(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
20 May 2010 (20.05.2010)

PCT

(10) International Publication Number
WO 2010/055430 A2

(51) International Patent Classification: Not classified

(21) International Application Number: PCT/IB2009/054802

(22) International Filing Date: 29 October 2009 (29.10.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0820672.4 12 November 2008 (12.1 1.2008) GB

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available):* AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available):* ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) Title: Power Supply Control Device and Method

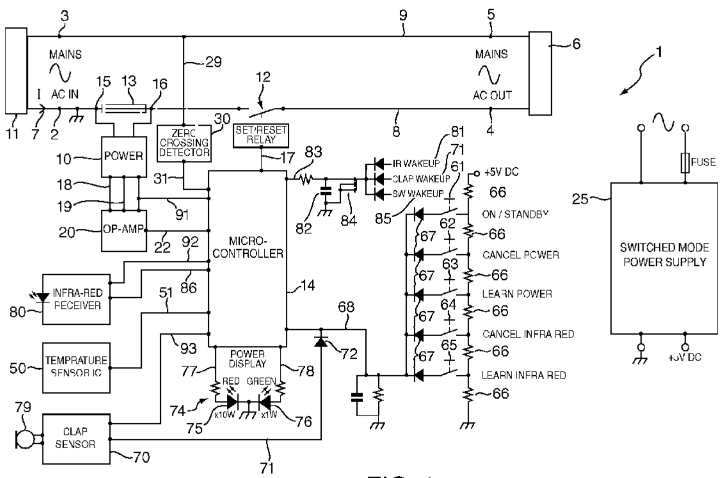

FIG. 1

(57) Abstract: The present invention relates to a device and method for saving electrical energy and to a corresponding method for saving electrical energy. A power supply control device (1) for controlling electrical power (7) drawn from a mains supply (11) comprises mains input terminals (2, 3) for connection to a mains supply, mains output terminals (4, 5) for connection to an electrical consumer apparatus (6), a power line (8, 9) extending between the mains input and mains output, and a power sense circuit (10) for sensing a measure of the power drawn by the apparatus from the mains output. A relay (12) is in series with the power line (8), and a controller (14) is arranged to open the relay to disconnect the circuit through the power line when the measure of power is below a threshold. The device also comprises an over-current protection fuse (12) in series with the power line (8). The power sense circuit (10) is arranged to utilise the current protection fuse (12) as a current sense resistor to generate an output signal to the controller (14) representative of the real power drawn by the consumer apparatus (6).

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Power Supply Control Device and Method

BACKGROUND

a. Field of the Invention

The present invention relates to a device for saving electrical energy and to a corresponding method for saving electrical energy. More particularly, the invention relates to a power supply control device that monitors the electrical power consumed by an electrical consumer apparatus and that automatically disconnects the supply of electrical power to the electrical consumer apparatus when the consumption of electrical power matches predetermined conditions.

b. Related Art

Electrical power consumption in the United Kingdom of electrical consumer apparatus turned off, but left in standby mode, has been estimated at between 2 to 3 GW. This is a sizable fraction of the typical total power consumption of about 50 GW. In fact, the waste due to standby power is worse than this because there is no requirement on electrical equipment manufacturers to control the power factor of drawn current and voltage when the power consumption is below 75 W, as it generally will be in standby mode. Power Factors as poor as 0.3 for apparatus in standby mode are typical. As a result, the actual amount of electrical power that needs to be generated to power apparatus in standby mode is considerably increased.

Numerous devices have been proposed for saving electrical energy when an electrical consumer device, for example a television set or a computer peripheral device such as a printer, or a group of such devices, is put into a lower power consumption state. Usually, this is when the electrical consumer device or devices (referred to hereinafter as an electrical consumer apparatus) are not being actively used, for example when in a standby mode after a period of inactivity or when a main power switch has been turned off. Some devices allow a user to manually set a power consumption threshold below which the power supply control device will switch off electrical consumer apparatus.

One example of such a power supply control device is disclosed in patent document US 2007/0297112 A1. This describes a power distribution strip having an adaptive standby threshold that can be set during a training stage when the device is put into operation. In order to monitor the power supplied by the power distribution strip, the electrical current drawn by the consumer apparatus passes through a resistor that may have a value between 0.10 Ω to 0.47 Ω. If the current is 13 A, then this equates to a power consumption in the sense resistor of between about 17 W and 80 W. The electrical losses in such a sense resistor are a waste of electrical power.

It is an object of the present invention to provide a more efficient power supply control device and method for saving electrical energy.

SUMMARY OF THE INVENTION

According to the invention, there is provided a power supply control device for controlling electrical power drawn from an alternating current (AC) mains supply, comprising mains input terminals for connection to a mains supply, mains output terminals for connection to an electrical consumer apparatus, a power line extending between terminals of the mains input and mains output, a power sense circuit for sensing a measure of the power drawn by said apparatus from the mains output, a relay in series with the power line, and a controller arranged to open the relay to disconnect the circuit through the power line when said measure of power is below a threshold, wherein:

- the device comprises an over-current protection fuse in series with the power line; and

the power sense circuit is arranged to utilise the current protection fuse as a current sense resistor to generate an output signal to the controller representative of the real power drawn by the consumer apparatus.

Also according to the invention, there is provided a method of controlling electrical power drawn by an electrical consumer apparatus from an alternating current (AC) mains supply, using a power supply control device, said device comprising mains input terminals, mains output terminals, a power line extending between said terminals of the mains input and mains output, a power sense circuit, an over-current protection fuse in series with the power line, a relay in series with the power line, and a controller, wherein the method comprises the steps of:

- connecting the mains input terminals to a mains supply;
- connecting the mains output terminals to an electrical consumer apparatus;
- using the current protection fuse as a current sense resistor to generate a signal representative of the electrical current through the fuse when electrical power is drawn by said apparatus;
- providing said signal to the power sense circuit and using the power sense to generate an output signal to the controller representative of the real power drawn by the consumer apparatus; and
- using the controller to open the relay to disconnect the circuit through the power line when said measure of real power is below a threshold.

Preferably, the power sense circuit is arranged to generate the output signal using an AC voltage representative of the electrical alternating current through the fuse corrected according to the power factor of the drawn alternating current with respect to the AC mains supply voltage.
The power factor of an alternating current electric power system is defined as the ratio of the real power to the apparent power, and is a number between 0 and 1 (frequently expressed as a percentage, e.g. 0.5 pf = 50% pf). Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit, disregarding any phase difference between the alternating current and voltage. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power can be greater

than the real power. Because the power supply control device provides a measure of the real power drawn by the consumer apparatus, the device can be used to sense more accurately the point where power should be cut to a consumer apparatus on standby. The real power can also be displayed to the user as an indication of the actual energy and cost savings achievable by using the device.

The power line will, in general comprise a pair of conductive paths connected at the input terminals to live and neutral mains connections, which may be integrated with a mains power plug. The relay and fuse will be in series with a circuit including the conductive paths that includes the load provided by the apparatus. In a preferred embodiment of the invention, the relay and fuse are in series in the same conductive path, but could alternatively be provided in different conductive paths.

In a preferred embodiment of the invention, the power sense circuit is arranged to take a measure of the current through the fuse (which is the same as the current through the consumer apparatus) and a voltage across the alternating current mains supply in order to generate an output signal representative of a power factor corrected measurement of the real power drawn by the consumer apparatus. In a preferred embodiment, the current through the fuse is multiplied by a voltage drop across the alternating current mains supply in order to generate this output signal. The fuse is a resistive element and so the current through the fuse is preferably measured by detecting a voltage generated across the fuse by the current passing through the fuse.

In a preferred embodiment of the invention, the output signal is generated by multiplying the AC supply voltage with an in-phase part of the current through the fuse to generate said measure of the real power drawn by said apparatus.

The microcontroller may be operable to determine and store the threshold value in response to a command from a user input and dependent on the measure of the power drawn by the consumer apparatus.

The threshold is preferably calculated from the measure of the power drawn by the apparatus plus an additional margin of power.

The power sense circuit is arranged to generate a differential signal representative of the electrical power dissipated by the consumer apparatus, the differential signal being level shifted in voltage entirely above or below a mains reference voltage.

In a preferred embodiment of the invention, the power sense circuit is an analogue circuit. The fuse and power sense circuit may then have opposite temperature coefficients so that, in combination, with a constant load connected, they generate a temperature compensated output over a temperature range, preferably a typical indoor range of at least 10-40 °C.

The power sense circuit may alternatively be a digital circuit. The digital circuit may then include an internal temperature sensor an output from which is used by the digital circuit to generate a temperature compensated output over an indoor temperature range, preferably of at least 10-40 °C.

The power supply control device may comprise additionally a temperature sensor, the microcontroller then being arranged to receive an output from the temperature sensor and to temperature compensate the signal from the power sense circuit over an indoor temperature range, preferably of at least 10-40 °C.

To help conserve power, the controller may be arranged to periodically enable operation of the power sense circuit, for example with the power sense circuit being enabled less than 10% of the time.

The power supply control device comprises additionally a zero crossing circuit for determining when the mains supply crosses through zero volts. The operation of the relay may then be synchronised by the microcontroller with respect to the zero crossing in order to control arcing or contacts within the relay. Preferably, this synchronisation is to switch on a falling slope of the mains voltage in order to minimise arcing of relay contacts. In a preferred embodiment of the invention, the inrush of current in the consumer apparatus is minimised by making the relay connect on the falling slope of the mains cycle approximately one-third from its peak value. As the relay makes contact the voltage is reducing and the inrush current surge is thereby minimised. When switching off power, the relay is disconnected as the mains voltage passes through zero.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be further described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a block circuit diagram of a power supply control device according to a preferred embodiment of the invention, for controlling electrical power drawn by an electric consumer apparatus from a mains supply; and

Figure 2 is a circuit diagram of the main components of power supply control device of Figure 1, showing a power sense circuit for measuring electrical power dissipated in a consumer apparatus by using an over-current protection fuse as the current sense resistor.

DETAILED DESCRIPTION

Figure 1 shows a block circuit diagram of a power supply control device 1, comprising a pair of mains input terminals 2, 3 for connection to a mains supply 11, and a pair of mains output terminals 4, 5 for connection to an electrical consumer apparatus 6 that provides an electrical load. The connection to the mains 11 will normally be made via a mains plug that can be plugged and unplugged from a socket. The consumer apparatus 6 may be one or more items of electrical equipment that draw a current (1) 7 from the mains supply, which will normally be provided at 110 VAC or 230 VAC.

The device 1 includes a power line consisting of a first conductor 8 and a second conductor 9. Each of the conductors 8, 9 extend between a pair of the terminals, one 2, 3 at the mains input and the other 4, 5 at the mains output. The device 1 includes a power sense circuit 10 for sensing a measure of the power drawn by the electrical load 6 from the mains output 4, 5, and also has a 16 Amp set/reset relay 12 and a 13 Amp fuse 13 in series with each other and with the input and output terminals 2, 4 of the first conductor 8 of the power line. The power sense circuit 10 has an input with a pair of terminals 15, 16 connected to the first conductor 8 on opposite sides of the fuse 13. As will be explained in more detail below, the power sense circuit 10 measures the true power dissipated by the consumer apparatus 6, corrected for power factor.

The device includes a controller, in this example is a microcontroller 14, that has an output 17 connected to the relay 12. The microcontroller 14 is arranged in response to the measured power through the fuse 13, to open the relay 12 to disconnect the circuit through the power line 8, 9, and in response to a command generated by a user of the device to reset the relay 12 when the circuit through the power line 8, 9 is to be reconnected.

A switched mode power supply 25 is been used to provide a 5 V supply for the microcontroller and various other associated components from which the microcontroller provides an output or receives an input. Other forms of power supply would also work but are unlikely to achieve a sufficiently low power consumption in standby mode necessary for efficient operation.

In this embodiment of the invention a switched mode supply 25 is used to achieve a standby power of about 0.1 W with a power factor of about 0.7. Typical electrical consumer apparatus 6 powered via the power supply control device 1 often have very poor power factors (for example, about 0.3 to 0.4) in standby mode and this, when applied generally across the national grid, causes a loss of electricity generating capacity.

The power sense circuit 10 has an output consisting of a pair of lines 18, 19 that provide differential minus (M) and plus (P) signals that are connected to corresponding inputs of an op-amp circuit 20 which amplifies these signals. The signals are sinusoidal AC signals offset by a varying millivoltage difference, with the difference being a varying DC signal representative of the instantaneous power consumption of the consumer apparatus 6. The op-amp 20 is a standard differential input instrumentation amplifier preceded by an emitter follower pnp matched transistor pair (labelled Q3A and Q3B) 27, 27'. The emitter followers act to DC shift the differential signals fully into the positive voltage domain relative to local ground point 24. The emitters of the transistor pair Q3A, Q3B 27, 27' provide a differential emitter output signal 47, 47' which is connected to positive inputs of a first op-amp 33 and a second op-amp 35, labelled OA3 and OA4. In this way the millivolt range output from the power sense circuit 10 is amplified to provide from the output 22 of the op-amp circuit 20 a voltage to the corresponding input of the microcontroller 14 before measurement by an analog-to-digital converter inside the microcontroller 14. The amplified output 22 is generated relative to a local ground point 24 which is taken from the first power line conductor 8 having the relay 12 and fuse 13.

The device includes a zero crossing detector circuit 30 that has an input 29 connected to the second power line conductor 9 and an output 31 connected to the microcontroller 14. The zero crossing detector circuit therefore detects a voltage of the power supply relative to the local ground 24 on the first power line conductor 8.

The zero crossing detector circuit 30 performs two functions. The first is to monitor when the mains voltage is passing through zero volts and when this does the circuit 30 provides an output to the microcontroller 14 to initiate an analogue to digital conversion and subsequent processing within the microcontroller of the amplified signal is received 22 from the op-amp circuit 20. Because the power consumption of the consumer apparatus 6 in a standby mode is often irregular, the microcontroller 14 takes measurements from the power sense circuit 10 over many mains cycles and then averages these to give a true power measurement. For a 50 Hz mains supply, the low to high zero crossing circuit initiates a measurement sequence every 20 ms. When the power sensing circuit 10 is thus enabled to take a measure of the power dissipation by the consumer apparatus 6, the microcontroller performs 64 analog to digital measurements within 20 ms, and then averages the results with previous similar measurements until 64 such measurement sequences have been performed. This is repeated over a 1.2 second period, with each of the 64 measurement sequences being averaged, in order to improve the accuracy of the overall measurement. Over 1.2 seconds 64 x 64 = 4096 samples are taken and the average reading is obtained. This method improves the accuracy of the wattage reading when measuring switched mode power supplies which are operating in a hysteretic [hiccup] standby mode.

For a 60 Hz supply mains the period is reduced from 20 ms to 16.66 ms but the same methodology is used.

As will be discussed in more detail below, to save power the power sensing circuit 10 is disabled most of the time. In this example, the power sensing circuit is enabled every 15 seconds to perform the measurement over the 1.2 second time period.

The output 31 from the zero crossing detector circuit 30 is also used by the microcontroller to synchronise the relay switch open and switch reset times with zero crossings of the mains voltage. This minimises inrush current at switch reset and contact arcing at switch open, thereby helping to maximise the lifetime of the relay 12.

In this embodiment of the invention the fuse 13 conforms to British Standard BS1 362 and has a resistance of about 0.005 Ω at 20 °C. The current 7 through the conductor 8 will therefore generate a voltage across the fuse 13. When the power sense circuit 10 is energised, the voltage across the fuse at the terminals 15 and 16 is provided to the power sense circuit simultaneously with the mains supply voltage. The power sense circuit instantaneously multiplies the voltage across the fuse representative of the current 7 through the fuse with the supply voltage.

The power sense circuit accomplishes this as follows. The supply voltage is divided by a two resistor pairs each of which has a 1 MΩ resistor 40, 40' connected to the second, or local live conductor 9 which is in series with a 33 Ω resistor 41, 41' connected to the first, or local ground conductor 8. Each of these reduced voltages is provided to the base of a matched pair of npn 42, 42' and pnp 43, 43' transistors, labelled Q1A, Q1B and Q2A, Q2B, that are preferably formed as a four transistor array within a single integrated circuit. The transistor pairs 42, 42' and 43, 43' are configured as long-tailed pairs (LTPs). The emitters of each of these transistors are all connected together 44 and to the local live conductor 9 through a resistance 45 of 440 kΩ. The pnp transistors 43, 43' are switched on to draw current through the resistance 45 when the supply voltage is in the positive half phase, and the npn transistors 42, 42' are switched on to draw current through the resistance 45 when the supply voltage is in the negative half phase. The collectors of each pnp transistor are connected 46, 46' to the collector from the npn transistor for the other pair at either the plus 19 or minus 18 differential outputs of the power sense circuit 10. The outputs are preferably smoothed by means of a 10 µF capacitor 21 connected between each of the plus and minus outputs and the local ground current conductor 7.

The power sensing circuit 10 includes in series with each of the resistors 41, 41' a protection fuse 49, 49', each of which has a resistance of about 6 Ω. The protection fuse 49' on the minus side 18 of the circuit is needed to prevent current from conductor 8 potentially short circuiting through the transistor Q2B 43' and the transistor Q3B 27' to the local earth 24 under fault conditions. The other protection fuse 49 is provided simply to balance the operation of the power sense circuit 10.

The fuse 13 takes the place of the current sensing resistor used in conventional power supply control devices. This arrangement provides several benefits. Low value high current resistors having a low temperature coefficient are more expensive then fuses, so there is a cost saving. The use of a protection fuse is, in any event, a requirement for low power electrical devices in many countries, and so the invention makes use of a component that will in general have to be provided in any event. There is also a significant savings in terms of reduced electrical power losses. A 13 Amp fuse conforming to BS1 362 will typically have a resistance of 0.005 Ω, and so with 13 Amps flowing through the fuse, only 1 W will be dissipated in lost power.

Finally, a particular advantage of this arrangement of power sense circuit 10 and fuse 13 is that it is possible to cancel out temperature related changes in the power sense circuit and fuse 13. The design is such that the voltage output of the power sense circuit 10 has a negative temperature coefficient. The fuse, which is used as the current sensing resistor, has a similar but positive temperature coefficient so that, in combination, with a constant load connected, they produce an approximately constant millivoltage output over a typical indoor usage temperature range of 10-40 °C.

If the invention is used to control an appliance taking the maximum allowed current from the supply socket then some self-heating of the fuse 13 will occur. To further improve the accuracy, should it be necessary, a correction can be made by the microcontroller 14 by using software and a temperature sensor integrated circuit 50 that provides an output 51 to the microcontroller 14, together with calibration data of power sensor circuit output variation with temperature over a typical usage temperature range of, for example 10-40 °C, and the previously measured and stored temperature at which the initial factory setting calibration (described below) was performed.

However for "standby mode" power measurements (for example, when setting a threshold at which the device will cut power to the electrical consumer 6) self-heating of the fuse 13 is not a problem. A 1 Amp current flow at 230 VAC represents 230 W of power dissipation in the connected load but the fuse dissipation would only be I^2 x 0.005 = 0.005 W. A standby power of 50 W at 230 VAC equates to a fuse dissipation of 0.00024 W.

The device 1 includes a user input 60 having number of user input buttons 61-65, including an On/Standby button 61, a Cancel Power button 62, a Learn Power button 63, a Cancel Infra Red button 64, and a Learn Infra Red button 65, each of which is connected at an input pole to a supply voltage divided down in steps by a series of resistors 66 so that a different supply voltage is present at each switch. An output pole of each switch is connected to a diode 67, the cathodes of which are all connected together and to a microcontroller ADC input port 68.

The five switches 61-65 therefore each output a different voltage onto the switch input line 68 of the microcontroller 14. The switches have a priority determined by their position in the resistive chain. The On/Standby button 61 has the highest priority and the adjacent diodes 67 block the lower voltages from the subsequent lower switches 62-65. The action of the buttons 61-65 in this embodiment of the invention is as follows: - pressing the button awakens the microcontroller 14 by switching on the transistor 84 via diode 85 to forcibly discharge capacitor 82 and releasing the button causes the action to be performed.

The On/Standby button 61 is used to turn the device on or put it into standby mode.

The Cancel Power button 62 is used to clear a memory location in the microcontroller 14 that holds the last power measurement data from the power sensing circuit 10. When this memory location is clear, the device 1 will not cut power to the attached apparatus 6.

The Learn Power button 63 is used to store a new value of the power measurement data into the memory location in microcontroller 14.

The Learn Infra Red button 65 is used to learn and store in a microcontroller memory location a specific choice of infra-red commands received by an infra-red receiver 80, described in more detail below.

The Cancel Infra Red button 64 is used to clear the microcontroller memory location holding the previously learnt infra-red commands.

Optionally, a clap sensor 70 may be provided as a further user input, having a microphone 79, a microphone amplifier and monostable generator, which outputs 71 a defined voltage pulse via a diode 72 onto the microcontroller ADC input port 68. In this embodiment of the invention two claps with a one second interval are required to bring the unit out of standby.

Optionally, the device 1 may include the infra-red receiver 80, which accepts transmitted codes from one or more infra-red handsets (not shown) and which then forward decoded commands on an output line 86 to the microcontroller 14. The microcontroller may be capable of learning a specific handset button code under software control for comparison or bring the unit out of standby with the reception of any infra-red code.

In this embodiment of the invention the microcontroller 14 drives a power display 74, including a red Light Emitting Diode (LED) 75 used to indicate a set power value of 10 Watts and a green LED 76 for 1 Watt. The LEDs 75, 76 are connected to corresponding outputs 77, 78 of the microcontroller 14. In operation the user initiates a Learn Power by pressing and releasing the appropriate button. The power sensing circuit 10 is activated by the microcontroller 14 and the measurement is made. The relay 12 is then opened, to switch the device 1 into standby mode and the power is displayed by a series of LED blinks. For example 23 Watts would be displayed as Red, Red, Green, Green, Green.

When the electrical consumer apparatus 6 is switched into "standby mode" the fuse 13 will commence to cool down and since the power sensing circuit measurement, which is made at timed intervals under control of the microcontroller 14, is compared with a stored power threshold, which includes the added software margin, for example 12.5% over the actual standby power measured when the user operated the Learn Power button 63, the automatic relay switching into standby mode will soon take place. In situations where the invention is used to control an electrical consumer apparatus 6 taking the maximum allowed current from the mains supply the user can also operate the Learn Power button 63 immediately when the electrical consumer apparatus enters "standby mode" after the apparatus has been in ON mode for some time. This will ensure that the power measurement is taken with a warm fuse 13 and will remove any excessive delay in automatic shutdown.

Once a power value is stored inside the microcontroller 14, the power value is used, in ON mode, to set a power threshold value which is the stored value plus a margin, preferably 12.5% that is used by the microcontroller to determine whether to switch the relay 12 from closed (On mode) to open (Standby mode). Measurements are made by the microcontroller 14 at intervals determined by the periodic wakeup of the microcontroller from a sleep mode. In this embodiment of the invention the first measurement below the power threshold does not switch off the relay but illuminates the Red LED and only if the power is still below the threshold at the second wakeup from sleep mode does the relay switch into standby mode. The power display then blinks the power measurement.

In this embodiment of the invention the maximum possible stored power for correct operation is 200 W. This allows the 12.5% margin to be within the absolute maximum storage range of the microcontroller 14.

The microcontroller sleep mode is an ultra-low low power consumption state that helps to conserve power. The sleep mode is operated by charging a capacitor 82 from an output port 83 of the microcontroller 14, and then using that same port as an input in sleep mode to monitor the voltage across the capacitor 82 as it decays. At a certain voltage the microcontroller 14 is automatically awakened and operates under software control before recharging the capacitor 82 and going back to sleep. By placing a MOSFET transistor 84 across the capacitor 82 it can be forcefully discharged by the operation of any switch 61 to 65 via diode 85 or any infra-red pulse via diode 81 or a clap signal via diode 71 to wakeup the microcontroller 14.

The overall power consumption of the power supply control device 1 is further minimised by means of three inhibit/enable modes provided by the microcontroller 14.

The power sensing circuit inhibit output 91, provided to both the power sensing circuit 10 and the op-amp 20, is used to minimise the power usage by these components, since it takes power to measure power. The power sensing circuit 10 is only activated either by a user pressing and releasing the Learn Power button 67 or by the microcontroller 14 waking from sleep mode when in ON mode with a stored power threshold already set.

An infra-red inhibit output 92 is used to disable the reception of infra-red codes whilst in ON mode. The user can also toggle ON or OFF the Infra-Red receiver 80 in normal standby operation by pressing and holding the Learn Infra-Red button 65 for about 10 seconds and then waiting for the LEDs 75, 76 to blink before releasing the button. Disabling the Infra-Red receiver 80 in Standby mode also reduces the standby power.

A clap inhibit output 93 is used to disable the clap monostable output during ON mode. The user can also toggle ON or OFF the clap sensor circuit 70 in normal standby operation by pressing and holding the Cancel Infra-Red button 64 for about 10 seconds and waiting for the LEDs 75, 76 to blink before releasing the button.

The set/reset relay 12 is a magnetic latching relay having two coils 94, 95 and is also a low power device, as this only requires power to change status. The relay consumes approximately 600 mW for 0.1 seconds when this is required to operate the relay coils 94, 95. In this embodiment of the invention the coil power is derived using a bridge rectifier 96 from the mains supply under microcontroller control 17 via an optical switch 97. If the mains supply to the power supply control device 1 is interrupted for any reason, by a power cut for instance, when the power is restored the relay 12 is automatically switched into standby mode. Because a set/reset relay 12 has no return spring and the switching action is helped by magnetic attraction within the relay, which reduces contact bounce, both the contact resistance and the contact wear are extremely low. The absence of a return spring also improves the durability of the relay 12.

As mentioned above, prior to use of the power supply control device 1, the analogue circuitry up to the op-amp output monitor 22 for the microcontroller 14 needs to be calibrated. The calibration is done in two stages. First, with no load apparatus connected (load power 0 Watts), a 1 kΩ potentiometer P1 23 labelled P1, that has a centre tap 26 connected to the power sense circuit input terminal 15, is adjusted to give zero volts at the output 22 to the op-amp circuit 20. This adjustment serves to balance any slight variation in the pair of npn Q1A, Q1B 42, 42' and pnp 43, 43' Q2A, Q2B transistors and any input offset voltage variation in Q3A, Q3B 27, 27' transistors and op-amps OA3, OA4 33,35

In the second of calibration an accurate non-reactive 5OW load apparatus is connected as the load 6. The first op-amp 33 of the op-amp circuit 20 receives at a positive input the voltage signal 47' generated by the current through the emitter follower transistor Q3B 27' that has the minus input 18. The second op-amp 35 receives at a positive input the voltage signal 47 generated by the current through the other emitter follower transistor Q3A 27 that has the plus input 19. The second adjustment serves to set the amplification gain of the dual op-amp stages OA3 and

OA4 by means of variable resistor VR1 37 such that the dc output voltage at 22 of the op-amp circuit 20 after digitisation by the 10 bit analog-to-digital conversion in the microcontroller 14 is equivalent to 200 steps out of an available 1024 steps. For comparison, an adjustment of 4 steps is equivalent to a 1W adjustment in the measured real power drawn by the load 6. After the second adjustment with the standard load the measured drawn power will be 5OW.

It would also be possible to use inbuilt software in the microcontroller 14 for example accessed by the infra-red receiver 80 using a special infra-red handset to access special routines in the microcontroller. This can greatly simplify the calibration procedure. The calibration measurements would then be made, in two stages, inside the microcontroller while the potentiometer P1 23 and variable resistor VR1 37 are adjusted in the manner described above by looking at the activation of the two LEDs 75, 76. These LEDs would then be controlled by the microcontroller 14 to blink rapidly or in a set pattern until the two adjustment controls are correctly set.

In summary, the fuse 13 is used as a current sense resistor to convert the apparatus load current into a voltage signal. The voltage signal is then input to long-tailed pairs (LTPs) formed by the paired npn and pnp matched transistor pairs Q1A, Q1B, 42, 42' and Q2A, Q2B, 43, 43'. The power sense circuit 10 uses two individually matched long tailed pairs to amplify the input voltage signal on both the negative and positive parts of the mains sinewave. Because the LTPs power supply is the varying mains voltage only the in-phase element of input voltage signal is amplified. The in-phase element of the input voltage signal is the fundamental frequency voltage which is effectively the fundamental frequency current flowing through the consumer apparatus load 6. At each instant in-phase current is multiplied by the mains voltage to give instantaneous watts.

In this manner the collector differential output 46, 46' is related to Watts rather than VoltAmps. The differential DC output is approximately 1 mV/Watt.

The common mode differential output voltages 18, 19 have an excursion that is both above and below the reference point 24. The negative part of the voltage cannot be directly fed to the Instrumentation amplifier OA3, OA4 33, 35 without causing distortion so they are first passed through the matched pair of pnp transistors Q3A, Q3B 27, 27' connected as emitter followers (therefore having no voltage gain). This DC level shifts the power sense circuit output voltages 18, 19 fully into the positive domain. The output 47, 47' from the emitter followers is then fed to the instrumentation amplifier OA3 and OA4 which performs the differential to single ended conversion.

The skilled person will appreciate that a number of modification to the arrangement describe above without departing from the scope of the invention as claimed. For example it would be possible to modify the power sense circuit described above to use just one pnp transistor pair (or alternatively one npn transistor pair) instead of two to achieve a similar result but the resultant conversion of power consumed into a voltage would only involve measurements on one half cycle of the mains supply, which would reduce the accuracy and/or speed of the measurement process.

Although not illustrated, it is also possible to replace the analogue power sensing circuit 10 with a digital integrated circuit. This would still use the fuse as the sensing resistor but would operate in the digital domain by digitising both the mains voltage and the sense resistor voltage, which is proportional to the mains current. This would use low pass digital filtering of the sense fuse/resistor voltage to extract the voltage at the mains fundamental frequency and then multiply the resultant output with the digitised mains voltage to give an output that can be equated to a true power measurement. The resultant output would still need to be compensated for the positive temperature coefficient of the fuse being used as the sense resistor; this could be achieved inside the integrated circuit with an internal temperature sensor or externally in the microcontroller in a similar fashion to the analogue version.

The invention therefore provides a convenient and efficient power supply control device operable over a wide range of power throughputs (e.g. up to 13A at 230 VAC), that automatically disconnects the power supply to electrical consumer apparatus when the apparatus is in a standby mode. The invention provides an energy saving device with the means to sense and store a desired standby power threshold under the user's control, to then disconnect the apparatus from the mains supply and to display to the user the power in Watts that have been saved. The measurement technique employed measures the true Watts and is unaffected by apparatus with poor power factor in standby mode. The invention also allows the full available current output from a mains supply socket with complete safety, owing to the integral fuse, and with minimal power loss.

CLAIMS

1. A power supply control device for controlling electrical power drawn from an alternating current (AC) mains supply, comprising mains input terminals for connection to a mains supply, mains output terminals for connection to an electrical consumer apparatus, a power line extending between terminals of the mains input and mains output, a power sense circuit for sensing a measure of the power drawn by said apparatus from the mains output, a relay in series with the power line, and a controller arranged to open the relay to disconnect the circuit through the power line when said measure of power is below a threshold, wherein:

- the device comprises an over-current protection fuse in series with the power line; and

- the power sense circuit is arranged to utilise the current protection fuse as a current sense resistor to generate an output signal to the controller representative of the real power drawn by the consumer apparatus.

2. A device as claimed in Claim 1, in which the power sense circuit is arranged to generate said output signal using an AC voltage representative of the electrical alternating current through the fuse corrected according to the power factor of said drawn alternating current with respect to the AC mains supply voltage.

3. A device as claimed in Claim 1 or Claim 2, in which the power sense circuit is arranged to take a measure of the current through the fuse and a voltage across the alternating current mains supply in order to generate an output signal representative of the real power drawn by the consumer apparatus.

4. A device as claimed in Claim 3, in which said output signal is generated by multiplying the AC supply voltage with an in-phase part of the current through the fuse to generate said measure of the real power drawn by said apparatus.

5. A device as claimed in any preceding claim, in which the microcontroller is

operable to determine and store said threshold value in response to a command from a user input and dependent on said measure of the power drawn by said apparatus.

6. A device as claimed in Claim 5, in which said threshold is calculated from said measure of the power drawn by said apparatus plus an additional margin of power.

7. A device as claimed in any preceding claim, in which the power sense circuit is arranged to generate a differential signal representative of the electrical power drawn by the consumer apparatus, said differential signal being level shifted in voltage entirely above or below a mains reference voltage.

8. A device as claimed in any preceding claim, in which the power sense circuit is an analogue circuit.

9. A device as claimed in Claim 8, in which the fuse and power sense circuit have opposite temperature coefficients so that, in combination, with a constant load connected, they generate a temperature compensated output over a temperature range of at least 10-40 °C.

10. A device as claimed in any preceding claim, in which the power sense circuit is a digital circuit.

11. A device as claimed in Claim 10, in which the digital circuit includes an internal temperature sensor an output from which is used by the digital circuit to generate a temperature compensated output over a temperature range of at least 10-40 °C.

12. A device as claimed in any preceding claim, comprising additionally a temperature sensor, the microcontroller being arrange to receive an output from the temperature sensor and to temperature compensate the signal from the power

sense circuit over a temperature range of at least 10-40 °C.

13. A device as claimed in any preceding claim, in which the controller is arranged to periodically enable operation of the power sense circuit.

14. A device as claimed in Claim 13 in which the power sense circuit is enabled less than 10% of the time.

15. A device as claimed in any preceding claim, comprising additionally a zero crossing circuit for determining when the mains supply crosses through zero volts, the operation of the relay being synchronised by the microcontroller with respect to said zero crossing in order to control arcing on contacts within the relay.

16. A method of controlling electrical power drawn by an electrical consumer apparatus from an alternating current (AC) mains supply, using a power supply control device, said device comprising mains input terminals, mains output terminals, a power line extending between said terminals of the mains input and mains output, a power sense circuit, an over-current protection fuse in series with the power line, a relay in series with the power line, and a controller, wherein the method comprises the steps of:

- connecting the mains input terminals to a mains supply;
- connecting the mains output terminals to an electrical consumer apparatus;
- using the current protection fuse as a current sense resistor to generate a signal representative of the electrical current through the fuse when electrical power is drawn by said apparatus;
- providing said signal to the power sense circuit and using the power sense to generate an output signal to the controller representative of the real power drawn by the consumer apparatus; and
- using the controller to open the relay to disconnect the circuit through the power line when said measure of real power is below a threshold.

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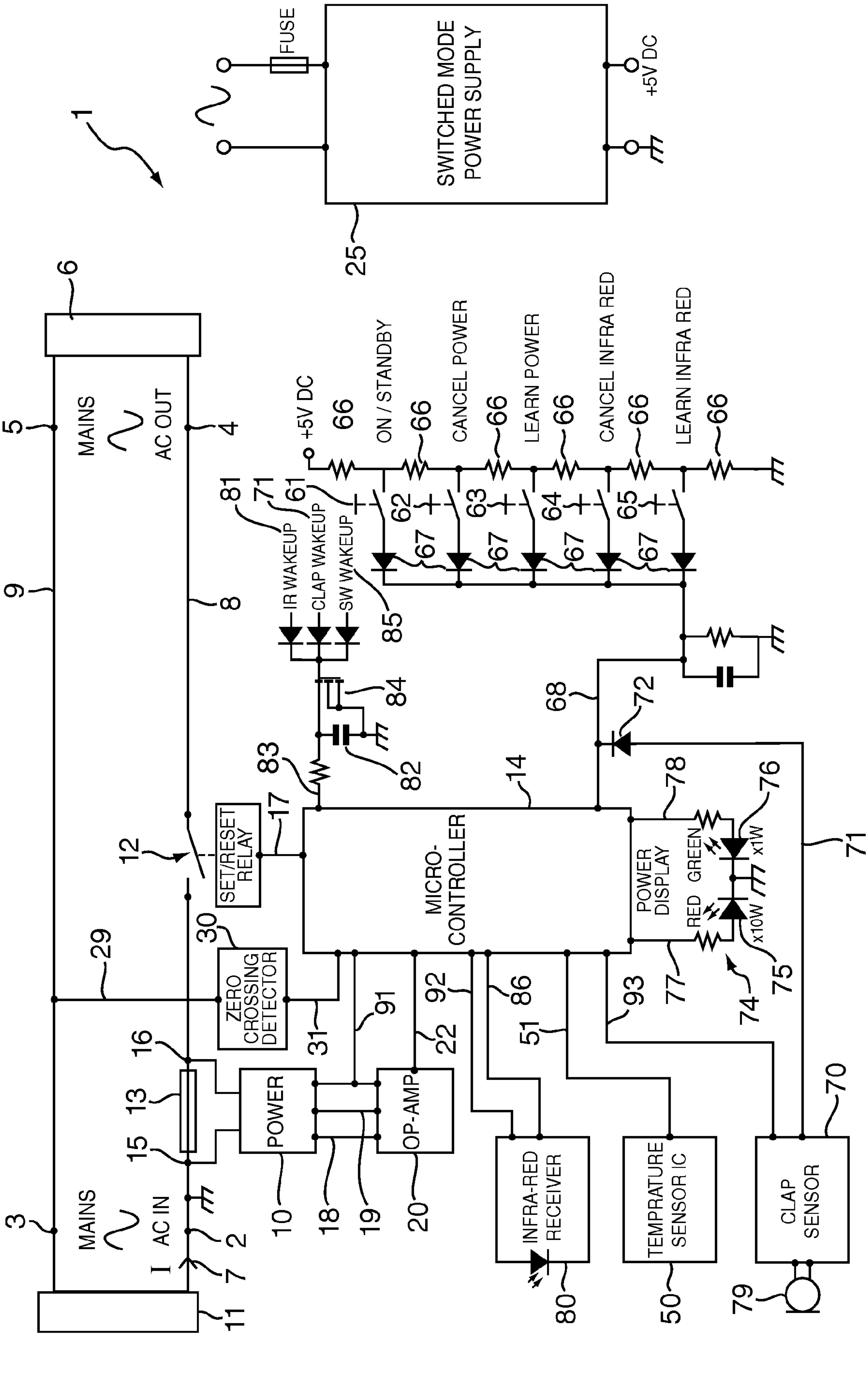
FUSE
SWITCHED MODE POWER SUPPLY
+5V DC
MAINS
AC OUT
AC IN
+5V DC
ON / STANDBY
CANCEL POWER
LEARN POWER
CANCEL INFRA RED
LEARN INFRA RED
IR WAKEUP
CLAP WAKEUP
SW WAKEUP
SET/RESET RELAY
MICRO-CONTROLLER
ZERO CROSSING DETECTOR
POWER
OP-AMP
POWER DISPLAY
RED
GREEN
x10W
x1W
INFRA-RED RECEIVER
TEMPRATURE SENSOR IC
CLAP SENSOR
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FIG. 1

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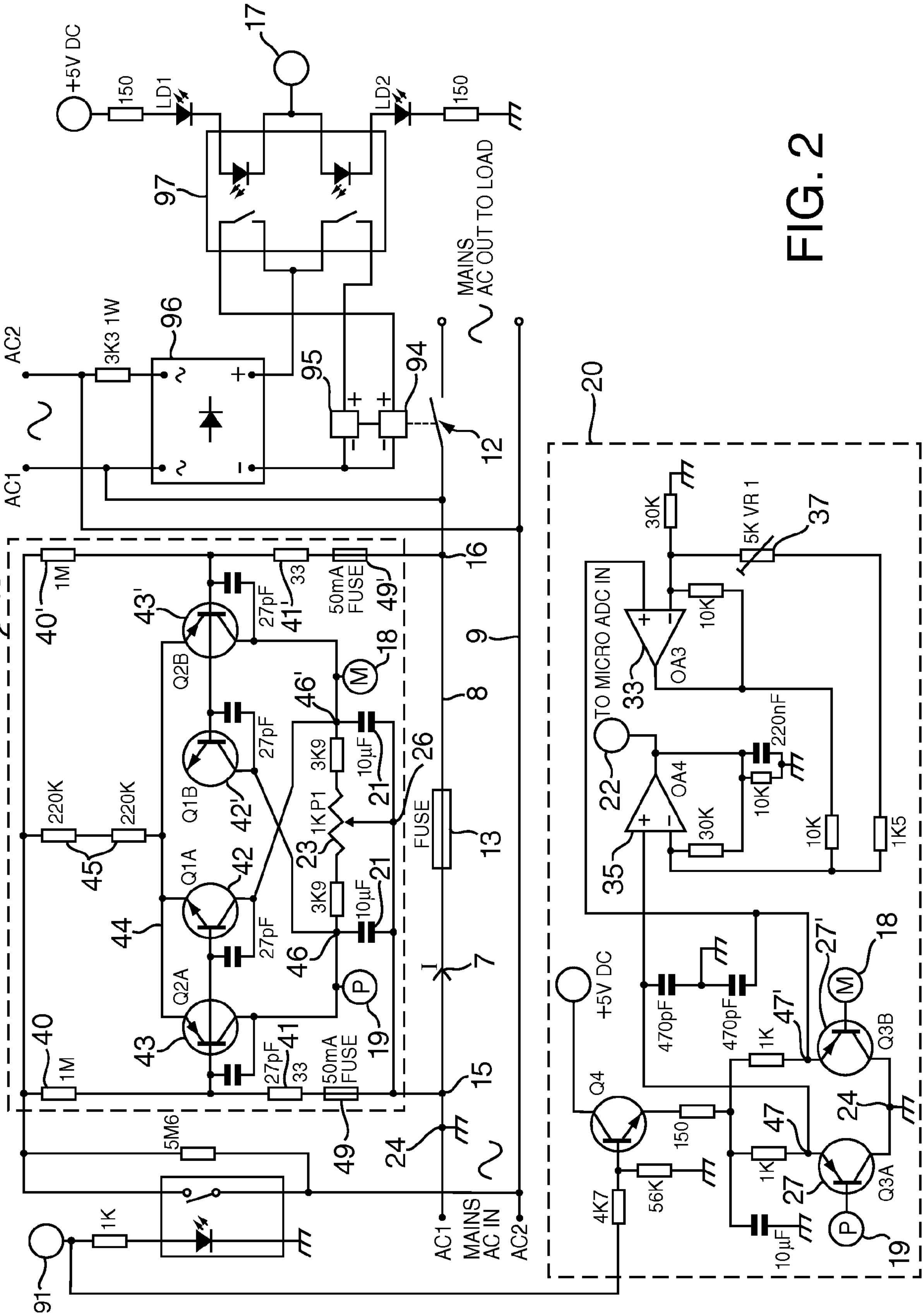

+5V DC
150
LD1
17
LD2
97
AC2
3K3 1W
96
AC1
95
94
12
MAINS
AC OUT TO LOAD
10
1M
40'
220K
45
40
33
41'
50mA
FUSE
49'
16
43'
Q2B
Q1B
27pF
42'
Q1A
42
44
Q2A
43
41
49
15
24
46'
46
3K9
10µF
1K P1
23
21
26
M
18
P
19
FUSE
13
7
8
9
5M6
1K
91
MAINS
AC IN
20
TO MICRO ADC IN
OA3
30K
5K VR 1
37
10K
22
220nF
OA4
1K5
35
470pF
Q4
Q3B
Q3A
47'
27'
47
27
56K
4K7

FIG. 2