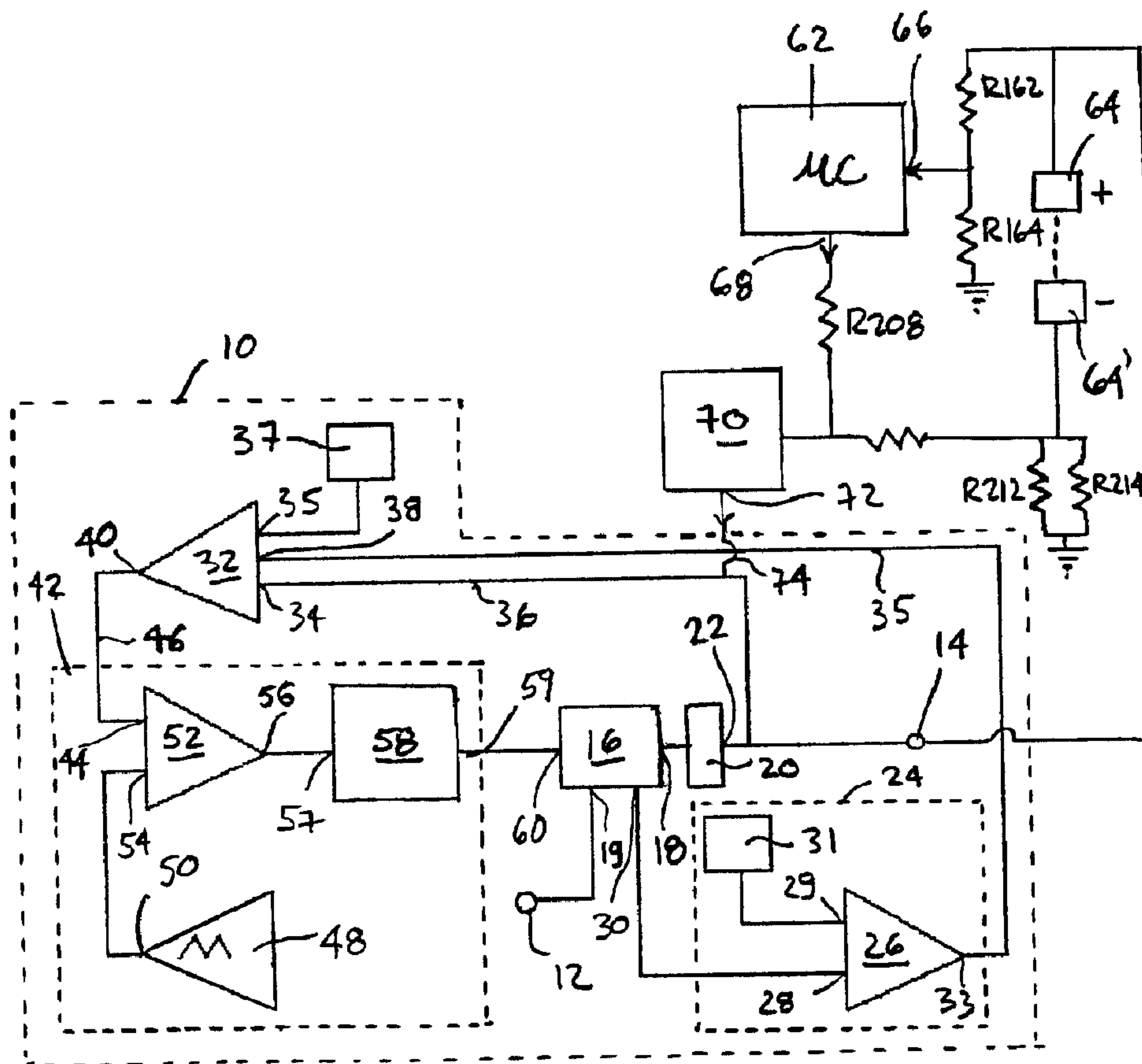




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(54) Titre : REGULATEUR DE TENSION COMMUTABLE
 (54) Title: SWITCHING VOLTAGE REGULATOR



(57) Abrégé/Abstract:

A switching voltage regulator circuit for converting an input voltage signal to a regulated DC output voltage signal to be applied to a load is provided. According to one embodiment, the circuit comprises a switching device receiving the input voltage signal and

(57) **Abrégé(suite)/Abstract(continued):**

having an output being coupled to an output filter generating the regulated output voltage signal; a current limiting device sensing current drawn by said load to generate a current error signal whenever the current exceeds a predetermined current limit value; a voltage comparator amplifier receiving the regulated output voltage signal and the current error signal and comparing thereof to a reference voltage to generate a voltage error signal; and a switching control device receiving the voltage error signal to generate a control signal for the switching device.

ABSTRACT OF THE DISCLOSURE

A switching voltage regulator circuit for converting an input voltage signal to a regulated DC output voltage signal to be applied to a load is provided. According to one embodiment, the circuit comprises a switching device receiving the input voltage signal and having an output being coupled to an output filter generating the regulated output voltage signal; a current limiting device sensing current drawn by said load to generate a current error signal whenever the current exceeds a predetermined current limit value; a voltage comparator amplifier receiving the regulated output voltage signal and the current error signal and comparing thereof to a reference voltage to generate a voltage error signal; and a switching control device receiving the voltage error signal to generate a control signal for the switching device.

SWITCHING VOLTAGE REGULATOR

Field of the Invention

The present invention relates to voltage regulator circuits for converting an input voltage signal to a regulated DC output voltage signal to be applied to a load, and more particularly to switching voltage buck regulator circuits.

Background of the Invention

Switching voltage regulators have been developed as an alternative to linear voltage regulators to provide higher efficiency with smaller size. A switching voltage regulator includes a switching control device coupled to one or more switches which are rapidly opened and closed according to a varying duty cycle to transfer energy between an input, unregulated voltage source to a load, through an output filter. Typically, the output voltage of the regulator is monitored in feedback by an error amplifier comparing thereof to a desired output reference voltage and sending an error signal to the switching control device which adjusts the duty cycle accordingly.

An example of known DC to DC switching voltage converter is disclosed in U.S. Patent No. 5,627,460 to Bazinet et al., which converter includes a bootstrap capacitor monitored by a digital logic controller to drive a high side of a switching device comprising a series connected pair of N-channel Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFET's), and to drive the low side of the switching device when the bootstrap voltage decreases below a predetermined level to maintain a minimum level of charge on the bootstrap capacitor. Another example of a known switching voltage regulator in a battery management application is disclosed in U.S. Patent 5,774,733 to Nolan et al., which teaches making use of a microcontroller and a digital-to-analog converter to provide reference voltage thresholds to a voltage comparator selectively used through operation of a logic gate as an error amplifier or a current monitor for driving an external power transistor coupled to external inductor and capacitor.

U.S. Patent 5,773,966 to Steigerwald, U.S. Patent No. 5,903,138 to Hwang et al. and U.S. Patent No. 5,955,871 to Nguyen disclose other switching voltage regulators showing complex multi-mode operation features providing adaptation to low and high power consumption levels of a connected load.

5 Although the above cited prior art regulator circuits show special features which may prove to be useful in certain specific applications, the complex design generally characterizing these known circuits contribute to increase manufacturing costs thereof. More particularly, although switching regulators are by far more efficient than linear regulators, they have never seen
10 wide spread use in alarm system panels design because of their greater costs. Therefore, there is still a need for simple circuit designs which prove to reduce manufacturing cost of switching voltage regulators.

Summary of the Invention

15 It is an object of the present invention to provide a switching voltage regulator circuit of a simple design exhibiting high efficiency and reducing manufacturing costs.

 It is another object of the invention to provide a switching voltage regulator circuit that can be used for implementing a back-up battery charging
20 device with battery testing feature.

 According to the first above object, from a broad aspect, there is provided a switching voltage regulator circuit for converting an input voltage signal to a regulated DC output voltage signal to be applied to a load. The circuit comprises a switching device receiving the input voltage signal and
25 having an output being coupled to an output filter generating the regulated output voltage signal, and a current limiting device sensing current drawn by the load to generate a current error signal whenever the current exceeds a predetermined current limit value. The circuit further comprises a voltage comparator amplifier receiving the regulated output voltage signal and the
30 current error signal and comparing thereof to a reference voltage to generate a

voltage error signal, and a switching control device receiving the voltage error signal to generate a control signal for the switching device.

According to the second above object, the regulated DC output voltage signal is to be applied to a back-up battery coupled to the load, the voltage regulator circuit further comprising a controller having a sensing input being
5 coupled to the battery and an output being coupled to the input of the voltage comparator amplifier for causing the regulator to change from a battery charging mode into a battery test mode allowing the controller to compare
10 sensed voltage supplied by the battery to a predetermined minimum voltage threshold and to generate an alarm signal whenever the sensed battery voltage is lower than the minimum voltage threshold.

Brief Description of the Drawings

A preferred embodiment of the present invention is illustrated in the
15 appended drawings, in which:

Fig. 1 is a schematic block diagram of the embodiment;

Figs. 2a and 2b represent a detailed schematic of the regulator of the
embodiment;

Fig. 3a is a detailed schematic of a microcontroller as part of a battery
20 charge control circuit of the embodiment;

Fig. 3b is a detailed schematic of a battery coupling circuit and a
microcontroller power supply circuit of the embodiment;

Fig. 3c is a detailed schematic of a voltage adjusting circuit for battery
test mode of the embodiment;

25

Detailed Description of the Preferred Embodiment

Referring now to Fig. 1, the switching voltage regulator circuit according to the present invention and generally designated at 10 is used to
convert a typically higher input voltage signal applied to an input terminal 12
30 into a typically lower regulated DC output voltage signal generated between

main and grounded output terminals 14 and 14' across parallel resistors R140 and R142 as better shown in Fig. 2b, to which terminals a load is to be connected. The basic regulator circuit 10 comprises a switching device 16 having an input terminal 19 being coupled to input terminal 12 through main line 17' for receiving the input voltage signal, the switching device 16 further having an output 18 being coupled to an output filter 20 generating the regulated output voltage signal at an output 22 thereof with reference to corresponding terminal 22'. The switching device 16 preferably makes use of a N-channel MOSFET 210, as shown in Fig. 2b. Although any other suitable electronic switch may be used to implement the switching device 16, the regulator circuit as shown is designed to accommodate the reverse polarity of the N-channel MOSFET. This reduces cost, since an N-channel FET is less expensive than a P-channel MOSFET. The filter 20 typically comprises one or more input inductors 27 coupled to one or more output capacitors 41. The high-energy current pulses from the switching device 16 are stored and filtered by inductors 27 and capacitors 41. A schottky diode 43 is also provided to clamp the back EMF of inductor 27 when the switching device opens. The regulator circuit 10 further includes a current limiting device 24 for sensing current drawn by the load. The current limiting device 24 preferably makes use of a first comparator amplifier 26 having a sensing input 28 preferably being coupled to an input terminal 30 provided on the MOSFET as shown in Fig. 2b, to receive a signal representative of the current drawn by the load. It is to be understood that other connecting configuration for the purpose of current sensing may be employed, such as an appropriate coupling to the output terminal 14. The regulator circuit 10 further comprises a second voltage comparator amplifier 32 receiving the regulated output voltage signal at a first input 34 thereof through a first node 39 connected to a feedback line 36, for comparison to a reference voltage applied to input 35 from reference voltage source terminal 37. As better shown in Fig. 2b, the current limiting device 24 is

configured to compare the signal entering at input 28 with a further reference voltage applied to input 29 from reference voltage source terminal 31 corresponding to a predetermined current limit value, to generate at an output 33 a current error signal whenever the current exceeds the set current limit value. The current error signal is fed through a line 35 to a second input node 38 connected to a transistor 41 having its output linked to first input node 39. The second voltage comparator 32 receives the current error signal for comparing thereof, in combination with the regulated output voltage signal, to the reference voltage applied to source terminal 37 to generate a voltage error signal at an output 40 provided on voltage comparator 32. The reference voltage level is set in accordance with the desired regulated output level. The regulator circuit 10 is further provided with a switching control device preferably of a Pulse Width Modulator (PWM) type and generally designated at 42, which receives at a first input terminal 44 thereof the voltage error signal through a line 46 to generate a control signal for the MOSFET 210 of the switching device 16. Basically, the PWM switching control device 42 makes the decisions to turn on and off the switch and for how long in generating pulses for controlling the duty cycle of switching device 16. The PWM switching control device 16 comprises a third voltage comparator amplifier 48 arranged in an oscillator configuration to generate a triangular ramp signal at an output 50 thereof, the frequency of oscillation being set an appropriate value selection for resistor R156 and capacitor C109. The PWM switching device 16 further comprises a fourth voltage comparator 52 receiving the voltage error signal at an input 45 for comparing thereof to the triangular ramp signal received from third comparator 48 at an input 54, to generate a Pulse Width Modulated output signal generated at an output 56 provided on fourth comparator amplifier 52. Since the output signal at 56 is not of a sufficient level to adequately control the MOSFET 210 of the switching device 16, the switching control device 42 further comprises a driving stage 58 receiving at an

input 57 thereof the signal from comparator output 56 for generating at an output 59 thereof a switching control signal of a sufficient level that is fed to an input terminal 60 provided on the switching device 16. In the example shown in Fig. 2b, the driving stage 58 conveniently makes use of only four (4) transistors 59, 61, 63 and 64 to keep manufacturing costs low, and the switching device input 60 is coupled to the gate terminal of MOSFET 210 through a resistor R132. It is to be understood that the switching device 16 may be implemented according to other designs, such as a pair of N-Channel MOSFET's alternately driven by an appropriate switching control circuit providing two different driving voltage levels for separately controlling the duty cycle of each MOSFET. It is pointed out that the preferred embodiment shown in Figs. 2a and 2b makes use of only four (4) independent comparator amplifiers 26, 32, 48 and 53, which can be advantageously provided by a single package integrated circuit readily available on the marketplace, such as the Quad comparator LM339 IC manufactured by National Semiconductor Corp. Since the reduced number of comparators required to implement a regulator circuit according to the present invention allows the use of such a single package IC, the cost of the regulator circuit may be reduced accordingly as compared to prior designs requiring a higher number of comparators or an expensive special function switching controller IC, while maintaining high efficiency.

As shown in Fig. 2a, the regulator circuit 10 is typically adapted to receive a rectified DC signal generated by a rectifier bridge circuit 11 being coupled with capacitors 13 between a pair of input terminals 15 connected to an alternating voltage source and the input terminal 12 through input line 17. It is to be understood that the regulator circuit according to the present invention can be adapted to receive DC input signals exhibiting other types of waveforms.

Referring again to Fig.1, the embodiment shown includes further components enabling the regulator circuit 10 to be used as a back-up battery charging device with battery testing feature which is useful in many

applications, such as for the management of back-up battery found in the control panel of electronic alarm systems. There is provided a controller 62, which is preferably an integrated microcontroller circuit having a sensing input 66 being coupled through a voltage divider formed by resistors R162 and R164 to the positive terminal 64 of a battery having its negative terminal 64' being coupled to ground through parallel protections 65 and 65' and parallel resistors R212 and R214, as better shown in Fig. 3b. The microcontroller 62 is preferably powered by a linear low power regulator 67, which is a LM78L05 SOT-89 integrated regulator package also manufactured by National Semiconductor Corp, in the example shown in Fig. 3b which is self-explanatory. The microcontroller 62 further has an output port 68 being coupled through line 68 and resistor R208 to a comparator voltage adjusting circuit 70 being coupled through lines 74, 36 and node 39 to input 34 of comparator 32, as better shown in Fig. 2a. In the example shown in Fig. 3c, the comparator voltage adjusting circuit 70 makes use of series connected voltage op-amplifiers 76 and 78. The interruption control signal generated by microcontroller 62 at its output 68 is sent through resistor R208 to a first input 80 of op-amplifier 76 having a second input 82 being coupled to ground through resistors R218 and R220. The output 84 of op-amplifier 76 is coupled to an electroluminescent diode 86 indicating a testing mode of operation and having a cathode terminal being coupled to ground through resistor R219. The op-amplifier output 84, which is coupled in feedback to input 82 through resistor R216, is also coupled to a second input 88 of op-amplifier 78 having its first input 90 receiving a reference voltage signal. The voltage adjust signal generated at output 92 of op-amplifier 78 is coupled, through diode 94 and resistor R206 connected to grounded capacitor C130, to comparator 32 of the regulator 10, as described before with reference to Figs. 1 and 2a. It is to be understood that different configurations for providing a voltage adjusting circuit operating in accordance

with other control principles, such as a control over the set reference voltage, may be used in accordance with the present invention.

In operation as a basic voltage regulator, referring again to Fig. 1, the circuit 10 is fed by an input voltage signal applied to input terminal 12, and directed to input terminal 19 of switching device which generates a power signal sent to the filter 22 for generating a regulated output voltage signal at an output 22 thereof, which signal is supplied to a load. Switching control for providing a desired regulation is performed by the voltage comparator 32 in combination with the current limiting device 24, which receives from the switching device 16 a signal representative of the current drawn by the load, for comparing thereof with the reference voltage corresponding to a predetermined current limit value, to generate at output 33 a current error signal whenever the current exceeds the set current limit value. The voltage comparator 32 receives the regulated output voltage signal and the current error signal at inputs 34 and 38, for comparison thereof to the reference voltage applied to input 35 from source terminal 37, to generate a voltage error signal at comparator output 40 when the compared voltages are different. The value of reference voltage is set and maintained stable in accordance with the desired regulated output level. Therefore, the voltage comparator 32 makes a decision as to if the regulated voltage is at the correct level. When it is not, it generates an error signal to the switching control device 42. The switching control device 42 receives at input 44 the voltage error signal to generate a control signal for the switching device 16, the duty cycle of which is being characterized by the control signal accordingly. More specifically, the comparator 52 causes the error signal to intersect the triangle waveform at different points; these different points corresponding to different duty cycles, the top of the waveform being very narrow and the bottom very wide. The error signal cause comparator 52 to select a corresponding intersection. Hence, when load conditions are severe the duty cycles are long and when load conditions are light duty cycles are low

accordingly. The voltage comparator 48 of the switching control device generates a triangular ramp signal at output 50, which is applied to input 54 of voltage comparator 52 also receiving the voltage error signal at input 44, to generate a pulse-width-modulated output signal generated at output 56. From
5 the PWM signal, the driving stage 58 generates at output 59 a switching control signal of a sufficient level that is fed to input terminal 60 of switching device 16, the duty cycle of which allows the generation of an output signal being characterized by the desired voltage level.

In operation as a battery charging device with battery testing feature, the
10 controller 62 is operated to receive at input 66 a battery check signal from positive battery terminal 64 through the voltage divider formed by resistors R162 and R164. The microcontroller 62 sends through output 68 a test signal to the voltage adjusting circuit 70, which in turn generates a corresponding voltage adjust signal to the comparator input 34 for causing regulator
15 interruption , thereby causing the regulator to change from a battery charging mode into a battery test mode allowing microcontroller 62 to compare sensed voltage supplied by the battery to a predetermined minimum voltage threshold. If the voltage supplied by the battery is stable, the test is passed and the regulator is caused to return in the battery charging operation mode. However,
20 if the sensed battery voltage is lower than the minimum voltage threshold, the microcontroller generates an alarm signal before causing the regulator to return to the battery charging operation mode.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A switching voltage regulator circuit for converting an input voltage signal to a regulated DC output voltage signal to be applied to a load, said circuit comprising:

a switching device receiving the input voltage signal and having an output being coupled to an output filter generating said regulated output voltage signal;

a current limiting device sensing current drawn by said load to generate a current error signal whenever said current exceeds a predetermined current limit value;

a voltage comparator amplifier receiving said regulated output voltage signal and said current error signal and comparing thereof to a reference voltage to generate a voltage error signal; and

a switching control device receiving said voltage error signal to generate a control signal for said switching device.

2. The switching voltage regulator circuit according to claim 1, wherein the switching device includes a N-channel Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFET).

3. The switching voltage regulator circuit according to claim 1, wherein said current limiting sensing device includes a further voltage comparator amplifier having a sensing input being coupled to said switching control device to receive a signal representative of said load drawn current, for comparing thereof to a further reference voltage corresponding to said predetermined current limit value.

4. The switching voltage regulator circuit according to claim 3, wherein the switching device includes a N-channel MOSFET, said sensing input being coupled to an input terminal of said MOSFET.
5. The switching voltage regulator circuit according to claim 3, wherein said output filter includes an input filter inductor coupled to an output filter capacitor.
6. The switching voltage regulator circuit according to claim 1, wherein said switching control device is a Pulse Width Modulator switching control device.
7. The switching voltage regulator circuit according to claim 6, wherein said Pulse Width Modulator switching control device comprises:
 - a first further voltage comparator amplifier receiving said voltage error signal for comparing thereof to a triangular ramp signal to generate a pulse-width-modulated output signal, and
 - a driving stage for generating said control signal.
8. The switching voltage regulator circuit according to claim 7, wherein said Pulse Width Modulator switching control device further comprises a second further comparator amplifier arranged in an oscillator configuration for generating said triangular ramp signal.
9. The switching voltage regulator circuit according to claim 1, wherein said regulated DC output voltage signal is to be applied to a back-up battery coupled to said load, said circuit further comprising a controller having a sensing input being coupled to said battery and an output being coupled to the input of said voltage comparator amplifier for causing the regulator to change

from a battery charging mode into a battery test mode allowing the controller to compare sensed voltage supplied by the battery to a predetermined minimum voltage threshold and to generate an alarm signal whenever the sensed battery voltage is lower than the minimum voltage threshold.

10. A switching voltage regulator circuit for converting an input voltage signal to a regulated DC output voltage signal to be applied to a load, comprising:

a switching device receiving the input voltage signal and having an output being coupled to an output filter generating said regulated output voltage signal;

a first voltage comparator amplifier sensing current drawn by said load to generate a current error signal whenever said current exceeds a predetermined current limit value;

a second voltage comparator amplifier receiving said regulated output voltage signal and said current error signal and comparing thereof to a reference voltage to generate a voltage error signal; and

a Pulse Width Modulator switching control device receiving said voltage error signal to generate a control signal for said switching device, said switching control device comprising:

a third voltage comparator amplifier arranged in an oscillator configuration to generate a triangular ramp signal;

a fourth voltage comparator amplifier receiving said voltage error signal for comparing thereof to said triangular ramp signal to generate a pulse-width-modulated output signal, and

a driving stage for generating said control signal;

11. The switching voltage regulator circuit according to claim 10, wherein said first, second, third and fourth comparator amplifiers are included in a single package integrated circuit.
12. The switching voltage regulator circuit according to claim 10, wherein the switching device includes a N-channel MOSFET.
13. The switching voltage regulator circuit according to claim 12, wherein said first voltage comparator amplifier has a sensing input being coupled to an input of said MOSFET to receive a signal representative of said load drawn current, for comparing thereof to a further reference voltage corresponding to said predetermined current limit value.
14. The switching voltage regulator circuit according to claim 10, wherein said output filter includes an input filter inductor coupled to an output filter capacitor.

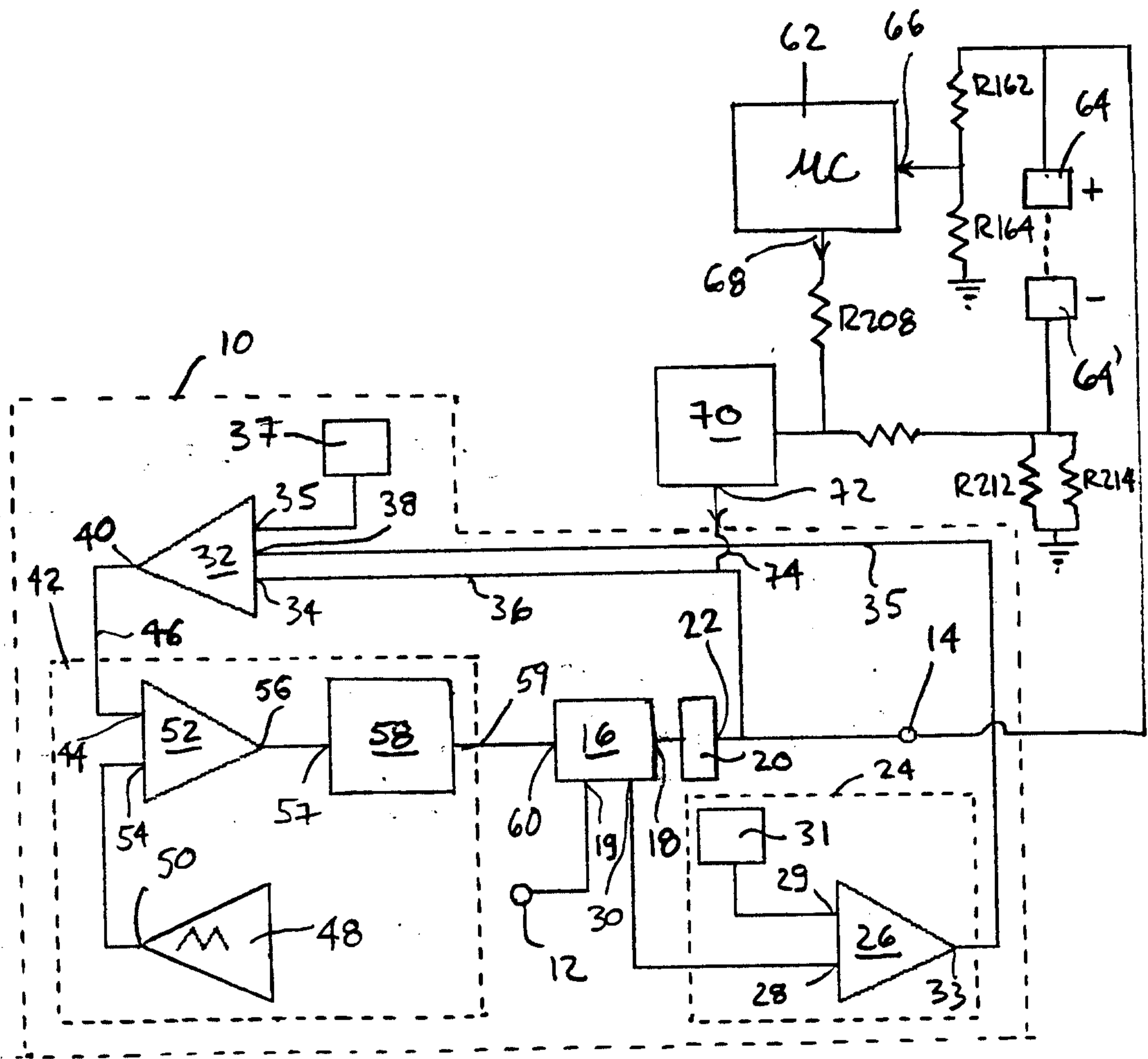
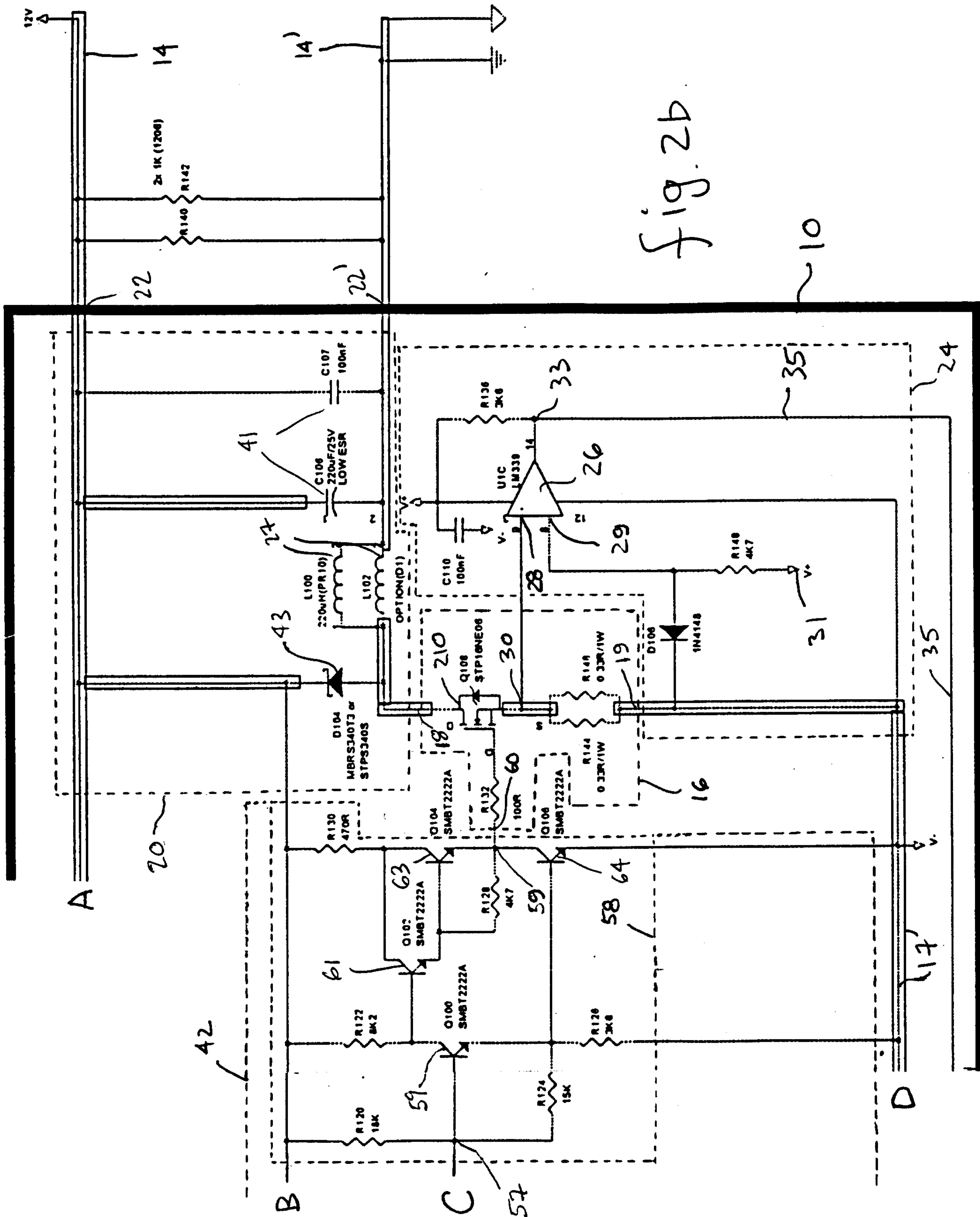


fig. 1



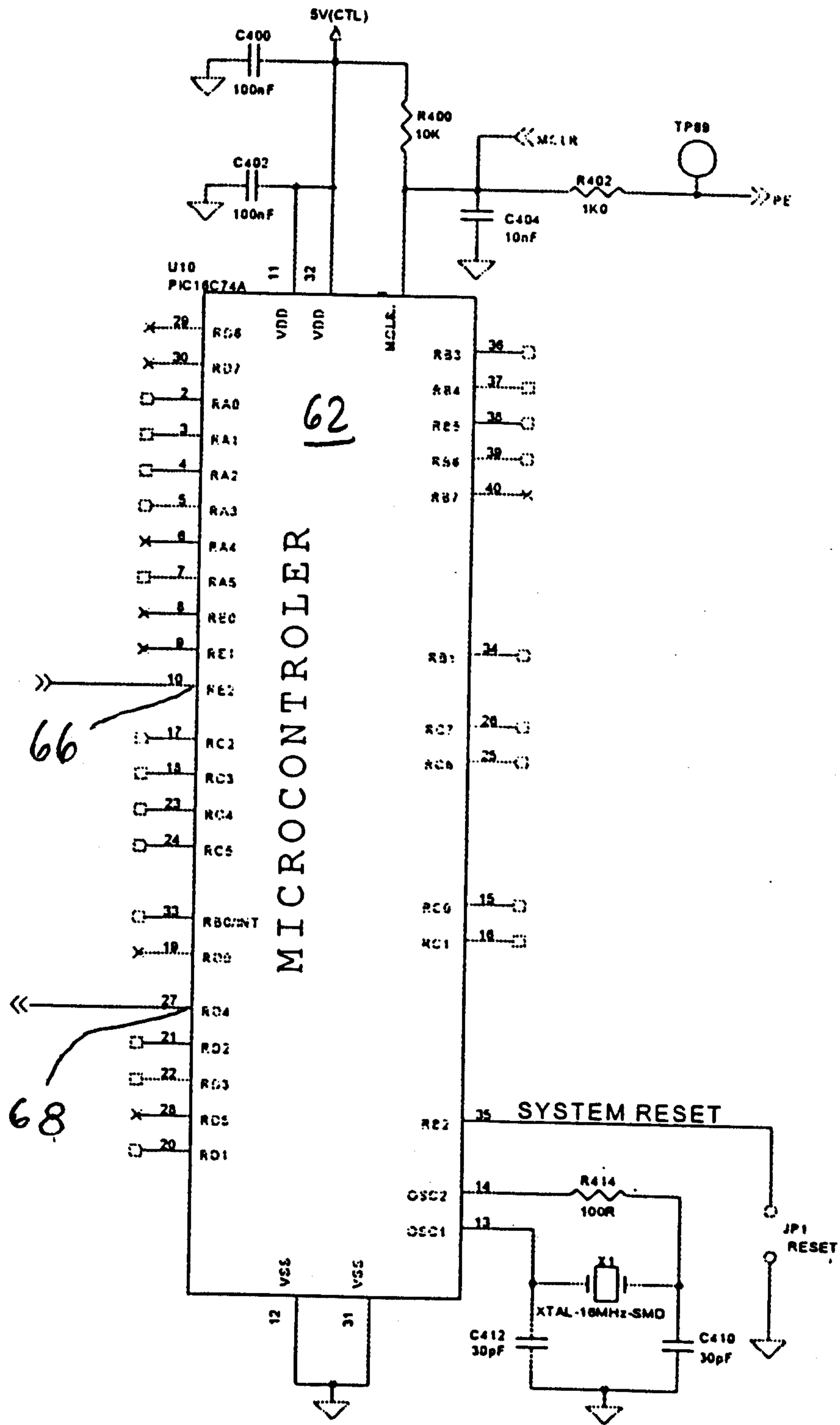


fig. 3 a

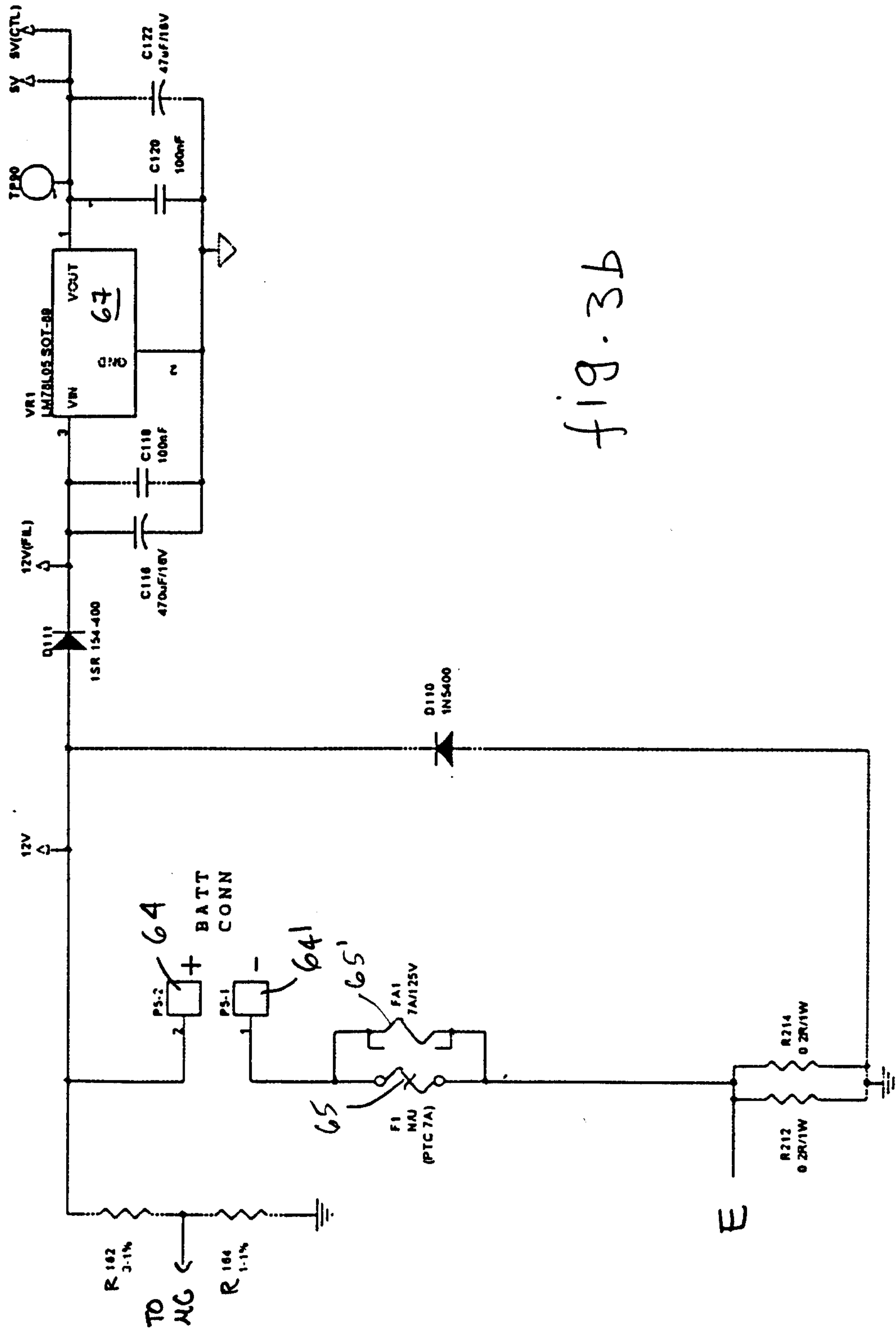


fig. 3b

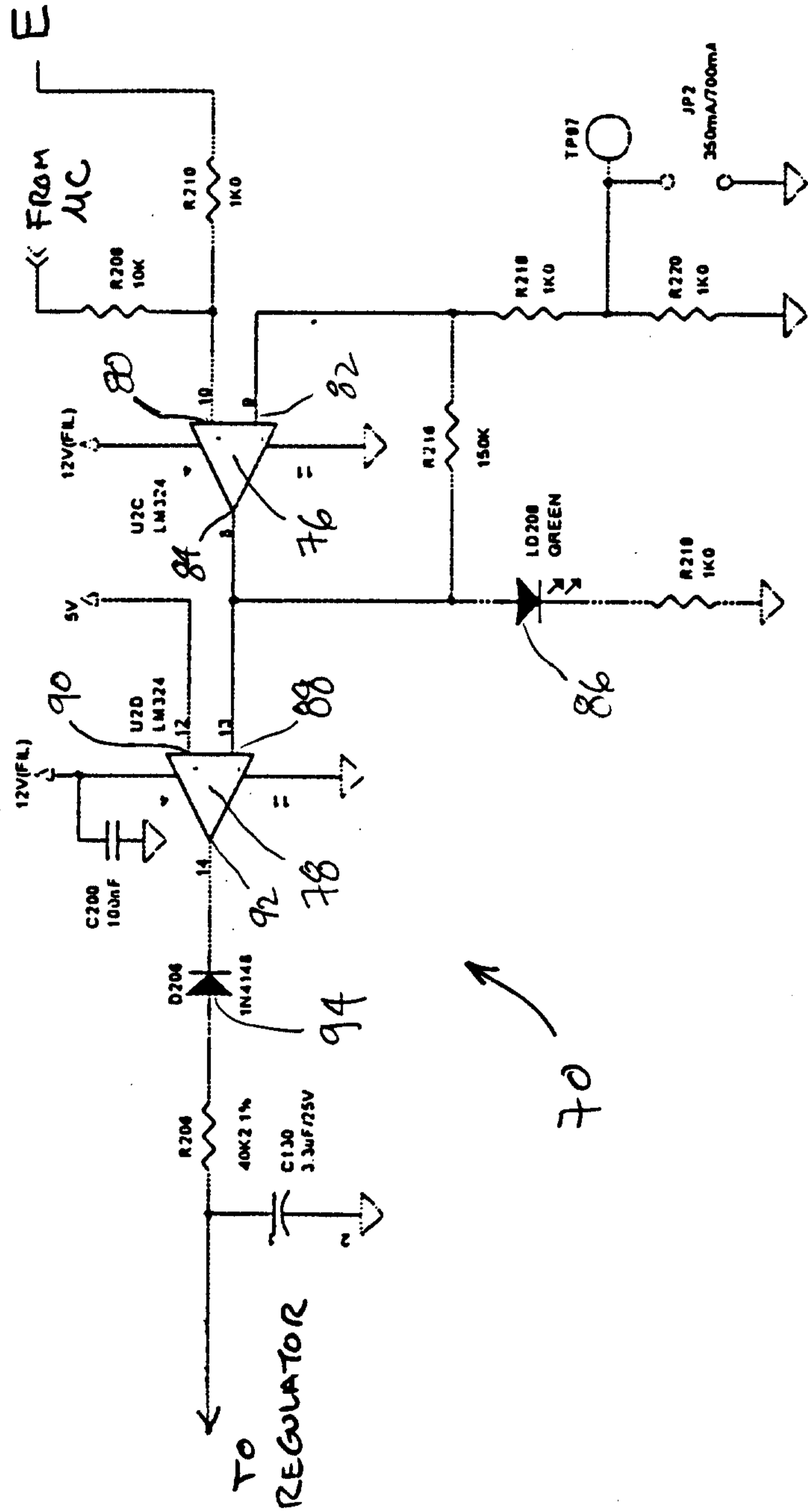


fig. 3c

