

[54] NON-REGENERATIVE SWITCHING
VOLTAGE REGULATOR

[76] Inventor: Slavko Milovancevic, P.O. Box 402,
Torrance, Calif. 90508

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323/25, 323/38

[51] Int. Cl. G05f 1/56

[58] Field of Search 323/4, 9, 17, 22 T,
323/22 SC, 38, DIG. 1, 23, 25; 321/16, 10

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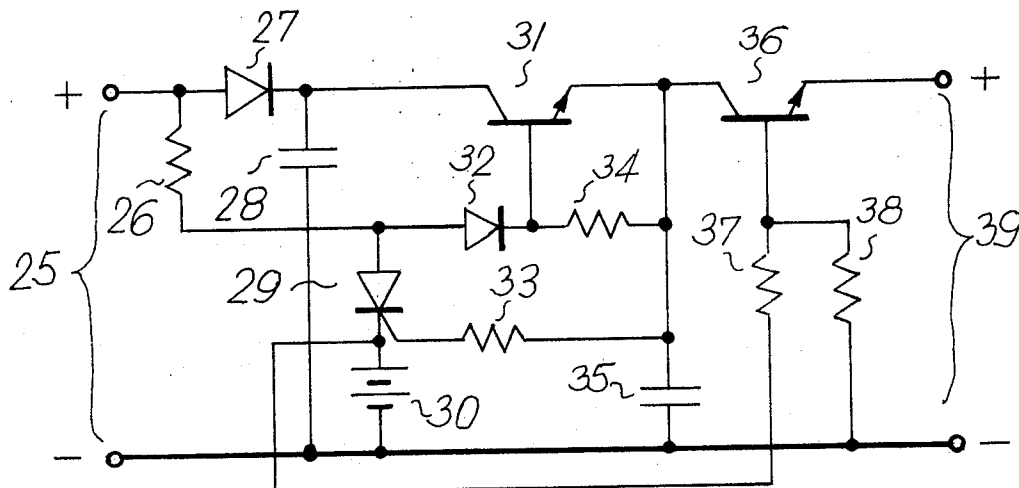
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Primary Examiner—Gerald Goldberg

[57] ABSTRACT

A non-regenerative switching voltage regulator and filter circuit for converting a pulsating DC input voltage to a regulated DC output voltage. Also a non-regenerative switching voltage regulator and filter circuit for converting a pulsating DC input voltage to a regulated and well filtered DC output voltage by use of an additional series type regulator, coupled to the same reference voltage as mentioned non-regenerative switching voltage regulator and filter circuit. The reference voltage embodied in the form of a Zener diode compensates for temperature changes in the circuit in both mentioned arrangements. In addition, for purpose of better switching and the base-emitter junction protection of the series pass transistor from conductive into non-conductive state a protective resistor is connected across said base-emitter junction. Invention uses no inductance in any form, heatsinks for power transistors are minimized and overall efficiency is good.

3 Claims, 5 Drawing Figures



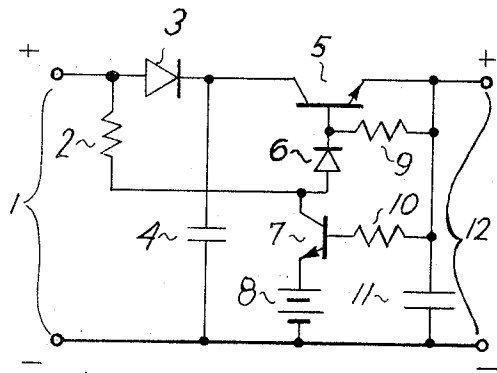


Fig. 1.

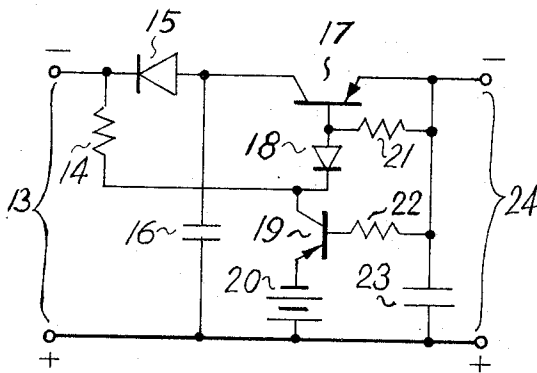


Fig. 2.

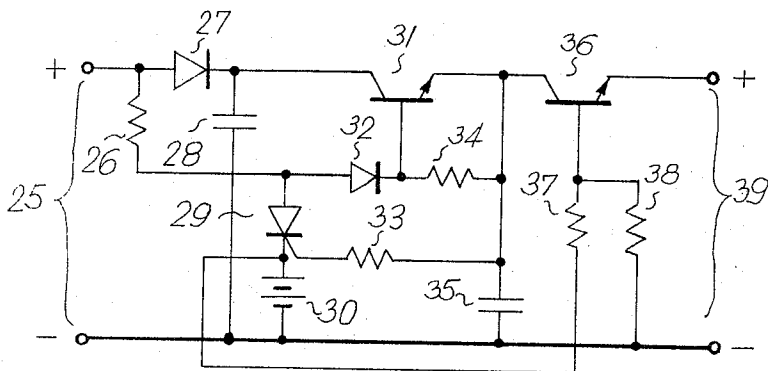


Fig. 3.

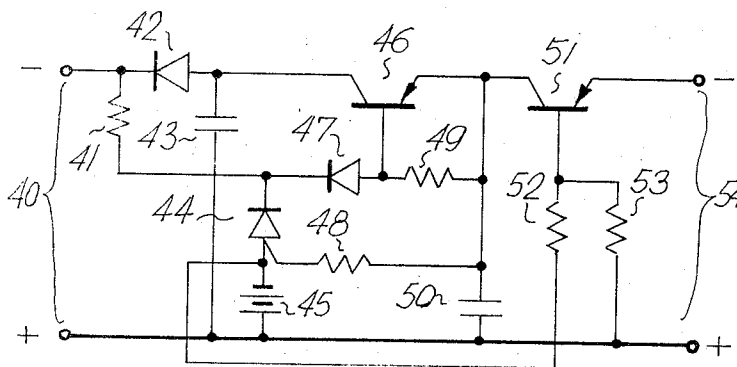


Fig. 4.

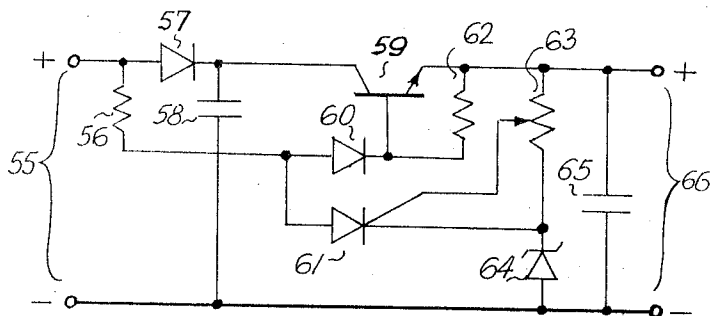


Fig. 5.

INVENTOR

Slavko Milovancevic

(SLAVKO MILOVANCEVIC)

NON-REGENERATIVE SWITCHING VOLTAGE REGULATOR

BACKGROUND OF THE INVENTION

1. Field of the invention

The present invention relates generally to control or regulation of the d-c pulsating voltage by electronic means and particularly to switching type or more precisely to non-regenerative (without positive feedback) switching regulator. This regulator uses a reference voltage (which can be also adjustable) to define magnitude (level) of the output voltage, a transistor or SCR to compare output to reference voltage and start conducting when output voltage is higher, to cut biasing of the first series pass transistor turn it off and prevent further rise of output voltage no matter how high input voltage rises.

2. Description of Prior Art

As far as known to applicant the only somewhat similar circuit is one that uses an SCR as series pass element and consequently has inferior line regulation capability. Hence the invention has not been known in Art.

The term "non-regenerative switch" as used in the specification is defined as follows: A non-regenerative switch is the one that stays normally in 'off' position - or as applied to a transistor used as a switch - that it stays normally in non-conductive state. In other words this type of switch assumes 'on' position, i.e., conducts only when necessary and usually for short periods of time. In addition, a non-regenerative switch does not have positive feedback since there is no need for it. As a contrast a regenerative switch must have positive feedback in order to remain in either conductive state. My recitation "non-regenerative (without positive feedback)" means that transistor used as a series switch operates as a non-regenerative switch, while expression 'without positive feedback' is to stress that very fact.

DESCRIPTION OF THE DRAWING

FIG. 1 is the circuit diagram of the regulator with two transistors as switching devices, for positive voltage output.

FIG. 2 is the circuit diagram of the regulator with two transistors as switching devices, for negative voltage output.

FIG. 3 is the circuit diagram of the regulator where an SCR is used instead of a transistor for positive voltage output and includes an additional regulator of series type.

FIG. 4 is the circuit diagram of the regulator where a CSCR is used in place of a transistor for a negative voltage output, and with an additional series regulator as in FIG. 3 except for polarities.

FIG. 5 is one of four possible modifications analogous to those in FIG's 1 through 4, and represents circuit diagram analogous to FIG. 3 but without additional series type regulator, and uses output voltage as the reference voltage. Instead of Zener diode a resistor can be used or cathode tied to ground.

DETAILED DESCRIPTION OF OPERATION

The objectives of this invention were: To find a regulator where bulky heatsinks could be reduced, where frequency of switching will stay constant and allow easy filtering, a simple and inexpensive regulator which will poses qualities of non-switching and switching regula-

tors while avoiding bad properties of both. I believe this was achieved.

Here s given 5 different circuits - based on same basic principle, though many more are possible. To describe this principle, one circuit would suffice, but for better explanation FIG's 1, 3, and 5 will be used. FIG's 2 and 4 are essentially same as FIG's 1 and 3, and the only difference is that voltages are of opposite polarity so consequently complements to elements in FIG's 1 and 3 are used.

Referring to FIG. 1, non-regenerative switching voltage regulator of present invention includes a pair of input terminals generally designated 1, a resistor designated 2, a silicon junction diode 3, a capacitor designated 4, silicon n-p-n type transistor 5, another silicon junction diode (low power) 6, a low power silicon n-p-n type transistor 7, a voltage reference source designated 8, resistors 9 and 10, a capacitor designated 11, and finally output terminals designated 12. Operation is as follows: when nonfiltered sinusoidal rectified voltage is applied to terminals 1, transistor 5 will be forward biased through resistor 2 and now forward biased diode 6, diode 3 is also forward biased so capacitor 4 is charged, transistor 5 conducts so capacitor 11 is charged at same time, resistor 2 is small enough that transistor 5 is biased near or into saturation and its collector dissipation is low despite possible high collector current. At same time load draws necessary current. Resistor 9 is much larger than input impedance of transistor 5, thus has no influence on its operating point. As input voltage increases so does the voltage across capacitors 4 and 11 till output voltage i.e. voltage across capacitor 11 and load reaches a value equal to reference potential 8 plus biasing potential of the base to emitter junction of transistor 7, which starts conducting and taking away base current (a part of it at beginning) and transistor 5 will decrease its emitter current after storage time is over. In meantime output voltage had risen enough to push transistor 7 into or near saturation through base current limiting resistor 10 so that voltage across diode 6 and collector of the transistor 7 will be nearly equal to reference potential 8, while output voltage is higher for a base to emitter junction saturation voltage. Output voltage will start decreasing slowly as load draws current from capacitor 11. However, input rectified sinusoidal voltage will drop sooner to zero so that transistor 5 will remain in off state, while transistor 7 will turnoff when said input sinusoidal voltage assumes a value approximately equal to the reference voltage 8. Output voltage will decrease further until a new sinusoidal input voltage biases forward transistor 5, i.e., when said voltage reaches value higher than output voltage at that moment. From now on the described process repeats over.

Resistor 9 serves to prevent breakdown of the reverse-biased base-emitter junction while transistor 5 is nonconductive, allowing only a small voltage drop across it. Diode 3 blocks the voltage across capacitor 4 so its voltage cannot forward/bias transistor 5 once transistor 7 is on and transistor 7 also will remain in off position once input voltage is low enough. Capacitor 4 limits the current through transistor 5 and absorbs the "kick-back" voltage when transistor 5 turns off (if a power transformer is used in the rectifier circuit) so that no damage is done to 5.

From the described operation is clear that line and load regulation are performed, because transistor 5

turns on as soon as the input voltage is high enough, and turns off as soon as output voltage is high enough. Efficiency is high because transistor 5 allows only as much current to capacitor 11 as needed to maintain output voltage within desired limits and its operating point is in or close to saturation. A drawback of the circuit is that transistor 5 must deliver load current in a short interval of time, thus its emitter current must be several times higher (larger) than average load current, and also twice larger for half wave rectifier, than for a full-wave connection. However, taking in consideration that collector to emitter voltage during conduction is low this fact regarding emitter current is not so critical as it might seem to be.

Referring now to FIG. 3 - operation is almost identical with exception that instead of transistor 7 in FIG. 1 an SCR is used as designated 29 in FIG. 3. Difference exists in operation in the respect that turn on and turn off of an SCR is better defined, in this case, so turnoff of transistor 31 will be better defined too, and consequently slightly better regulation will result, while kick-back voltage will be higher due to faster turnoff of transistor 31, also more harmonics and with higher amplitude will be generated for same reason. To avoid harmonics and get a better regulation an additional series type regulator is used consisting of resistors 37 and 38, connected across reference voltage source 30, and a series pass transistor 36. As being supplied from a reference voltage base of transistor 36 sees no voltage changes so output voltage will be constant, although collector to emitter does change as appears across capacitor 35. This will have negligible effect (in most cases) an output voltage. Because voltage changes across capacitor 35 are relatively small, collector to emitter voltage of 36 can be kept low all the time, regardless how high is the voltage across capacitor 34, because 36 is an emitter follower stage. For that reason collector power dissipation is low and efficiency is high, and also collector to emitter breakdown voltage requirement is not critical at all resulting in inexpensive power transistor used as 36.

Note also that if different output voltages are desired only reference voltage 30 has to be changed, i.e., adjusted while rest of the circuit remains unchanged.

Referring now to FIG. 5, non-regenerative switching voltage regulator of the present invention includes elements 55 through 66. Here diode 57 and input charging capacitor 58 are not essential for operation, because reference voltage source is not used (which in most cases will be a Zener diode and a resistor as in FIG's 1 through 4 in practice), but output voltage itself. Here the reference voltage is developed across potentiometer 63 and Zener diode 64, and sensed by the SCR 61. The operation of this circuit is same as for circuit in FIG. 1 was described, with exception that reference voltage will be developed after output voltage is large enough so that Zener diode starts conducting. Zener current will produce a voltage drop between cathode and gate of SCR 61 and when sufficiently high it will turn on SCR 61, which in turn turns off series pass transistor 59 and prevent this way further increase of output voltage. Naturally, instead of Zener diode 64 a resistor could be used. However, Zener diode has positive temperature coefficient, while gate to cathode voltage of an SCR has a negative temperature coefficient, thus with temperature increase SCR will tend to turn on sooner resulting in a lower output voltage, while Zener voltage

increases with temperature resulting in an increase in output voltage. As just described the two effects are opposite in sign and will cancel each other more or less resulting in a more constant output voltage with temperature change, than if a resistor were used in place of Zener diode 64. If ambient temperature decreases effects will be opposite to those just described for Zener diode 64 and SCR 61, but resulting output voltage will remain practically the same. Capacitor 65 serves to deliver current to the load while transistor 59 is in off state, and receive additional charge (and store it) while transistor 59 is conducting. Of course, the circuit of FIG. 5 can not be as efficient regarding regulation as other four circuits, but it is economical and simple especially when diode 57, capacitor 58 are omitted and Zener diode 64 replaced with a resistor. Additional explanation of operation of circuit in FIG. 5 is as follows: A load across terminals 66 is assumed present at all times. Load draws a current consisting of electrical charge (electrons) stored in capacitor 65. Since potential across an electrically charged capacitor is proportional to the quantity of the stored charge, and since the charge (current) from capacitor 65 is being drawn by the load (note: while transistor 59 is non-conductive) voltage across capacitor 65 must be decreasing all the time until the transistor 59 starts conducting again to replenish the charge across capacitor 65 to its maximally possible value under given conditions. In normal operating conditions (not shorted output terminal 66) output voltage fluctuations will be small enough and output voltage will never drop quite close to Zener diode 64 breakdown voltage, thus a positive current flowing through resistor 56, SCR 61 (which conducts to keep transistor 59 non-conductive), will close its path at the negative input terminal - while it had started at the positive terminal (input terminals designated 55). This current will not flow through resistor 63 since each point of it is at a potential higher than Zener diode 64 breakdown voltage as indicated.

In normal operating conditions diode 60 is reverse biased and non-conductive whenever transistor 59 is non-conductive and SCR 61 is conductive. This will become clear when considering that cathode of said diode 60 sees a positive potential through resistor 62 which equals the output potential, while its anode at the same time sees a potential equal to the sum of positive potentials of Zener diode 64 and voltage drop across conductive SCR 61, said sum is smaller than output voltage. Thus diode 60 is reverse-biased and non-conductive indeed whenever SCR 61 is conductive and transistor 59 non-conductive.

Naturally, many more modifications and refinements are possible, all of which fall within the scope and essence of this invention.

I claim:

1. A non-regenerative switching voltage regulator and filter circuit for converting a pulsating DC input voltage to a regulated DC output voltage and including a common terminal and an input terminal for receiving said input voltage, and an output terminal for delivering said output voltage, comprising:

first series pass regulating transistor having its emitter-collector circuit in series between said input terminal and a collector-emitter circuit of a

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second series pass regulating transistor having its emitter-collector circuit connected also to said output terminal,

a reference voltage source having one terminal thereof connected to said common terminal, 5

a switching control means connected between the other terminal of said voltage reference source and the base of said first regulating transistor for switching said regulating transistor out of conduction periodically during each pulsation of said input DC voltage, 10

a storage capacitor interconnected between series connection of said first and said second regulating transistor and said common terminal, 15

a diode interposed between the base of said first regulating transistor and said switching means,

a resistor interposed between the base and the emitter electrodes of said first regulating transistor,

a resistor interposed between said input terminal and 20

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interconnection of said switching control means and said diode being connected to the base of said first regulating transistor,

a resistor interconnected between control electrode of said switching control means and interconnection of said first and said second regulating transistor and said storage capacitor.

2. The circuit of claim 1 and further including:

a resistor for coupling said other terminal of said reference voltage source to the base of said second regulating transistor.

3. The circuit of claim 2 and further including :

a diode connected between said input terminal and said emitter-collector circuit of said first regulating transistor and

another storage capacitor connected between common terminal and interconnection between said diode and said first regulating transistor.

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