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(54) **Low loss voltage preregulator**

(57) A preregulator circuit is connected between the battery supply of a cellular phone and the input of an integrated circuit regulator to maintain the input of the integrated circuit at a voltage consistent with its rated

voltage. To avoid the voltage drop in the preregulator when the battery is low, a shut off circuit is actuated to short circuit or minimize the voltage drop of the preregulator.

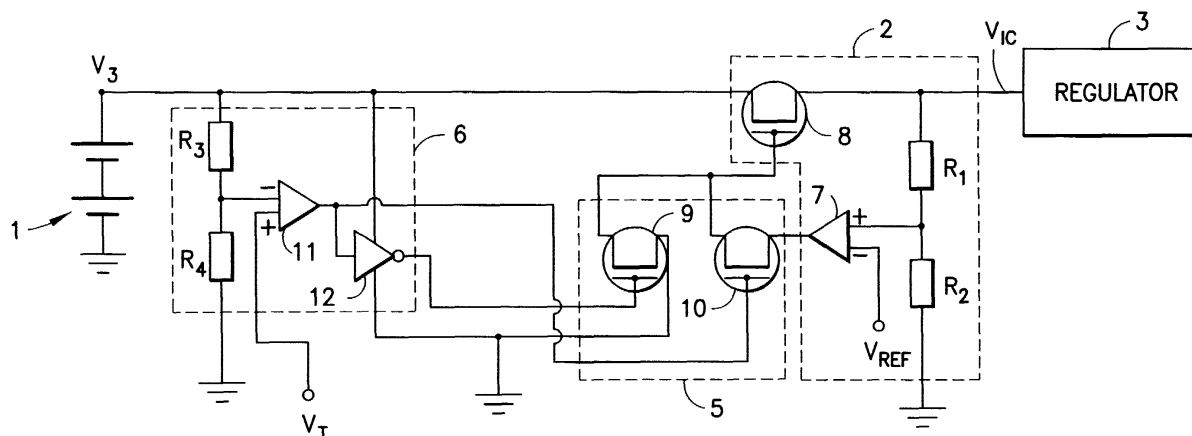


FIG.3

Description

[0001] This invention relates to a low loss voltage pre-regulator configuration and has particular but not exclusive application to protecting circuitry in portable electronic apparatus such as a mobile telephones.

[0002] To provide reasonable design flexibility in the use of integrated circuit components, it is sometimes necessary to accommodate components within a circuit in spite of the fact that, under certain conditions, the design limits of the integrated circuit may be exceeded. This occurs in radio telephone applications where it is desirable to use common components across product lines that may use different battery types. Occasionally therefore, some of the components may not be rated for the full battery voltage. For example, it may be cost effective to utilize an integrated circuit voltage regulator, rated at 4 volts, in a radio telephone which is provided with a 5 volt battery supply. In these instances it is necessary to avoid over voltage to the particular integrated circuit.

[0003] In order to protect the integrated circuit voltage of the above example, a preregulator is used to avoid applying the excess voltage to the regulator. This is somewhat straight forward at full battery power, but, as the power supply dwindles with use, the voltage drop across the preregulator becomes burdensome. This will shorten the useful life of the battery between charging cycles. It is a purpose of this invention to provide a simple preregulator circuit having means to shut down or minimize the voltage drop through the preregulator when the battery power is at the low end of its cycle.

[0004] In an embodiment of the invention, a preregulator circuit is connected between the battery supply of a cellular phone and the input of an integrated circuit regulator to maintain the input of the integrated circuit at a voltage consistent with its rated voltage. This requires a voltage drop in the preregulator circuit. Although this voltage loss is not a problem when the battery is fully charged, it may limit phone operation at the lower end of the battery charge cycle. In order to avoid this a shut off circuit is employed to limit the voltage drop in the preregulator at low voltage. The shut off circuit is actuated by a comparator which compares battery voltage to a predetermined minimum threshold voltage. The comparator activates a relay or other switching means to short circuit the preregulator or convert its operation to minimize any voltage drop caused by the preregulator.

[0005] In order that the invention may be more fully understood embodiments thereof will now be described by way of illustrative example with reference to the accompanying drawings in which:

Figure 1 is a block diagram showing the main components utilised according to the invention;

Figure 2 is a flow diagram of the processing steps

of a method in accordance with the invention;

Figure 3 is a circuit diagram of an embodiment of the invention;

Figure 4 is a circuit diagram showing an alternative embodiment of this invention; and

Figure 5 is a circuit diagram showing a second alternative embodiment of this invention.

[0006] The basic components of the regulator system are shown in the block diagram of figure 1 and includes a battery 1 which supplies a supply voltage (V_s) to the system. A preregulator circuit 2 is connected to limit the input voltage (V_{IA}) to an integrated circuit 3. An integrated circuit voltage regulator 3 supplies the microprocessor control unit 4 of a cellular phone or other device with a substantially constant voltage. The preregulator 2 controls the voltage (V_{IA}) to the integrated circuit regulator 3. This control is required to reduce the integrated circuit regulator supply voltage V_{IC} to conform to the rated voltage of integrated circuit 3 to insure the proper operation of the regulator 3.

[0007] A switch module 5 is connected to preregulator 2 to shut down the preregulator 2 when V_s falls below a predetermined minimum threshold (V_T). The supply voltage is sensed by voltage monitor 6. V_T can be set at a voltage level just above the minimum operational voltage of the microprocessor control unit 4 and considering the voltage drops of the IC regulator 3 and preregulator 2. Shut down of the preregulator 2 can be accomplished in many ways, but for the present purpose, it is defined as minimizing the voltage drop of the preregulator. This would include a short circuit as shown in the alternate embodiment shown in figure 4. This effectively eliminates the negative effect of the preregulator 2 when $V_s < V_T$. Operation of the cellular phone or other device is therefore extended for an additional period of time.

[0008] The regulator 3 can be any of the known types of integrated circuit voltage regulators. Its purpose is to provide the microprocessor control 4 with substantially constant voltage for operation of the device. As is well known, the operation of the device is limited by the battery cycle and it is important to preserve the voltage level in particular at the low end of the cycle.

[0009] As shown in figure 2, the system operates by monitoring the battery voltage V_s and comparing it to a threshold voltage V_T and minimizing the voltage drop in the preregulator 2 when V_s falls below V_T . During normal operation, the preregulator 2 senses a voltage V_P equal to $V_s(R_2/R_1+R_2)$ which is indicative of the input voltage V_{IC} to the integrated circuit 3 and generates a voltage drop to compensate for the difference between a reference voltage V_{REF} and V_P . The reference voltage can be set relative to the rated operational voltage for integrated circuit 3. Variations in operational voltage for the particular IC circuit used are generally accommodated

by selecting the values of resistors R_1 and R_2 .

[0010] The preregulator 2 is typically designed using a differential amplifier 7 which is connected to control the current through MOSFET 8. By adjusting the bias of the MOSFET 8 a voltage occurs that is relative to V_{REF} . The positive terminal of amplifier 7 is connected to a voltage divider made up of resistors R_1 and R_2 . The negative terminal of amplifier 7 is connected to a voltage V_p , which is relative to the rated voltage V_{IC} for the IC regulator 3 by the voltage divider resistances R_1 and R_2 . Although the particular circuit shown is useful in the context of the embodiments presented, the preregulation function can be accomplished in a variety of ways.

[0011] In the preferred embodiment shown in figure 3, the switching module 5 consists of a pair of MOSFETS 9 and 10 which are connected to adjust the bias of MOSFET 8 and thereby convert its function to that of a low resistance switch. When the battery is fully charged, MOSFETS 9 and 10 allow the MOSFET 8 to operate as preregulator 2 described above in response to the differential amplifier 7. The resistances R_1 and R_2 are selected to provide a voltage V_{IA} to the regulator 3 which is limited to the rated voltage of the regulator e. The V_{REF} may be standardized while the resistances are varied to accommodate the particular IC regulator used.

[0012] Voltage monitor 6 consists of another differential amplifier or comparator 11 which is connected through a voltage divider made up of a pair of resistors R_3 and R_4 . Comparator 11 is connected to sense the voltage between the resistances R_3 and R_4 which is indicative of the battery voltage V_s , i.e. $V_s(R_4/R_3+R_4)$ and compare it to the low threshold voltage V_T . When $V_s(R_4/R_3+R_4)$ falls below V_T , an output voltage from comparator 11 is applied through inverter 12 to the switching module 5. This will trigger the MOSFETS 9 and 10 to alter the operation of the preregulator 2 as discussed above. As the battery is recharged, this process is reversed and the preregulator is again engaged to drop the voltage to regulator 3.

[0013] To avoid undesirable cycling of the switch module 5 and the comparator 11, it is beneficial to design in some hysteresis in comparator 11. Comparator 11 is therefore comparing the battery indicator voltage assigned to different voltage levels. When the battery voltage decreases this indicator voltage is equal to V_T minus hysteresis voltage. Conversely when the battery voltage increases this indicator voltage is V_T plus hysteresis voltage.

[0014] An alternative embodiment is shown in figure 4. In this embodiment the MOSFETs 9 and 10 of switch module 5 are replaced with a relay 12 that is operated directly from the output voltage of the differential amplifier 11. The relay closes when the V_s falls below V_T and completes the shunt circuit 15 to short out the preregulator 2.

[0015] Another alternative embodiment is shown in figure 5. In this embodiment the differential amplifier 11

is replaced with an analog to digital converter 13 whose output is processed by microprocessor 14. Using appropriate algorithms, microprocessor 14 generates an actuation signal for the relay 12 which will close the shunt circuit 15. This arrangement could also be used to trigger the operation of the MOSFETS 9 and 10 in the circuit of figure 3.

[0016] In this manner the negative effects of the voltage drop provided by the preregulator 2 are overcome while the integrated circuit regulator 3 is protected from excessive voltages.

Claims

1. In a battery operated device, a circuit for limiting the voltage input to an integrated circuit having a rated voltage comprising:

a preregulator connected to the input of said integrated circuit and constructed to compare said input voltage to a predetermined reference voltage and to adjust said input voltage in response to said comparison;

a switch module connected to control the operation of the preregulator, wherein said preregulator is shut down when the battery voltage diminishes to a predetermined voltage threshold; and

a voltage monitor connected to sense a voltage indicative of the battery voltage, compare said battery voltage to said predetermined minimum threshold, and actuate said switch module when said battery voltage falls below said voltage threshold.

2. In a battery operated device, a circuit for limiting the voltage input to an integrated circuit having a rated voltage, as described in claim 1, wherein the preregulator comprises a MOSFET operatively connected to a differential amplifier; and wherein the switch module comprises a circuit connected to the MOSFET for adjusting the bias of the MOSFET to minimize the voltage drop caused thereby upon actuation by the voltage monitor.

3. In a battery operated device, a circuit for limiting the voltage input to an integrated circuit having a rated voltage, as described in claim 1, wherein the switch module comprises a relay connected within a shunt circuit to short out the preregulator when the switch module is actuated by the voltage monitor.

4. In a battery operated device, a circuit for limiting the voltage input to an integrated circuit having a rated voltage, as described in claim 1, wherein the volt-

age monitor comprises a comparator connected to compare a voltage indicative of the battery voltage to a predetermined minimum threshold voltage.

5. In a battery operated device, a circuit for limiting the voltage input to an integrated circuit having a rated voltage, as described in claim 1, wherein the voltage monitor comprises an analog to digital converter connected to sense a voltage indicative of the battery voltage and to generate a digital signal in response thereto, wherein said digital signal is processed by a microprocessor which is programmed to generate a signal for actuating the switch module when the battery voltage diminishes to a predetermined minimum threshold. 5
6. In a battery operated device, a circuit for limiting the voltage input to an integrated circuit having a rated voltage, as described in any preceding claim, wherein the voltage reference is set relative to the rated voltage of the integrated circuit. 10
7. In a battery operated device which includes a circuit for limiting the voltage input to an integrated circuit having a rated voltage, a method for operating the limiting circuit comprising the steps of: 15
 - sensing the input voltage to the integrated circuit; 20
 - setting a predetermined reference voltage; 25
 - comparing said input voltage to the reference voltage and adjusting the input voltage relative thereto; 30
 - sensing the voltage supplied by the battery; 35
 - setting a predetermined minimum threshold voltage; and 40
 - comparing said supply voltage with said predetermined minimum threshold voltage and switching said limiting circuit to a shut down state when said supply voltage falls below said predetermined minimum threshold. 45
8. In a battery operated device which includes a circuit for limiting the voltage input to an integrated circuit having a rated voltage, a method for operating the limiting circuit, as described in claim 7, wherein the step of adjustment of the input voltage causes a reduction in said voltage. 50
9. In a battery operated device which includes a circuit for limiting the voltage input to an integrated circuit having a rated voltage, a method for operating the limiting circuit, as described in claim 7, wherein the 55

step of switching to the shut down state comprises minimizing the voltage drop of the limiting circuit.

10. In a battery operated device which includes a circuit for limiting the voltage input to an integrated circuit having a rated voltage, a method for operating the limiting circuit, as described in claim 7, wherein the step of switching to the shut down state comprises shorting out the limiting circuit.
11. In a mobile telephone for communicating within a cellular network, said telephone having a microprocessor control unit for operating the telephone and an integrated circuit voltage regulator for controlling the voltage to the microprocessor control unit, said voltage regulator having a rated voltage, a circuit for limiting the voltage input to said integrated circuit comprising:
 - a preregulator connected to the input of said integrated circuit and constructed to compare said input voltage to a predetermined reference voltage and to adjust said input voltage in response to said comparison;
 - a switch module connected to control the operation of the preregulator, wherein said preregulator is shut down when the battery voltage diminishes to a predetermined voltage threshold; and
 - a voltage monitor connected to sense a voltage indicative of the battery voltage, compare said battery voltage to said predetermined minimum threshold, and actuate said switch module when said battery voltage falls below said voltage threshold.
12. An electrical preregulator circuit comprising: an integrated circuit device (4) to be driven by a battery and a preregulator (2) operable to derive an input voltage (VIA) for the integrated circuit device from a variable supply voltage (Vs) from the battery which is nominally greater than the input voltage, **characterised by** means (5,6) operable to sense when the supply voltage (Vs) from the battery falls below a predetermined threshold (VT) and to cease said operation of the preregulator in response thereto.
13. An electrical preregulator circuit according to claim 12 including a regulator device (3) to receive the input voltage (VIA) and regulate the voltage fed to the integrated circuit

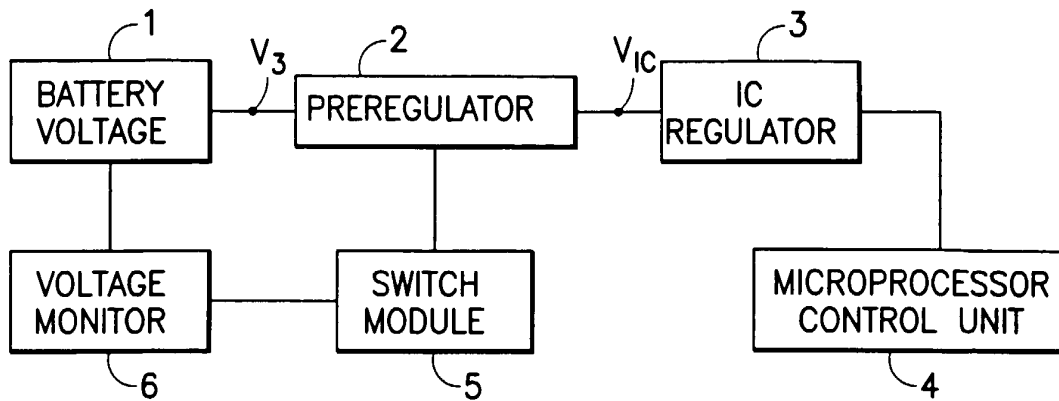


FIG. 1

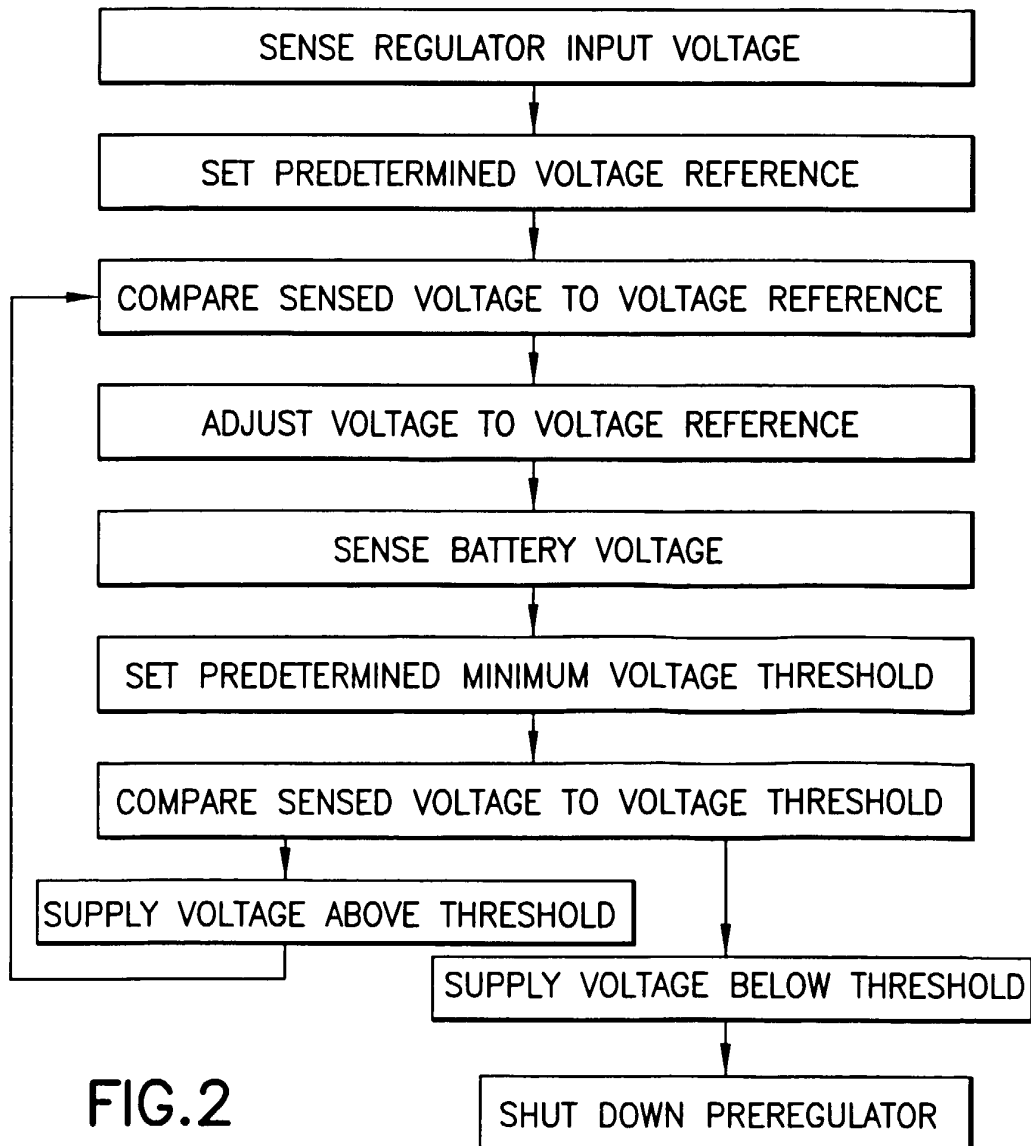


FIG. 2

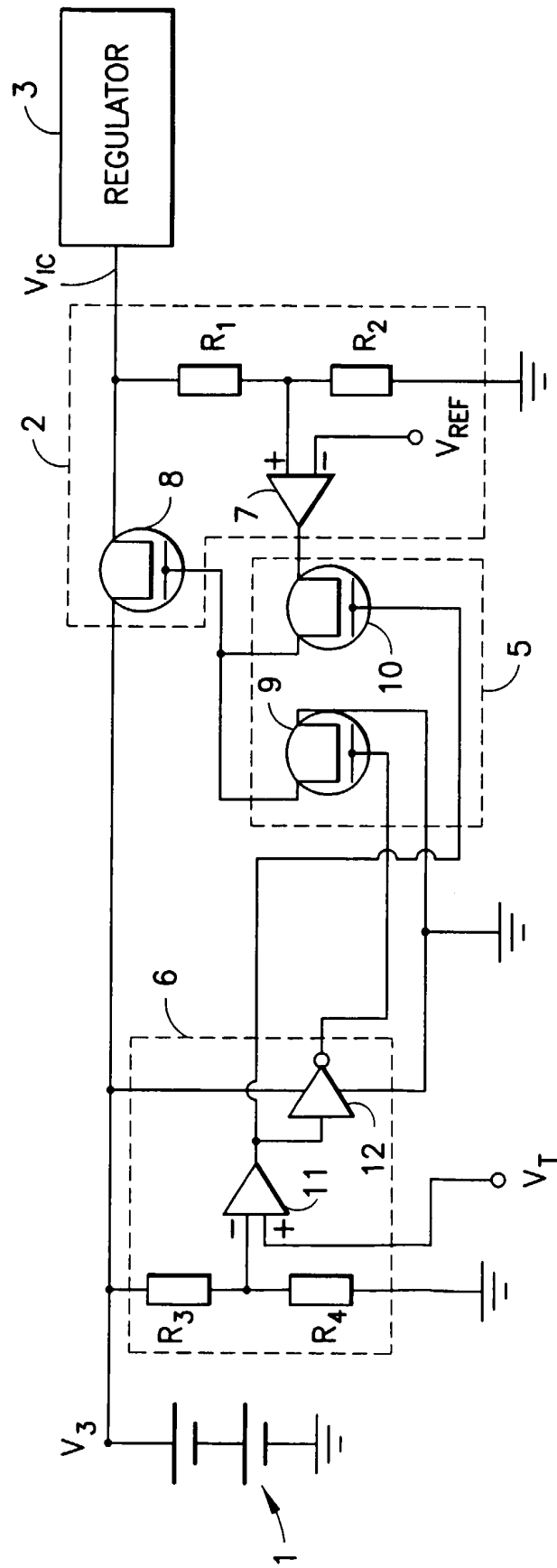


FIG.3

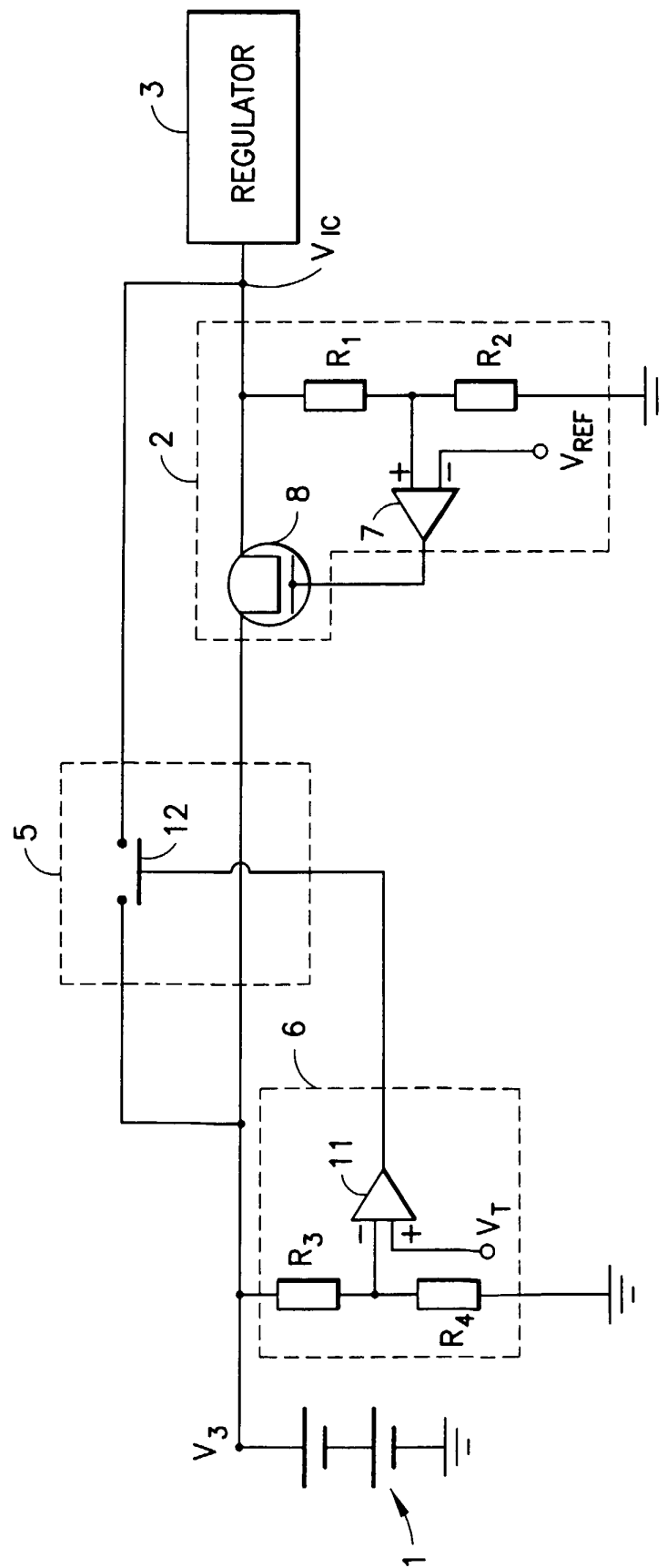


FIG. 4

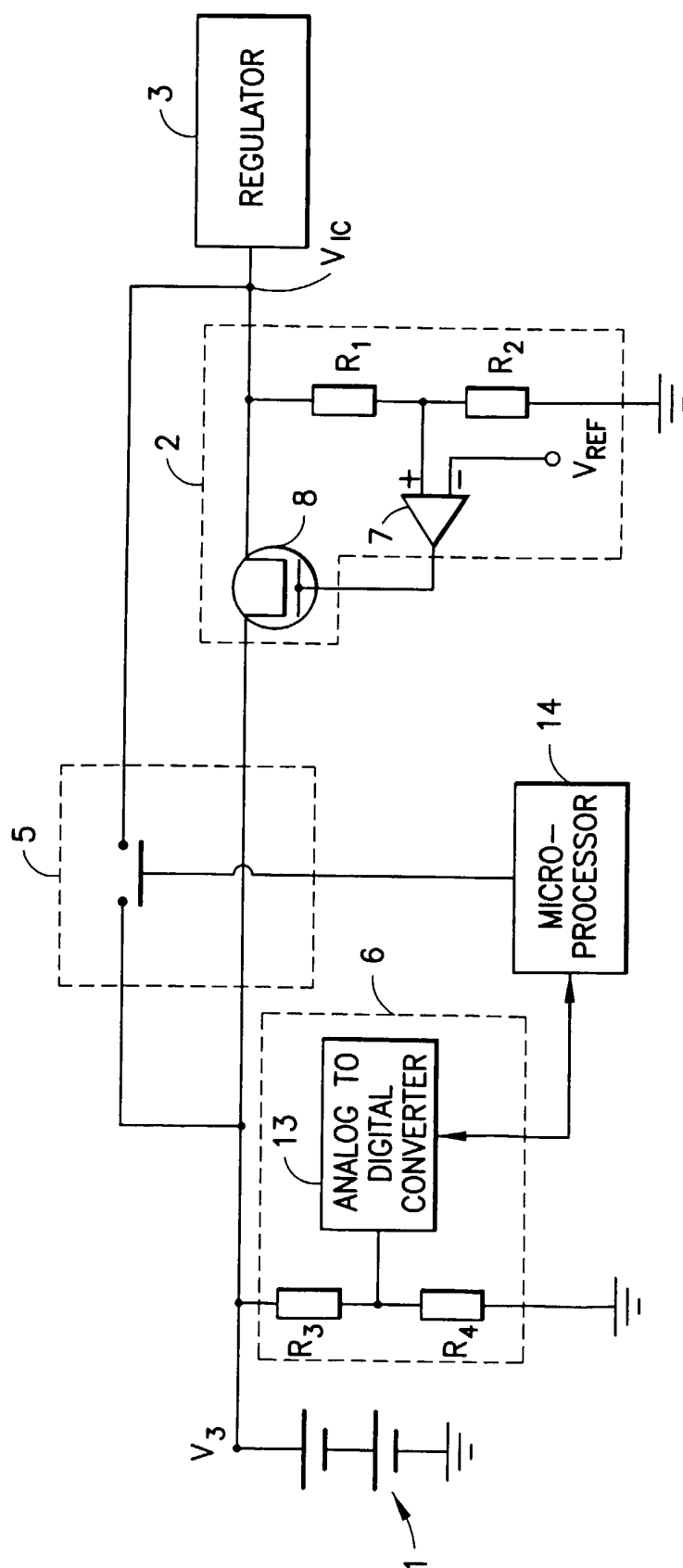


FIG. 5



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EUROPEAN SEARCH REPORT

Application Number
EP 00 30 9544

DOCUMENTS CONSIDERED TO BE RELEVANT			
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X	US 5 629 609 A (NGUYEN BAOSON ET AL) 13 May 1997 (1997-05-13)	1,2,4, 7-10,12, 13	G05F1/575 G05F1/56
A	* column 3, line 37 - column 5, line 47; figure 1 *	3,5,6,11	
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			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			G05F
The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 13 February 2001	Examiner Jonda, S
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 00 30 9544

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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13-02-2001

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