2. The point P of series connection of the capacitors C_2 and C_4 is similarly connected between the rectifiers R_2 and R_3. Through this construction, the familiar quadrupling effect is produced such that at the output terminals 3 and 5, high voltage is available and stored in capacitor 12 through charging resistor 11, for discharge between the anode + and the cathode − of a flash lamp or similar load 2 that is to be repetitively triggered by, for example, a variable repetition rate trigger circuit 4, in conventional fashion, as disclosed in the above-reference patents.

For many years, it has been considered essential, as taught in the literature, to use relatively large values of storage capacitors C_1 through C_4 in order to minimize output voltage regulation with load current fluctuations. In addition, the filtering of ripple due to the alternating current source voltage has consistently been considered in the art as necessary through the use of such large capacitors.

In accordance with a discovery underlying the present invention, however, it has been found that by reducing at least one of the appropriate capacitors to a very small capacitance value, far less than the values required for voltage regulation before-discussed, an entirely new phenomenon and operation occurs that, in addition, solves a problem underlying the present invention. Specifically, as the capacitor C_3 is made of a very low value, a substantially pure capacitive reactance-limited effect is provided which produces a reactive voltage drop within the supply circuit giving rise to a substantially linear, not exponential, variation of the ultimate output voltage charge and stored at the output terminals 3 and 5 with discharge current produced through the load 2 in response to triggering at 4, as more particularly shown in the graph of FIG. 2 (b).

This phenomenon can be more readily understood by reference to the equivalent Thevenin circuit shown in FIG. 2 (a), wherein V_{TH} represents the no-load supply voltage, R_{TH} represents the Thevenin resistance, and R_L represents a variable resistance load. The load voltage of such a circuit varies in the linear manner shown by the regulation curve 8 of FIG. 2 (b), with the slope determined by the value of R_{TH}. The advantage of this circuit is that the magnitudes of the V_{TH} and R_{TH} may be set over wide ranges by varying the number of stages of voltage multiplication and the values of the storage capacitors, respectively.

While this unconventional small intermediate series reactance capacitor C_3 will give rise to large ripple voltages across itself as the load current increases, the large values of capacitance C_2 and C_4 in the output have been found to serve most adequately to minimize such ripple, as seen by the load, and thus reduce the attendant undesirable short-term fluctuation of light output. Image brightness compensation of the flashes produced by the lamp 2 with variation in discharge repetition rate over wide ranges is effected by the resulting reactive dropping of the supply voltage, substantially eliminating any resistive excess heat dissipation in the charging resistor 11, as shown in the flat curve 9 of FIG. 3, and, in view of the linear characteristics of FIG. 2 (b), resulting in a substantially constant power supplied to the lamp and image brightness over a wide flash lamp rate or repetition range. Since the ripple on the flash lamp voltage is maintained low over the range of output voltage variation, satisfactory uniform flash-to-flash lighting output has been thus obtained. In addition, a low ripple content low voltage may be provided to power other circuits 7, as at point 6 in FIG. 1, by proper placement of the reactive dropping capacitor C_3, as shown. Curve 10 in FIG. 3, on the other hand, illustrates the power which would be dissipated as heat in the charging resistor 13 of the corresponding conventional stroboscope circuit of FIG. 4, demonstrating the marked efficacy of the invention.

In a successful circuit of this character, the values of capacitors C_2 and C_4 were set at the large regulation value of 24 μ and the capacitor C_1 was set to almost 3 times that value at 69 μ. The reactance limiting capacitor C_3 was adjusted to the relatively very small value of 1.3 μ, producing an output voltage V_o of approximately 650 to 350 volts over the normal range of flash rate (0 to 60 flashes per second). The circuit had a Thevenin resistance of approximately 14.7 kilohms and produced approximately 8 watts maximum output.

The above technique is also obviously applicable to other voltage-multiplying circuits where this type of output regulation is desired, and further modifications are thus considered to fall within the spirit and scope fo the invention as defined in the appended claims.

What is claimed is:

1. A process for supplying voltage to a load such as a flashtube and the like that is to be repetitively discharged by voltage periodically charged and stored in a voltage-multiplying power supply, that comprises, applying alternating-current voltage to a plurality of interconnected capacitor storage circuits each comprising closed charging and storing loops containing separate voltage-multiplying capacitors and rectifier elements with certain of the loops sharing common rectifier elements to enable voltage multiplication, triggering the discharge of the stored voltage developed across the storage circuits to discharge the same through the load, controlling said triggering to effect the same repetitively, each time following the substantially complete voltage charging and storing in the plurality of storage circuits, varying the repetition rate of said charging and storing, and adjusting the value of at least one of the voltage-multiplying capacitors to a value very small compared with the large voltage-regulating capacitance value of other of the voltage-multiplying capacitors to eliminate substantial resistive dissipation with

variation of repetition rate and to provide a substantially linear variation of stored voltage across the storage circuits with current produced thereby through the load, when triggered, in order to produce substantially constant power in the load irrespective of the variation in the said repetition rate.

2. Apparatus for supplying voltage to a load such as a flashtube and the like that is to be repetitively discharged, having, in combination, voltage-multiplying circuit means containing a plurality of voltage-multiplying storage capacitors connected with a plurality of rectifiers in closed loops sharing certain of the rectifiers and having an output circuit, means for connecting a load to be repetitively energized from the voltage periodically stored in the output circuit, means

for varying the rate of repetition of such storing and energizing of the load, and means comprising a voltage multiplying capacitor adjusted to a value very small compared with the value of said storage capacitors and connected in the voltage-multiplying circuit therewith to provide substantially constant power in the load irrespective of variation in said repetition rate.

3. Apparatus as claimed in claim **2** and in which the rectifiers and capacitors are adjusted so that ripple of the output voltage due to the input alternating current voltage is negligible for any level of output voltage supplied to the load and determined by the flash repetition rate and consequent load current irrespective of the variation of the flash repetition rate.

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