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(54) Voltage regulator circuit with a safety detector

(57) The present invention is related to a regulator circuit comprising a regulator circuit input and a regulator circuit output, a regulating element in connection with the regulator circuit input and the regulator circuit output, and a control circuit arranged for being fed with a signal related to the regulator circuit output. The regulator circuit further comprises a safety detector arranged for being fed with the signal related to the regulator circuit output. The safety detector is further arranged to control a switch, being in connection with the control circuit's output and with the regulating element.

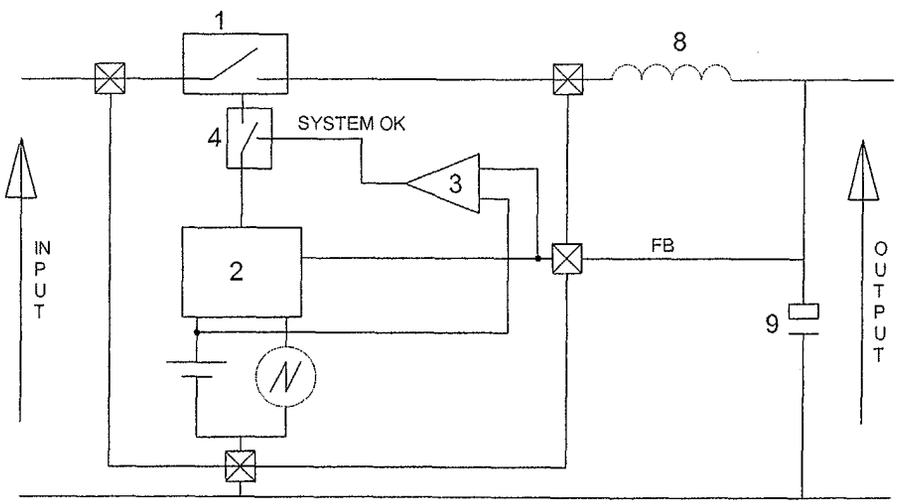

Fig.2

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Description

Field of the invention

[0001] The present invention is related to a circuit that deals with overvoltage error shutdown in order to protect attached electronic circuits.

State of the art

[0002] Almost any electronic circuit has a power supply that generates the working voltage(s) of the entire system. Regulation systems exist in many flavours. If the regulator should fail, or by mistake generate an incorrect (too high) supply voltage, the connected electronics might be damaged.

[0003] Regulators are built using a regulation loop, being essentially a circuitry that decides to 'add' (positive voltages or currents) or 'remove' (negative voltages or currents) energy to or from the output, and a regulating element. The regulating element is the actual element that conducts the electricity between input and output.

[0004] For example, but not limited to this example, there are step-down switching regulators. If the switching element in this kind of regulator is stuck in the 'on' position, because of malfunction of the regulator control or the regulation loop, then the full input voltage is passed to the output by the regulating element. Thus the 'step-down' functionality ceases to exist and the circuit connected to it may be destroyed.

[0005] The same holds for linear regulator systems. Should the regulating loop fail then the protection mechanism will perform an 'emergency stop' of the regulating element.

[0006] Furthermore regulators using external feedback, where the end user can adjust the output voltage by influencing the feedback signal, can fail if this feedback signal should be interrupted. The regulating loop will enter a run-away condition leading to the regulating element being stuck in the 'on' position.

[0007] Fig.1 shows the basic principle of a switching regulator. A switch (the regulating element (1)), controlled by a regulating loop (comprising a control circuit (2)) that depends on the feedback signal (FB), trickles the input voltage through the coil to the output capacitor (9), thus charging it. The coil (8) acts as a smoothing device here. When a preset level is reached, indicated by the level of the feedback signal FB, the switch is opened. Normally the output capacitor (9) is discharged by the attached circuit load taking energy out of it.

[0008] Two different failures can occur that might cause an unwanted overvoltage condition :

I) The internal regulation system fails and closes the switch permanently. In this case the full input voltage is applied to the output, overloading and possibly destroying the attached circuit.

II) The feedback line is interrupted. The regulation loop no longer receives vital information and keeps pumping charge in the output capacitor, thus increasing the voltage and causing the same problem as in case I.

Although at first sight the end result of these two faults is the creation of an overvoltage, the conditions and causes are different in each problem. The present invention offers a solution for both cases.

Aims of the invention

[0009] The present invention aims to provide a regulator circuit that protects attached electronic circuits by dealing with overvoltage errors. The invention also provides a method to detect overvoltage errors.

Summary of the invention

[0010] The invention relates to a regulator circuit comprising a regulator circuit input and a regulator circuit output, a regulating element in connection with the regulator circuit input and output, and a control circuit arranged for being fed with a signal related to the regulator circuit output. The regulator circuit further comprises a safety detector arranged for being fed with the signal related to the regulator circuit output. The safety detector is further arranged to control a switch being in connection with the control circuit's output and with the regulating element.

[0011] Preferably the regulating element is a switching regulator or a linear regulator.

[0012] In a preferred embodiment the signal related to the signal at the regulator circuit output is said signal at the regulator circuit output itself. Advantageously it is a signal from a voltage divider.

[0013] In another preferred embodiment the regulator circuit further comprises means for detecting a disconnection of the signal to be fed to the control circuit.

[0014] Alternatively the regulator circuit further comprises a current source between the regulator circuit input and the safety detector's input. The current source can be a resistor.

[0015] In an advantageous embodiment the safety detector is a voltage comparator. Preferably the safety detector is in connection with a time-out block, that further is connected to the switch.

[0016] The invention also relates to a regulator system comprising a regulator circuit as described above.

[0017] In a further aspect the invention relates to an integrated circuit comprising a regulator circuit as described.

Short description of the drawings

[0018] Fig. 1 represents a prior art regulator circuit.

[0019] Fig. 2 represents a regulator circuit according

to the invention.

[0020] Fig. 3 represents a regulator circuit with means for detecting disconnection of the feedback signal.

[0021] Fig. 4 represents an embodiment with a linear regulator.

Detailed description of the invention

[0022] In a solution according to present invention a 'safety detector' (3) is added to the circuit to provide protection for case I (see Fig.2). The detector circuit monitors the output voltage. If it surpasses a certain safety limit, it will disable the switch independently from the regulation loop. As long as there is no overvoltage detected the '*system ok'* signal is given, enabling the control of the regulating element (1) by the control circuit (2) of the primary regulation loop. If the regulation loop fails for whatever reason internal to the system and an overvoltage situation occurs, the '*system ok'* signal will disappear and thus disable the switching element (1).

[0023] For added/improved protection a 'final block' can be implemented. Once the circuit has 'tripped' it will lock out the entire system until the input voltage has been removed. Alternatively a timeout can be implemented that attempts to restart the system after a given period. After all it is possible the system has been restored to normal operation. These functions should be introduced between the block (3) creating the 'system ok' signal and the switch enabling element (4).

[0024] In case the feedback signal (FB) disappears completely then the protection mechanism for case I will no longer work. So somehow the missing signal must be detected. This can be done by sensing the impedance between the feedback pin and the output pin of the system.

[0025] One solution would be to insert a small current source (5) (see Fig.3), delivering a couple of μAmpère, between the input voltage and the feedback pin. Should the feedback signal FB be disconnected (high impedant or floating state) then this current source (5) will cause an immediate voltage rise of the internal feedback signal. This will immediately trip the overvoltage detector described in case I and disable the regulation system. The current source (5) could even be working on an interval basis (pulsed) if low power operation were desired. In its most minimalistic implementation this current source (5) can be a well chosen resistor from the input to the feedback signal FB inside the integrated circuit.

[0026] While the example was given using a switching regulator the same can be done with a linear regulator. The entire protection system simply needs to disable the regulating transistor in the linear regulator. An equivalent schematic is given in Fig.4.

[0027] This example gives an idea of an implementation in a linear regulator. Here the application is slightly different. In case an adjustable regulator is used, the full system can be implemented. The integrated circuit user sets the desired output voltage by trimming the voltage divider on the feedback signal FB (see Fig.4). Should this divider get disconnected, then the protection mechanism will engage. In case a fixed voltage regulator is used, there is no risk of the feedback signal FB becoming disconnected since it resides inside the integrated circuit. But still the overvoltage protection can be implemented.

[0028] The trip-point needs to be chosen in function of the expected end load. Most integrated circuits can survive a couple of 100 mV of overvoltage. So for a 3.3 V regulator this trip-point could be set at 3.4 or 3.5 V for instance. This parameter is up to the discretion of the integrated circuit designer.

[0029] This circuit can be used anywhere an overvoltage shutdown mechanism is required to protect electronics. Its main intention is to be embedded inside the regulator system or integrated circuit.
Typical applications would be step down regulators, as these have a potential 'dangerous' condition where the conducting element gets stuck in 'On' mode.

[0030] By adding two simple elements, a small current source (which can be a simple resistor) and a voltage comparator (a practical implementation of the overvoltage detector), the switching regulator can be made a lot safer for the attached circuitry. The same goes for a linear regulator.

[0031] Most regulation loops today are of the 'demand' type, meaning that the loop checks if there is 'enough' voltage at the output, according to the system settings. If there is not enough voltage or current, then the regulator will attempt to increase.

[0032] The proposed circuit adds a check for 'too much' voltage or current at the output and disables the regulation element when this erroneous condition arises. Whether the condition is internal (failure of primary regulation mechanism) or external (loss of feedback signal) does no longer matter. The proposed circuit can catch both conditions and will react by entering fail-safe mode.

Claims

1. Regulator circuit comprising a regulator circuit input and a regulator circuit output, a regulating element (1) in connection with said regulator circuit input and said regulator circuit output, and a control circuit (2) arranged for being fed with a signal related to said regulator circuit output, **characterised in that** it further comprises a safety detector (3) arranged for being fed with said signal related to said regulator circuit output, said safety detector further arranged to control a switch (4), said switch being in connection with said control circuit's (2) output and with said regulating element (1).

2. Regulator circuit as in claim 1, wherein said regu-

lating element (1) is a switching regulator or a linear regulator.

3. Regulator circuit as in claim 1 or 2, wherein said signal related to the signal at said regulator circuit output is said signal at said regulator circuit output itself.

4. Regulator circuit as in claim 1 or 2, wherein said signal related to the signal at said regulator circuit output is a signal from a voltage divider.

5. Regulator circuit as in any of the previous claims, further comprising means for detecting a disconnection of said signal to be fed to said control circuit (2).

6. Regulator circuit as in any of the previous claims, further comprising a current source between said regulator circuit input and said safety detector's (3) input.

7. Regulator circuit as in claim 6, wherein said current source is a resistor.

8. Regulator circuit as in any of the previous claims, wherein said safety detector (3) is a voltage comparator.

9. Regulator circuit as in any of the previous claims, wherein said safety detector (3) is in connection with a time-out block, said time-out block further being connected to said switch (4).

10. Regulator system comprising a regulator circuit as in any of the previous claims.

11. Integrated circuit comprising a regulator circuit as in any of the previous claims.

12. Method to protect a regulator circuit against overvoltage or overcurrent errors, said regulator circuit comprising a regulator circuit input and a regulator circuit output, a regulating element (1) in connection with said regulator circuit input and said regulator circuit output, and a control circuit (2), said method comprising the steps of

- feeding both said control circuit (2) and a safety detector (3) with a signal related to said regulator circuit output,
- controlling a switch (4) by means of said safety detector (3), said switch being in connection with said control circuit's (2) output and with said regulating element (1), and
- opening said switch (4) in case an overvoltage or overcurrent error is detected.

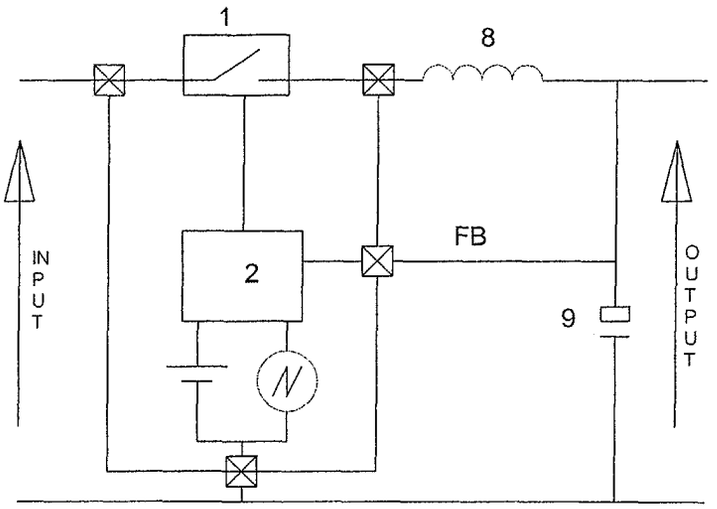

Fig.1

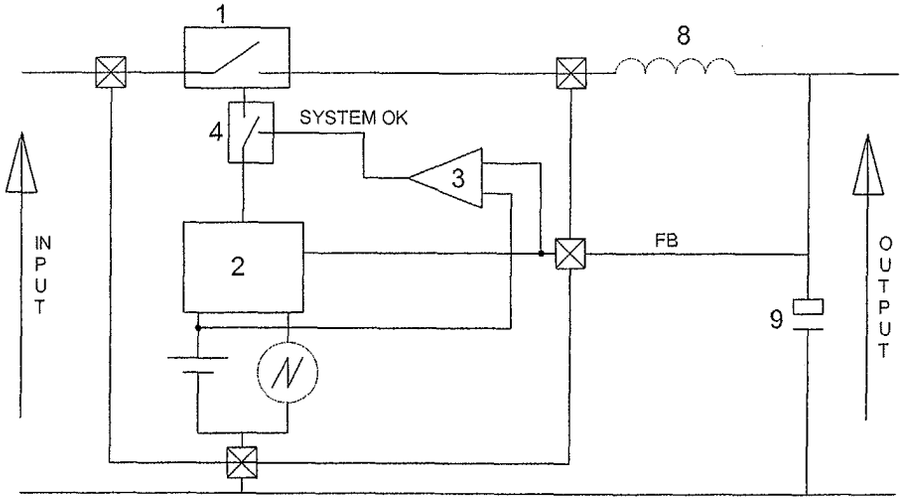

Fig.2

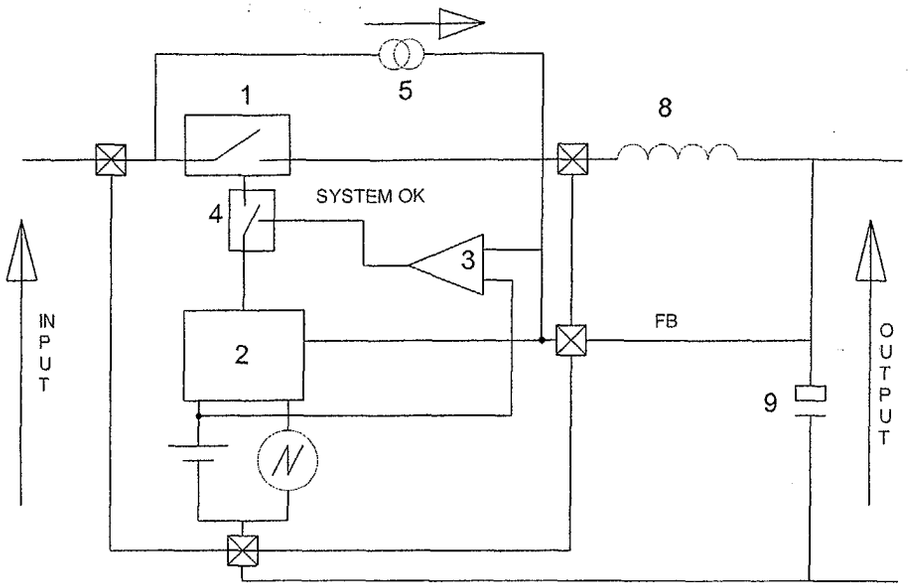
1
5
8
SYSTEM OK
4
3
FB
2
9
INPUT
OUTPUT

Fig.3

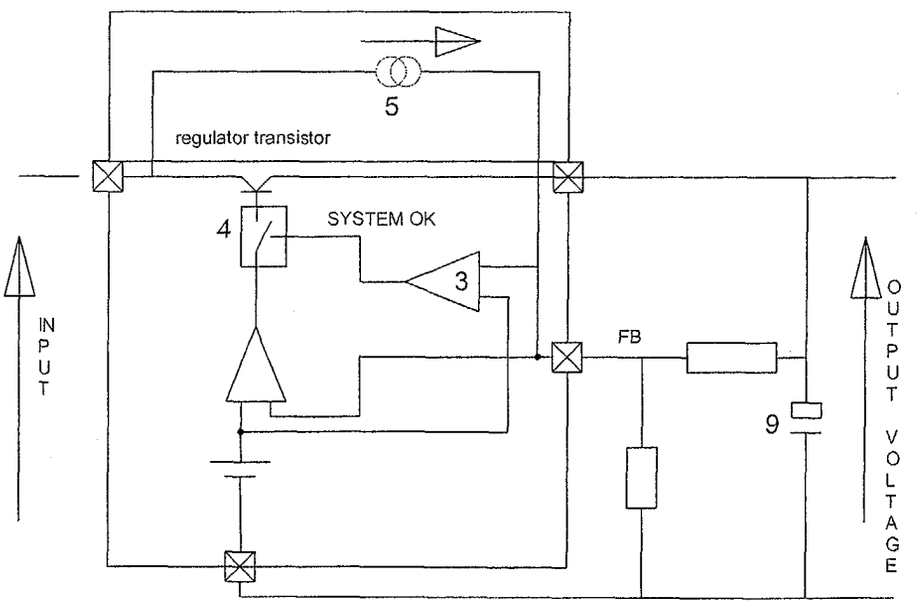
5
regulator transistor
SYSTEM OK
4
3
FB
9
INPUT
OUTPUT VOLTAGE

Fig.4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 44 7121

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	PATENT ABSTRACTS OF JAPAN vol. 0082, no. 15 (P-305), 2 October 1984 (1984-10-02) & JP 59 099510 A (FUJITSU KK), 8 June 1984 (1984-06-08) * the whole document * -----	1-12	G05F1/56
A	DE 33 22 278 A (SIEMENS AG) 20 December 1984 (1984-12-20) * abstract * -----	1-12	
A	US 2003/076638 A1 (PEROL PHILIPPE ALFRED ET AL) 24 April 2003 (2003-04-24) * abstract * -----	1-12	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			G05F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	18 October 2004	Schobert, D

CATEGORY OF CITED DOCUMENTS

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18-10-2004

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