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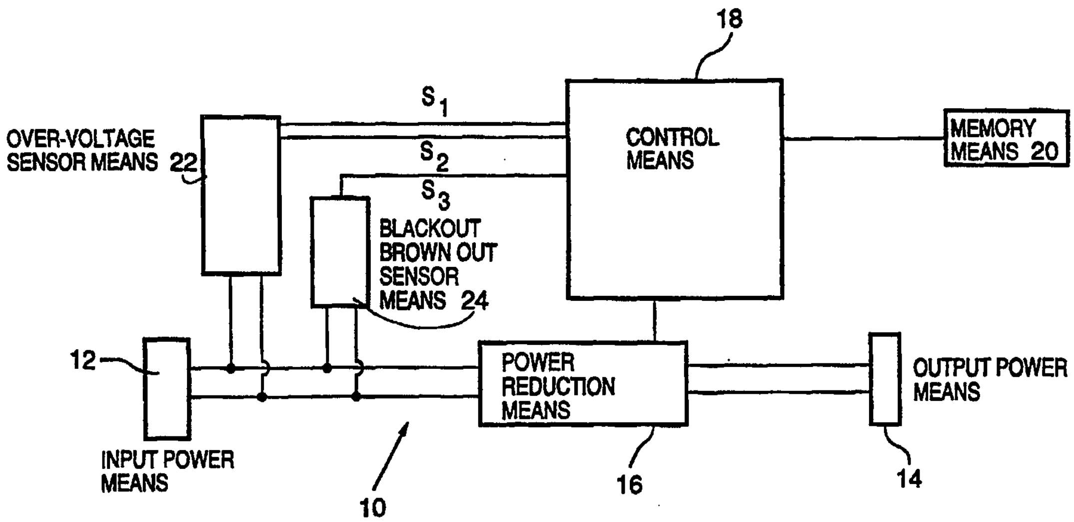

(57) Abstract

In a method for remotely controlling the power consumption of an electrical load a switching device for controlling the supply of power to the load is responsive to preselected, deliberate signal deviations such as brownout intervals or overvoltage spikes and reduces or increases output power to the load accordingly. In a preferred embodiment a single signal deviation of a specified length or a sequence of signal deviations occurring over a specified time, or a combination of these two parameters, are used to remotely address the switching device. In this fashion, the power supplied to the load can be remotely controlled by a power utility over existing power supply mains.

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METHOD AND APPARATUS FOR REMOTE CONTROL OF AN ELECTRICAL LOAD

Field of Invention

This invention relates to a method and system which controls electrical loads. In particular, this invention relates to a method and system whereby a utility can remotely control the power supplied to electrical loads in the premises of the utility's subscribers, by communication through the power supply mains.

Background of the Invention

Electrical power utilities typically face regular cycles of power usage requirements. Peak usage periods occur generally during business hours, with the highest usage in the morning and evening, while the lowest power demand occurs late at night. Meeting energy demands during peak periods, and disposing of excess electrical energy during low-demand periods, has long been a problem facing electrical utilities.

Many measures have been undertaken in recent years with a view to solving this problem, from educating consumers to the development and implementation of electrical or thermal storage devices which store energy acquired during low-demand periods and release it during peak periods. However, the general trends and cycles associated with electrical power usage cannot precisely predict usage requirements during any given period, particularly where climate is a relevant factor and heating and air conditioning requirements can vary widely depending upon the weather. Moreover, generating capacity can be affected by unpredictable factors, including equipment failure, which can reduce the amount of power available during peak periods significantly below the anticipated supply.

It is therefore advantageous to an electrical utility to be able to communicate with electrical loads to control power usage at their subscriber's premises in specific geographic regions: reducing power available to one region in favour of a more urgent need in another; sharing temporary power reductions between various regions; and initiating energy storage operations when demand for power is low, during so-called "free-wheeling" conditions when power consumption drops below the power capable of being produced by the utility's generators.

It is also desirable for a utility to be able to reduce the power consumption in any particular subscriber's premises to match the available power supply, by deactivating or reducing power to certain loads in the premises (such as a water heater, lighting etc.) while continuing to deliver power to higher priority loads (such as electric heating). In order to effect this degree of control, it is necessary for the utility to communicate with the premises, to monitor the power supply available to the premises and to instruct power controller devices to shift or shed specific loads upon demand.

Systems are available which enable a utility to communicate with subscribers' premises over a telephone line, such as that described in U.S. Patent No. 5,168,170 issued December 1, 1992. However, because it is far too costly to expect each subscriber to maintain a dedicated telephone line for this purpose, in practice each subscriber's existing telephone line is used for communication between the utility and the power controller at the subscriber's premises. If desired a second telephone number can be assigned to the telephone line, and a telephone signal routing device such as that described in U.S. Patent No. 4,998,273 can be used to automatically route calls to the power controller when the number assigned to it is dialled.

This is satisfactory for the power supply monitoring function, which is not highly time-dependent. If the telephone line is in use by the subscriber when the utility tries to dial the subscriber power controller for information on power usage at the premises, the utility can simply redial at desired intervals until the telephone line is free. However, this is not satisfactory for the control function, since load shedding or power modulation to specific loads may be required by the utility immediately in order to avoid a complete brownout in a particular region. For purposes of reacting quickly to high demand conditions, it is necessary that the utility be able to address the power controllers at a subscriber's premises immediately, and those at a number of subscribers' premises simultaneously. Without a telephone line dedicated for this purpose, this presents a considerable problem to the design of an integrated power control system within the control of the utility.

Since by definition all subscribers are already connected to the utility through existing power mains, one alternative is to communicate with the subscribers' power controllers, at least for the control function, over the power mains. However, any such system must be able to send signals to the subscribers' power controllers without disrupting the mains power signal and thereby inadvertently affecting the operation of electrical loads in the system. Modes of communication over the existing power mains do exist, such as "spread spectrum" communication which uses frequencies that do not interfere with the power supply, however these types of signals suffer from severe attenuation over the distribution network. Present convention calls for a repeater for approximately every 1.5 km of wire, to avoid complete attenuation of the spread spectrum signal before it reaches the subscriber's premises. In densely populated regions such as metropolitan areas, this is extremely costly and maintenance-intensive.

Summary of the Invention

The present invention overcomes these problems by providing a method and system for communicating with power controllers controlling one or more electrical loads at one or more subscriber's premises, through existing power mains using the actual power supply to address and instruct the controllers. The system comprises a power modulator device, which may reduce or increase power to the load, or simply deactivate and reactivate the load, responsive to signal deviations such as brownout intervals or overvoltage spikes in the supply signal that are deliberately created by the utility. Such brownouts or spikes can be selectively delivered by the utility on demand to one or more specific geographic regions, for example a single building, a city block or a larger area, and because each brownout interval overvoltage spike has a duration in the order of a tens of milliseconds or less, the deviation from the nominal signal voltage does not adversely affect the normal operation of ordinary electrical loads.

Thus, during peak demand periods the utility can control power consumption for selected intervals and in selected regions, communicating with electrical loads through the existing power mains. The utility can reduce power demands by reducing the power delivered to certain loads or deactivating the loads completely when required. Similarly, the utility can activate or increase power to energy storage devices, such as water heaters, during periods of reduced power demand, to obtain a better distribution of power consumption over the course of a daily power consumption cycle.

Moreover, the controller devices at each user's premises can be programmed to modulate or switch power to specific loads in priority. The controller may be programmed to recognize signal deviations representing different levels of priority, each actuated by a different brownout signal or sequence of brownout signals. For example, a three priority level embodiment might define a first level in which the controller deactivates or reduces power to only non-essential loads eg. certain lights, water heater, clothes dryer; a second level in which the controller deactivates or reduces power to some essential loads eg. all lights, oven/stove; and a third level in which the controller deactivates or reduces power to all but the most essential loads eg. electric heating. Each priority level would be implemented automatically when the controller detects the preset signal deviation or sequence of signal deviations on the mains power supply assigned to that particular priority level.

By communicating over the power mains in this fashion, there is no attenuation of the activating signal or sequence of signals. The signal or sequence of signals is generated by the utility at the autotransformer closest to the area to be affected, and the relationship between the voltage reduction or increase at the autotransformer retains its integrity through to the subscribers' premises, resulting in a voltage reduction or increase of virtually identical proportion at the subscribers' power mains, regardless of the distance from the autotransformer. This is accomplished in the method and system of the present invention without the need for specialized signal generating, boosting or repeating equipment.

The power control method and system of the present invention thus enables a utility to remotely control load reductions and increases to varying degrees and with various levels of priority, for a single premises or for any particular group of premises, by communicating directly through the power distribution network. This is accomplished without requiring access through a subscriber telephone line, and yet without interfering with the operation of loads connected to the distribution network.

The present invention thus provides a method of altering the magnitude of electrical power consumption by an electrical load supplied by a supply signal carried by power supply mains, using power modulating means including input power means, output power means, sensing means for detecting a signal deviation in the supply signal received by the input power means, control means including a memory for recording a preselected signal deviation or sequence of signal deviations and comparing a signal deviation or sequence of signal deviations detected by the sensing means with the preselected signal deviation or sequence of signal deviations programmed into the memory, and a switch for altering the signal supplied to the load by the output power means in response to a signal deviation or sequence of signal deviations corresponding to the signal deviation or sequence of signal deviations programmed into the memory, comprising the steps of interposing the switching means between the power supply means and the load, and transmitting within the supply signal a predetermined signal deviation or sequence of signal deviations over the power supply mains to the switching means to alter the power consumption of the load.

The present invention further provides a method of altering the magnitude of electrical power consumption by an electrical load supplied by a supply signal carried by power supply mains, comprising the steps of recording in a memory a preselected signal deviation or sequence of signal deviations, monitoring the supply signal to detect a signal deviation or sequence of signal deviations, comparing the monitored signal deviation or sequence of signal deviations with the recorded signal deviation or sequence of signal deviations, and where a signal deviation or sequence of signal deviations in the supply signal matches the recorded signal deviation or sequence of signal deviations, activating a switch to alter the signal supplied to the load in a predetermined fashion and thus reduce or increase the power consumption of the load.

The present invention further provides a method of communication over an electrical distribution network between an electrical power utility and a device located at a subscriber's premises adapted to detect fluctuations in a voltage across power supply conductors at the premises, comprising creating a signal or a sequence of signals to be delivered over the network to the subscriber's premises, the signal or sequence of signals being composed of one or more momentary fluctuations in the voltage of the power supply of a predetermined magnitude or a predetermined duration or both.

The present invention further provides a system for enabling an electrical utility to control a load at a subscriber's premises, the utility delivering electricity to the premises through a distribution network provided with means for momentarily increasing or reducing a voltage at predetermined points within the network, the system comprising a power controller at the subscriber's premises connected to the distribution network through power supply conductors, having input power means connected to the power supply conductors, output power means connected to the load, voltage detection means for monitoring a voltage of the power supply, power reduction means for reducing power to the power output means in response to deliberate fluctuations in a voltage across the power supply conductors created by the utility, and means for decoding the fluctuations in the voltage across the power supply conductors and activating the power reduction means in response thereto.

Brief Description of the Drawings

In drawings which illustrate by way of example only a preferred embodiment of the invention,

Figure 1 is a block diagram of one embodiment of the power modulator of the invention;

Figure 2 is a diagrammatic view of an embodiment of the power modulator of the invention controlling a water heater;

Figure 3 is a schematic diagram of the power supply and signal deviation sensing means circuitry for the power modulator of Figure 1;

Figure 4 is a schematic diagram of the load switching circuitry for the power modulator of Figure 1;

Figure 5 is a schematic diagram of the microprocessor for the power modulator of Figure 1; and

Figure 6 is a graph illustrating a typical power supply profile for a metropolitan area over a weekday period of 24 hours.

Detailed Description of the Invention

Figure 6 graphically illustrates an example of a typical power supply profile for a 110/220V power main over a 24 hour period during an ordinary week in a metropolitan area. The mean supply voltage ranges from about 6% below nominal voltage during peak periods such as during business hours, to about 6% above nominal voltage during low demand periods such as late night.

A "brownout" condition is generally considered to exist whenever the supply voltage drops 6% or more below the nominal voltage, and an overvoltage is generally considered to occur whenever the supply voltage rises to 6% or more above the nominal voltage. The profile of Figure 6 illustrates the many naturally occurring brownout and overvoltage intervals over the course of a typical workday.

However, signal deviations such as brownout and overvoltage conditions can also be created deliberately. The invention takes advantage of this capability, using deliberate brownout intervals and overvoltage spikes created by a power utility on demand to communicate with a power modulator 10 delivering electrical power to one or more loads at the subscriber's premises.

The power modulator 10 is used to control the delivery of power to any electrical device at the subscriber's premises, especially electrical devices which are capable of storing thermal energy. Some devices store thermal energy in and of themselves, for example a water heater, a refrigerator, a freezer or a thermal storage system such as a brick heater or the Air Conditioning System With Thermal Storage Cycle Control described in U.S. Patent No. 5,165,250. Other devices store thermal energy in their surrounding environment, as in the case of an ordinary baseboard or room heater, or a furnace or the like, which can superheat the environment during periods of low power demand and thus reduce the power needed to operate the device during peak periods because the temperature of the environment can be allowed to fall over time while still remaining within tolerable levels. Similarly, an ordinary room or central air conditioner can supercool its environment during low demand periods, and the temperature of the environment can then be allowed to rise during peak periods while still remaining within a reasonable comfort range.

By interposing a power modulator 10, described below, between the mains power supply at the subscriber's premises and the load (ie. the electrical device), all connected electrical devices can be instantly and effectively controlled by the power utility on demand, through existing power mains. This method can significantly reduce power demands during peak periods, particularly in densely populated metropolitan areas.

Electrical power is delivered to each subscriber through a regional autotransformer (often referred to as an electrical "substation"), and then through a local autotransformer, each being a point in the distribution network at which the voltage is stepped down for further distribution and ultimately subscriber use. The utility has available to it means for adjusting the output voltage from each autotransformer, and can thus create momentary signal deviations that are transmitted to the subscribers' premises.

The affected geographic region will be the region serviced by the autotransformer at which the signal deviation is initiated, and the utility can thus selectively control the premises to which these signal deviations are transmitted by creating the signal deviation in the output of the autotransformer closest to the region desired to be affected, be it a single building, a city block or an entire municipality.

The signal deviation created at the autotransformer output retains its fundamental characteristics, for example its duration and the proportion of reduction or increase that it represents relative to the autotransformer output voltage, throughout the distribution network to the subscribers' premises. For example, a 45 ms voltage reduction of 10% at the autotransformer output will create, almost exactly, a voltage reduction of 10% having a 45 ms duration at the subscribers' power mains. Thus, regardless of the output voltage at the source of the signal deviation, the signal deviation will retain its integrity when sensed at the subscribers' premises. As such, different types of signal deviations created at an autotransformer are delivered intact to the premises of all subscribers serviced by that autotransformer.

A preferred embodiment of the invention, comprising a power modulator 10, is illustrated in Figures 1 through 5. The power modulator 10 comprises power input means 12, power output means 14, power reduction means 16 and microprocessor 18.

The power input means 12, illustrated schematically in Figure 3, is capable of receiving input power from an alternating current power source (not shown). This could be any alternating current power source, including a standard wall plug as found in any residential building and which derives power from the local electrical utility.

The power output means 14 is capable of providing output power from the power modulator 10 to an electrical load such as a water heater, baseboard heater, air conditioner or the like.

As shown in Figure 1, in a preferred embodiment the power modulator 10 further comprises voltage reduction means 16 electrically associated with both the power input means 12 and the power output means 14. The power reduction means 16 is able to reduce the output power delivered to the load by the output power means 14, by discrete intervals, ranging from 0% (complete deactivation) to 100% of the available power supply.

Figure 3 illustrates the power input means 12, comprising a power supply circuit including a bridge rectifier 50. The microprocessor 18 is stimulated to energize the power output means 14 by a zero crossing firing circuit 52, also shown in Figure 3, which serves to fire the TRIACs at the zero crossing point of the input signal and thus eliminates the effects of radio interference and surge currents, eliminates frequency dependence because the firing circuit resets with each cycle of the input signal, and controls power reduction during "phase firing" by ensuring that the ac signal is consistently delivered to the load in complete half-cycle increments. The zero crossing firing circuit 52 also initiates timing for measurement of the supply voltage, as described below.

The power reduction means 16 modulates the power to the load device through a combination of conventional means such as "cycle stealing", which entails periodically eliminating half cycles or full cycles from the alternating current being supplied to the load, and "phase firing", which fires the TRIACs of the output power means 14 at a preselected phase of each ac cycle (preferably the zero crossing point), withholding a portion of each cycle from the load. In this way, both the power consumed by the load and the power supplied by the alternating current source are reduced, thereby resulting in a net power decrease and attendant reduction in power consumption.

Figure 3 also illustrates means for detecting deviations in the supply voltage, comprising a brownout detection circuit 24, which detects changes in the supply voltage and signals the microprocessor 18 when the voltage drops below a preset level, preferably 6% of the nominal supply voltage; and an overvoltage detection circuit 22 which signals the microprocessor 18 when the voltage rises above a preset limit, again preferably 6% of the nominal supply voltage.

The brownout and blackout sensor means 24 could be combined as one sensor means, as shown in Figure 1, or could be two separate sensors. The brownout and blackout sensor means 24 includes a supply voltage detection circuit 15, which as noted above continuously senses the power being delivered to the input power means 12 from the alternating power source. The brownout and blackout sensor means 24 detects the commencement of a brownout or blackout as a voltage drop to the preset minimum, which may be 10% of nominal supply voltage, and turns the load off until the voltage detection circuit 15 senses that the brownout or blackout has ended. This assists utilities by decreasing the general power demand during brownouts.

When the voltage detection circuit 15 senses a resumption of supply power above the preset minimum after a brownout or blackout, the brownout and blackout sensor means 24 sands a signal S3 to the microcontrollor 18. In response to the signal S3, the microcontrollor 18 will deliver power to a resistive load in gradually increasing increments (of 10% in the preferred embodiment) rather than immediately increasing the output power to the preset output level, a so-called "soft-start". This helps to prevent "fly-back", which is a condition that occurs after a blackout or brownout when the power supply resumes and electrical devices switched on at the time of the blackout or brownout all begin to draw power simultaneously, creating a power surge which overloads the system and can cause another brownout or blackout.

It is important to measure the supply voltage accurately, so that the power modulator 10 does not misread detected signal deviations in the power supply. In a preferred embodiment the power modulator 10 is thus provided with a reference voltage, preferably 2V dc.
This voltage remains constant regardless of the temperature of the power modulator 10 and fluctuations in the supply voltage, and provides a reference against which the microcontroller 18 can determine the magnitude of detected signal deviations within acceptable limits. To further ensure the accuracy of the measurement of supply voltage, the microcontroller 18 is timed to sample the supply signal at the peak of the ac waveforms, which occurs 4.167 ms

after each zero crossing point.

Figure 4 illustrates the output power means 14 for the power modulator 10 illustrated in Figure 1, comprising in the example shown switching circuits 14a, 14b for each of the upper and lower resistance heating elements 3, 4 of a water heater 2 as illustrated in Figure 2 for purposes of example. A low current (100 mA) opto-isolator 56 signalled by the microprocessor 18 switches a heavy duty TRIAC 58 which controls the output power to the load 2. A single switching circuit will suffice for electrical devices having a single load, and multiple switching circuits are required for controlling multiple loads, each load being connected to its own switching circuit.

Figure 5 illustrates the control means comprising a microprocessor 18 and E2PROM memory 20. The memory is programmed with an upper voltage limit representing an overvoltage condition, and a lower voltage limit representing a brownout condition. If the voltage of the supply signal reaches or exceeds either of these limits, the main task of the microprocessor 18 is engaged. This task monitors information from the voltage deviation detection means and compares this to preselected signal fluctuation parameters programmed into the memory 20.

For example, if a power reduction parameter programmed into the memory 20 is a sequence of two brownout intervals of 60 milliseconds each occurring over a period of 180 milliseconds, the microprocessor 18 monitoring information from the voltage deviation detection means 24 and comparing this information against the preselected power reduction parameter, will signal the output power means 14 to reduce power to the load by a programmed amount.

The magnitude of modulation effected by the voltage reduction means 16 can be variable, with different magnitudes corresponding to different signal deviations. For example, the microcontroller might be programmed to effect a power reduction of 100-, when the brownout detection circuit 24 senses two sequential brownout intervals of 60ms each in a period of 180ms; a reduction of 25% upon detection of two sequential brownout intervals of 50ms duration in the same period; and complete deactivation of the load upon detection of two brownout intervals of 40ms duration in the same period.

Thus, in a preferred embodiment the power modulator 10 is programmed to be responsive to one or more specific types of signal deviations. In one case, the power modulator 10 is responsive to a signal deviation of a specific predetermined duration. In the second case, the power modulator 10 is responsive to a sequence of signal deviations occurring over a specific predetermined period of time. Both of these alternatives are designed to avoid unintended switching of the load in response to a naturally occurring signal deviation.

For example, the power modulator 10 can be programmed to reduce power to the load by 10% if it detects a brownout of exactly 11 ms in duration, or if it detects a series of three discrete brownout intervals over 100 ms. The latter method is less likely to result in accidental power reduction, since the chances of three discrete brownout intervals occurring naturally over 100 ms are extremely small; nevertheless, the first method will still work most of the time because of the low probability of a naturally occurring brownout of exactly the correct duration.

To decrease the possibilities for accidental switching even further, these two parameters can be combined such that the power modulator 10 would reduce power in response to, for example, three discrete brownout intervals of exactly 11 ms each over a period of 100 ms. The probability of this occurring naturally is so low as to render accidental switching virtually impossible. Moreover, the brownout intervals are so short that they will not affect the operation of the load or any other electrical device connected to the same power mains. An example of a power supply profile incorporating this sequence of signal deviations is identified in Figure 6.

The power modulator 10 can likewise be programmed to increase power to the load upon detecting an overvoltage spike (or brownout interval) of a specific duration, for example 10ms, or upon detecting a specified number of discrete signal deviations over a specific period, for example three over a period of 80 ms. Again, for purposes of further reducing the possibility of accidental switching the power modulator 10 may be programmed to respond only to a combination of these two parameters for example, a sequence of two overvoltage spikes each of exactly 12 ms in duration over a period of 100 ms. An example of a power supply profile incorporating this sequence of signal deviations is identified in Figure 6.

The possible combinations are virtually limitless, the only limitations being that the duration of the signal deviation must be sufficiently short that it does not interfere with the normal operation of electrical devices which may be supplied by the affected power mains, and that the duration of a signal deviation or the number of times that it occurs over the selected period must be unlikely to occur naturally, which preferably means that there is less than a 0.0596 probability that such a signal deviation or sequence of signal deviations will occur naturally. Since in a preferred embodiment the utility will monitor the power supply profile of regions using the method as described below, the utility can take corrective action if a signal deviation to which the power modulator 10 is programmed to respond occurs naturally.

The power modulator 10 can be programmed to respond to different signal deviations or sequences of signal deviations in different ways. For example, a series of three brownout intervals over 100 ms could reduce power to the load by some specified increment, a series of four brownout intervals over 100 ms could reduce power by a different increment, and a series of five brownout intervals over the same period could shut off power completely. Alternatively, the differential switching responses can be actuated by the same number of brownout intervals where the intervals are of different lengths, or occur over different periods of time. Again, the possible combinations and permutations are virtually endless.

The memory 20 may be programmed with any number of power reduction parameters, each of which will either deactivate the load or reduce power by a certain amount; similarly, the memory 20 can be programmed with any number of power increase parameters, responsive to a preselected brownout interval or a series of brownout intervals in sequence, or to an overvoltage spike or series of overvoltage spikes in sequence, to reactivate the load or increase power by desired, preselected increments. (Theoretically it is also possible to use overvoltage intervals to effect power decreases, but as noted below it will generally be easier to generate brownout intervals at times when supply is low and power reductions are required.)

In a variation of the above method, a cumulative system can be employed whereby, for example, each time the overvoltage sensing means 22 detects an overvoltage spike of exactly 7 milliseconds in duration the microprocessor 18 increases output power to the load by a specified amount, for example 10%. Cumulative power reduction can similarly be effected in this manner, through deliberate brownout intervals sensed by the brownout sensing means 24. A specific signal deviation parameter, preferably an overvoltage spike, may be delivered to reset the power modulator 10 to full output power.

The method and system of the invention can also be used to modulate (or deactivate/reactivate) power to multiple loads independently of each other, in a "stepped power-down" method in which the utility establishes a load-shedding or power modulating priority based on the needs of the subscriber. Each load is provided with its own switching circuit, such as 14a and 14b shown in Figure 4, and each switching means in the output power means 14 is addressed independently by the microprocessor 18. A specific signal deviation or sequence of signal deviations is programmed into the microprocessor 18 to correspond to modulation of the power output through a specific switching circuit or circuits, corresponding to a specific load or loads. The utility can thus define groups of loads, each assigned a priority activated by the corresponding signal deviation or sequence. The example set out above describes a typical residential priority setting, having a first level in which the controller deactivates or reduces power to only non-essential loads such as certain lights, water heater, clothes dryer, refrigerator; a second level in which the controller deactivates or reduces power to some essential loads such as all lights, an oven or stove; and a third level in which the controller deactivates or reduces power to all but the most essential loads e.g. electric heating. A fourth level priority signal deviation would effect a complete deactivation of all loads in the subscriber's promises. Each priority level would be implemented automatically when the controller detects the preset signal deviation, such as a brownout interval or sequence of brownout intervals on the mains power supply assigned to that particular level.

A different assignment of priorities would be appropriate for institutional subscribers such as hotels and hospitals, commercial buildings, industrial complexes etc. In each case the memory 20 is programmed by the utility to effect a preset power modulation to a preset load or load group depending upon the signal deviation detected by the power modulator.

In a preferred embodiment the utility monitors the various power modulators in any particular region, either periodically or randomly, to asses the load usage at each subscriber's premises relative to the available power supply. Instantaneous power usage information is provided by the voltage monitoring means (i.e. the brownout detection circuit 24 and the overvoltage detection circuit 22), through the microcontroller 18. In any situation where the demand form power in the premises exceeds the readily available supply, the utility can initiate the appropriate signal deviation or sequence of signal deviations to match the load to the available power.

For example, if the line voltage detected by supply voltage detection circuit 15 drops by a predetermined amount for a predetermined time period, the power modulator 10 of the present invention can automatically decrease power applied to the load by a predetermined percentage of the decrease in available line voltage. For example, microcontroller 18 may be programmed so that a 2% drop in a nominal supply voltage over a period of 20 milliseconds (eg. 10 AC cycles at 60 (Hertz), results in a firing of the TRIAC 56 in such a fashion as to "Steal" one half cycle out of every 20 half cycles of the AC signal applied to the load. Similarly, microcontroller 18 may be programmed so that a 3% drop in nominal line voltage sensed at the power mains results in a 10% decrease in power applied to the load (i.e. 2 half cycles out of every 20 half cycles of the AC signal applied to the load). The percentage decrease in power applied to the load relative to the decrease in nominal line voltage sensed via voltage detection circuit 15 is entirely programmable. Furthermore, it is contemplated that these relationships as well as other programmable aspects of the microcontroller 18 may be programmed directly on-site, or remotely via telephone line connection, amplitude, modulation along the power mains, or other suitable means.

According to this aspect of the invention, the power applied to the load is made to follow the sensed line voltage to compensate for any situation where the demand for power in the premises exceeds the readily available supply.

Microcontrollor 18 may also be programmed to cause an increase in power applied to the load responsive to increases detected in the available line voltage, for returning system operation to normal levels when the excessive demand situation is resolved. For example, microcontrollor 18 may be programmed to begin reinserting "Stolen" half cycles of the AC signal applied to the load in response to detected percentage increases in the available line voltage, where such detected increases are sustained beyond a predetermined time period. The time period is entirely programmable so that "fly-back" conditions can be successfully avoided.

If desired, a power usage profile from the premises over any desired period can be stored in the memory 20 and accessed by the utility during a monitoring call.

The monitoring function utilizes the subscriber's existing telephone line, preferably in conjunction with a call routing device so that the user is not inconvenienced by incoming calls to the power controller. If the user's line is engaged when a monitoring call is attempted, the utility can extrapolate from previous power usage profiles for those premises, or from instantaneous power usage information obtained from neighboring premises, to determine whether corrective action in required.

In extreme or urgent situations the utility can initiate power reduction to any desired priority level, without having to first determine tho status of power usage at the premises. Also, in the case of service disruption caused by broken power lines or other equipment failure, the subscriber telephone line can be used as a backup to address the power modulator 10 for the control function, instructing the power modulator to shed certain loads or reduce output power as required to avoid "fly-back" when the power comes back on line.

The above description describes the method and system of the invention using brownout intervals (momentary voltage decreases) and overvoltage spikes (momentary voltage increases) to signal the power modulator 10. A third type of signal deviation which can be used to control power to the load is the phase angle between voltage and current. The phase angle will change naturally as other loads are turned on or off, but the phase angle can also be changed deliberately. Power increase and reduction parameters programmed into the memory 20 can be associated with specific changes in the phase angle between voltage and current, to actuate the power modulator 10 in the same manner as the brownout intervals and overvoltage spikes discussed above.

As noted above, brownout intervals are created more readily than overvoltage spikes under most conditions. Accordingly, brownout intervals can be used both to increase power to (or activate) the load and decrease power to (or deactivate) the load, while overvoltage spikes would generally be used only to increase power to (or activate) the load during free-wheeling conditions, since it may be difficult to create overvoltage spikes during periods of low power supply when load reduction/de-activation would ordinarily be desirable. Deviations in the phase angle of the supply signal are readily created regardless of the available power supply, but greater care must be taken to ensure that the selected signal deviation or sequence is one that is unlikely to occur naturally.

There are numerous advantages to using the method and system of the invention for remotely addressing power controllers at the subscribers' premises. As noted above, the additional expense of a dedicated telephone line is avoided, but at the same time the utility can address a power controller whenever required, even when the subscriber's line in engaged for long periods. Each signal deviation retains its integrity from the source to the subscribers' premises, without the need for additional equipment. The power modulators 10 can be addressed over as small or as large a region as is desired, simply by creating the signal deviation at the appropriate autotransformer, using equipment already available to the utility (the only additional equipment required being the power modulator 10). Moreover, the power modulator 10 itself accommodates different loads and shut-down priorities, enabling the utility to avoid a complete loss of power by maintaining power to essential loads.

The power modulator 10 can also be used to activate a backup system, for example, in a water heater 2 such as that illustrated in Figure 2 which is of the type described in U.S. Patent No. 5,115,491. There are many situations, particularly in commercial uses, where major problems can arise where an element malfunctions in a hot water heater. To avoid this problem, a backup element can be employed when the primary element burns out; in Figure 2 a backup element 5 is provided to replace the upper element 3 in case of malfunction. However, there must be some means of switching from the primary element 3 to the backup element 5.

The power modulator 10 can accept inputs from temperature sensors T1 and T2 associated with the heating elements 3,4 respectively. When the element is turned on the temperature must rise, and this information would be transmitted to the power modulator 10. The microprocessor 18 can be programmed to monitor the temperature rise through, for example, sensor TI, and if there is no rise in temperature after a certain delay following activation of the heating element 3, the microprocessor 18 would automatically switch off the heating element 3 and activate the backup heating element 5. This system can be used as a means of switching to a backup element automatically (or on command through the method of communication described herein), and to prevent persons from tampering with the water heater 2, for example removing the sensor T1 with a view to getting more hot water. The microprocessor 18 could similarly be programmed to deactivate the elements 3, 4 when the temperature sensors T1, T2, respectively, read maximum temperature (sensor shorted out) or minimum temperature (sensor removed).

Mechanical valves can present a problem when the hot water is first turned on. Since water standing in the pipes will cool to room temperature, when the tap is opened the water typically comes out at higher temperatures until the valve stabilizes, which can cause scalding problems. The power modulator can be programmed to monitor temperatures received from the temperature sensors T1, T2 of the upper and lower heating elements 3, 4, and a third sensor T3 placed at the output of the water heater 2. Since hot water always rises to the top of the water heater 2, the sensor with the highest temperature reading is used to control the mixing valve 6. Input from a temperature sensor T4 monitoring the temperature of the cold water supply can also be monitored by the microprocessor 18 to adjust the valve 6.

The invention having been thus described with reference to an example of a preferred embodiment, it will be obvious to those skilled in the art that certain modifications and adaptations may be made without departing from the scope of the invention. It will also be appreciated that the specific numbers of signal deviations, their intervals and the periods over which they may be made to occur are given as examples only and are in no way restrictive of the invention as a whole.

WE CLAIM:

1. A method of reducing or increasing electrical power consumption by an electrical load at a subscriber's premises powered through power supply mains, using power modulation means including input power means, output power means, sensing means for detecting a signal deviation in the supply signal received by the input power means, control means including a memory for recording a preselected signal deviation or sequence of signal deviations and comparing a signal deviation or sequence of signal deviations detected by the sensing means with the preselected signal deviation or sequence of signal deviations programmed into the memory, and output power means for altering the signal supplied to the load in response to the signal deviation or sequence of signal deviations corresponding to the signal deviation or sequence of signal deviations programmed into the memory, comprising the steps of

interposing the switching means between the power supply means and the load, and

transmitting within the supply signal a predetermined signal deviation or sequence of signal deviations over the power supply mains to the switching means to alter the power consumption of the load.

2. The method of claim 1 in which the signal deviation is a brownout interval.

3. The method of claim 1 in which the signal deviation is an overvoltage spike.

4. The method of claim 1 in which the signal deviation is a change in the phase angle between voltage and current.

5. The method of claim 1 in which the switching means is responsive to a sequence of signal deviations occurring over a preselected period of time.

6. The method of claim 1 in which the signal deviation or sequence of signal deviations programmed into the memory has a low probability of occurring naturally.

7. A method of altering the magnitude of electrical power consumption by an electrical load supplied by a supply signal carried by power supply mains, comprising the steps of

recording in a memory a preselected signal deviation or sequence of signal deviations,

monitoring the supply signal to detect a signal deviation or sequence of signal deviations,

comparing the monitored signal deviation or sequence of signal deviations with the recorded signal deviation or sequence of signal deviations, and

where a signal deviation or sequence of signal deviations in the supply signal matches the recorded signal deviation or sequence of signal deviations, activating a switch to alter the signal supplied to the load in a predetermined fashion and thus reduce or increase the power consumption of the load.

8. The method of claim 7 in which the signal deviation is a brownout interval.

9. The method of claim 7 in which the signal deviation is an overvoltage spike.

10. The method of claim 7 in which the signal deviation is a change in the phase angle between voltage and current.

11. The method of claim 7 in which the sequence of signal deviations occurs over a preselected period of time.

12. The method of claim 7 in which different signal deviations or sequences of signal deviations correspond to different specific output power reductions or increases to the load.

13. The method of claim 7 including the step of monitoring the power supply mains and taking corrective action when a preselected signal deviation or sequence of signal deviations occurs naturally.

14. An apparatus for controlling a water heater, comprising output power means for actuating heating elements in the water heater or a solenoid mixing valve controlling hot water output, or both, and a microprocessor responsive to inputs from temperature sensors associated with the heating elements, whereby following activation of a heating element the microprocessor monitors the temperature sensor associated with that heating element to determine whether the temperature of that element is increasing, and if the temperature is not increasing switches output power to an alternate element.

15. The apparatus of claim 14, including a temperature sensor associated with a hot water output of the water heater, whereby the microprocessor activates the heating elements or mixing valve according to the highest temperature input by the temperature sensors.

16. The apparatus of claim 14, including a temperature sensor associated with a cold water supply, whereby the microprocessor adjusts the mixing valve in response to inputs from the temperature sensors to maintain a hot water output at a constant temperature.

17. A method of communication over an electrical distribution network between an electrical power utility and a device located at a subscriber's premises adapted to detect fluctuations in a voltage across power supply

conductors at the premises, comprising creating a signal or a sequence of signals to be delivered over the network to the subscriber's premises, the signal or sequence of signals being composed of one or more momentary fluctuations in the voltage of the power supply of a predetermined magnitude or a predetermined duration or both.

18. A system for enabling an electrical utility to control a load at a subscriber's premises, the utility delivering electricity to the premises through a distribution network provided with means for momentarily increasing or reducing a voltage at predetermined points within the network, the system comprising

a power controller at the subscriber's premises connected to the distribution network through power supply conductors, having

input power means connected to the power supply conductors,

output power means connected to the load, voltage detection means for monitoring a voltage of the power supply,

power reduction means for reducing power to the power output means in response to deliberate fluctuations in a voltage across the power supply conductors created by the utility, and

means for decoding the fluctuations in the voltage across the power supply conductors and activating the power reduction means in response thereto.

19. A system for enabling an electrical utility to control a load at a subscriber's premises, the utility delivering electricity to the premises at variable voltage levels, the system comprising

a power controller at the subscriber's premises connected to the utility through power supply conductors, said power controller having

input power means connected to the power supply conductors,

output power means connected to the load,

voltage detection means for monitoring said variable voltage levels received from the utility,

power adjustment means for adjusting power applied to the load to predetermined further levels as a percentage of said voltage levels monitored by said voltage detection means.

20. The system of claim 19 further comprising means for effecting said adjusting of power after a predetermined time following a change in the voltage levels determined by said utility.

21. The systems of claims 18 or 19 further comprising means for returning power applied to the load to an initial value after a predetermined time delay following return of power delivered by said utility to its initial value.

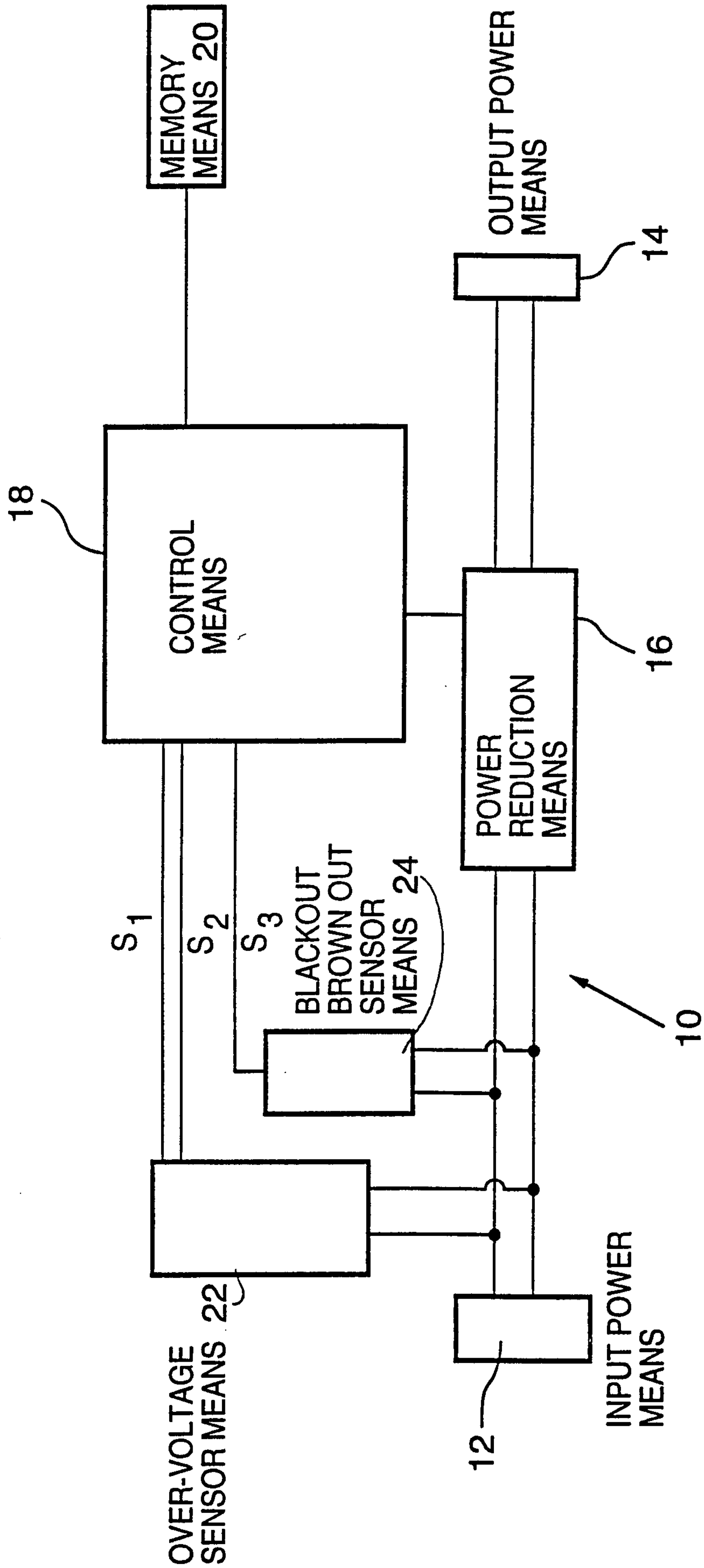

MEMORY MEANS 20
OUTPUT POWER MEANS
14
18
CONTROL MEANS
16
POWER REDUCTION MEANS
S1
S2
S3
BLACKOUT BROWN OUT SENSOR MEANS 24
10
OVER-VOLTAGE SENSOR MEANS 22
INPUT POWER MEANS
12

FIG.1.

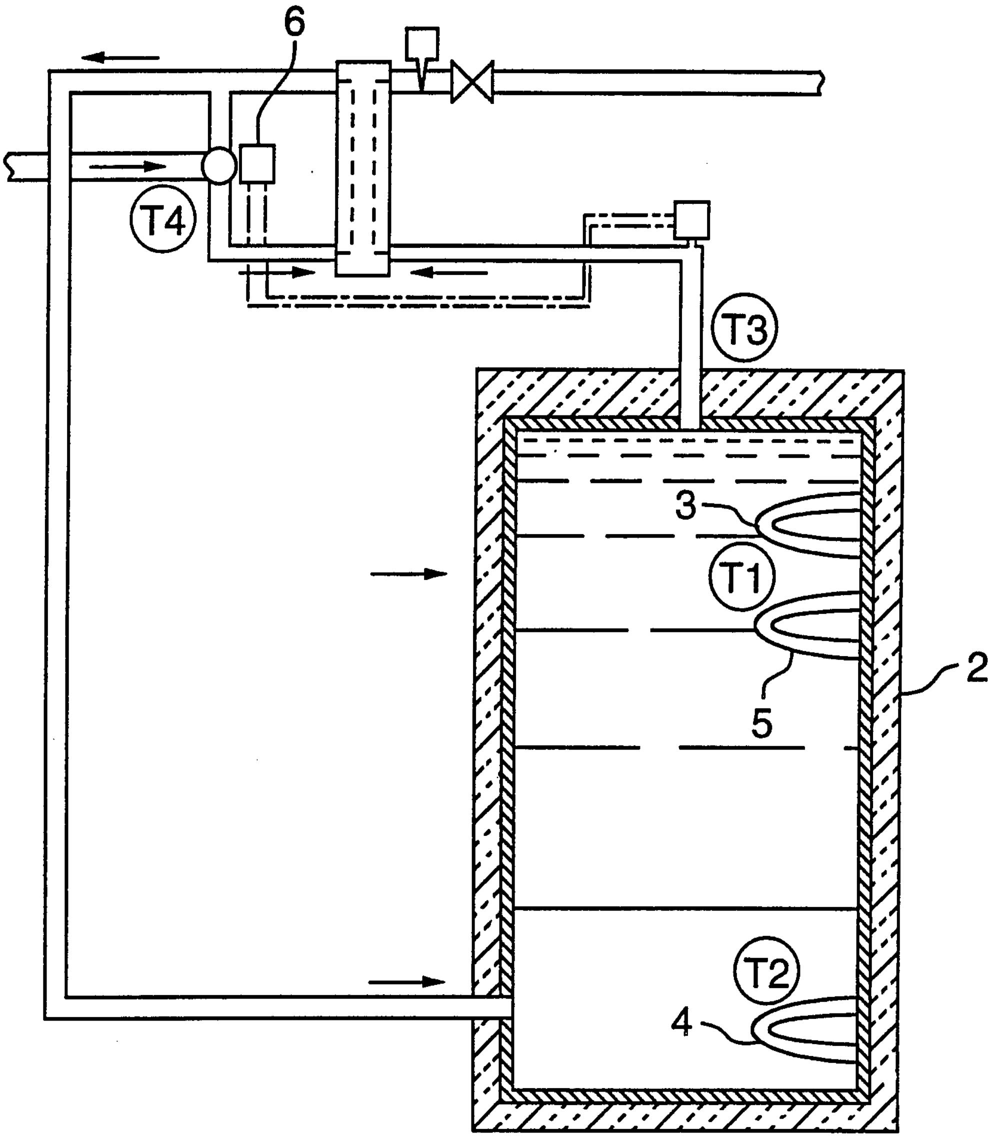
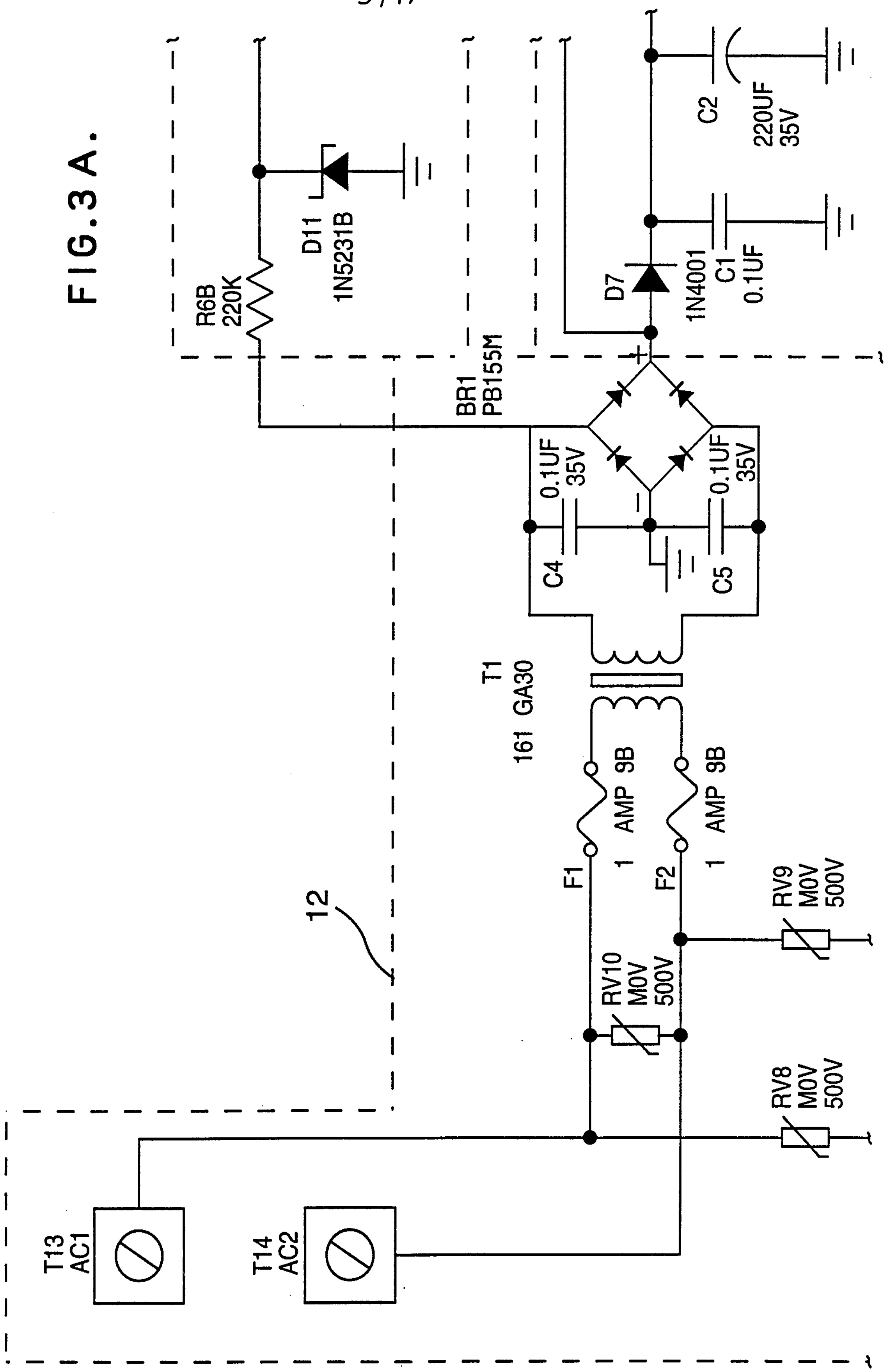


FIG.2.



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BR1
PB155M
D7
1N4001
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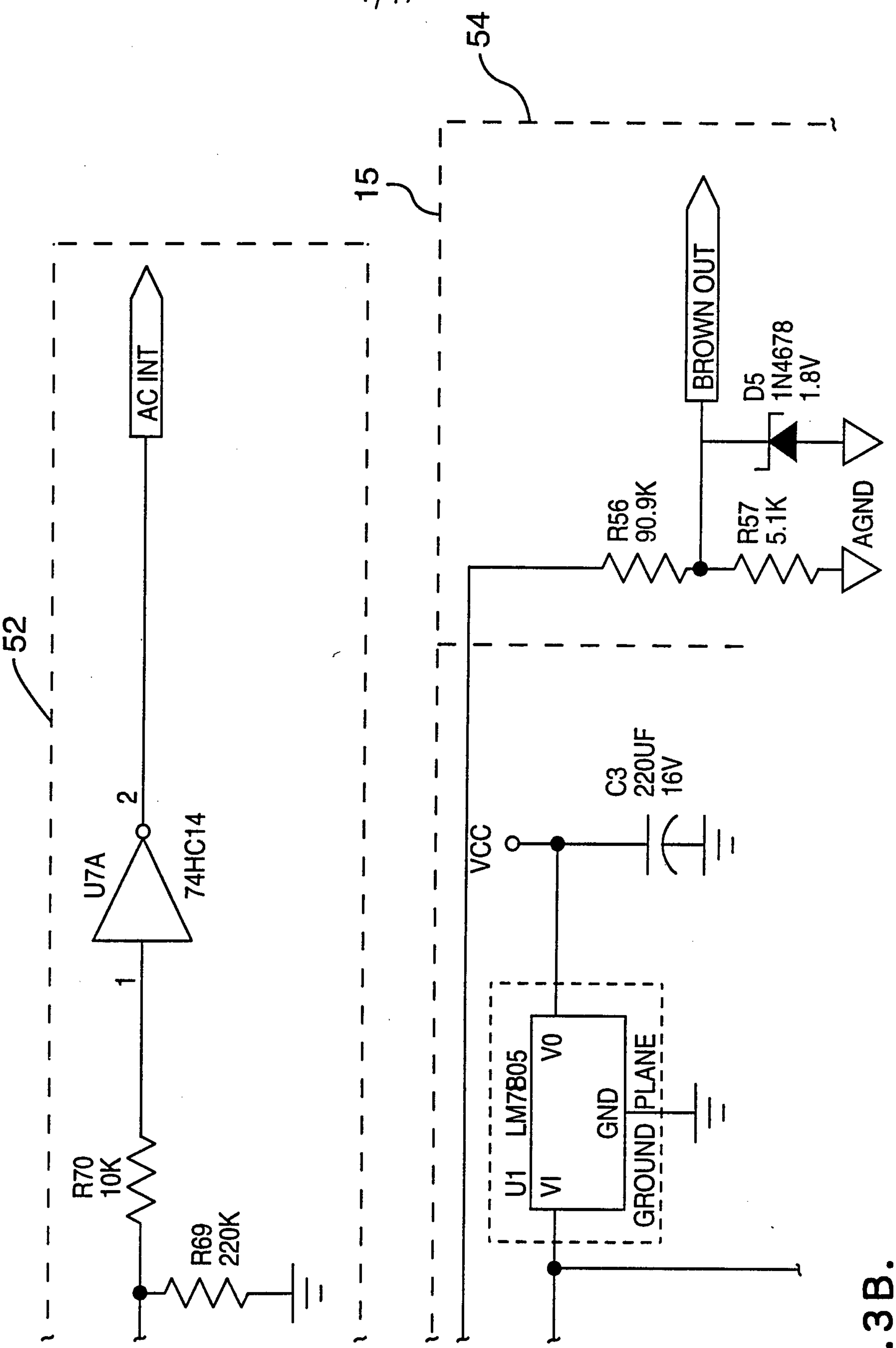
C2
220UF
35V
C4
0.1UF
35V
C5
0.1UF
35V
T1
161 GA30
F1
1 AMP 9B
F2
1 AMP 9B
RV10
MOV
500V
RV9
MOV
500V
RV8
MOV
500V
12
T13
AC1
T14
AC2

FIG.3A.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15
52
AC INT
2
U7A
74HC14
1
R70
10K
R69
220K
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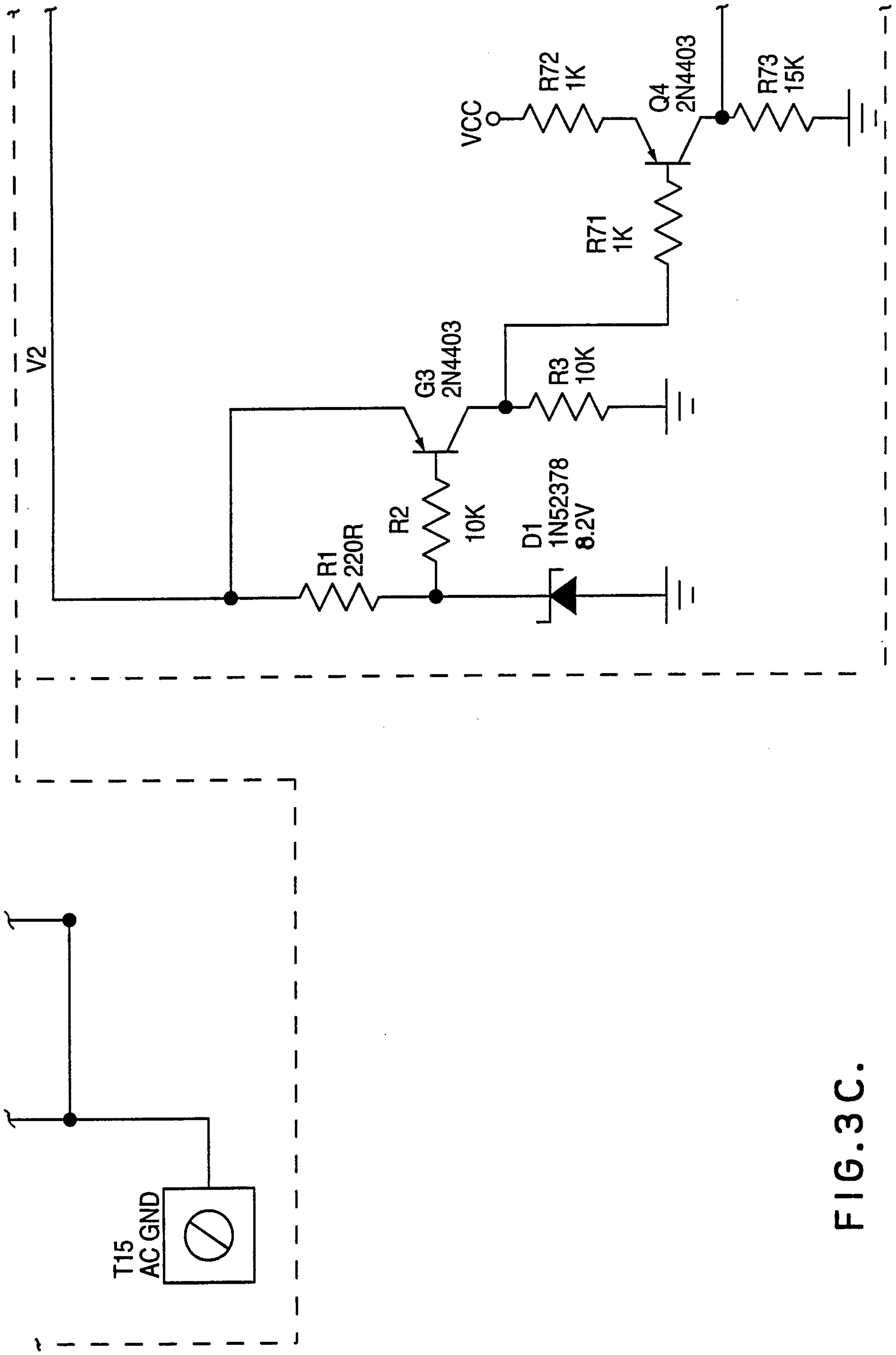
D5
1N4678
1.8V
R56
90.9K
R57
5.1K
AGND
C3
220UF
16V
VCC
U1
LM7805
V0
VI
GND
GROUND PLANE

FIG.3B.


V2
VCC
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1K
Q4
2N4403
R73
15K
R71
1K
G3
2N4403
R3
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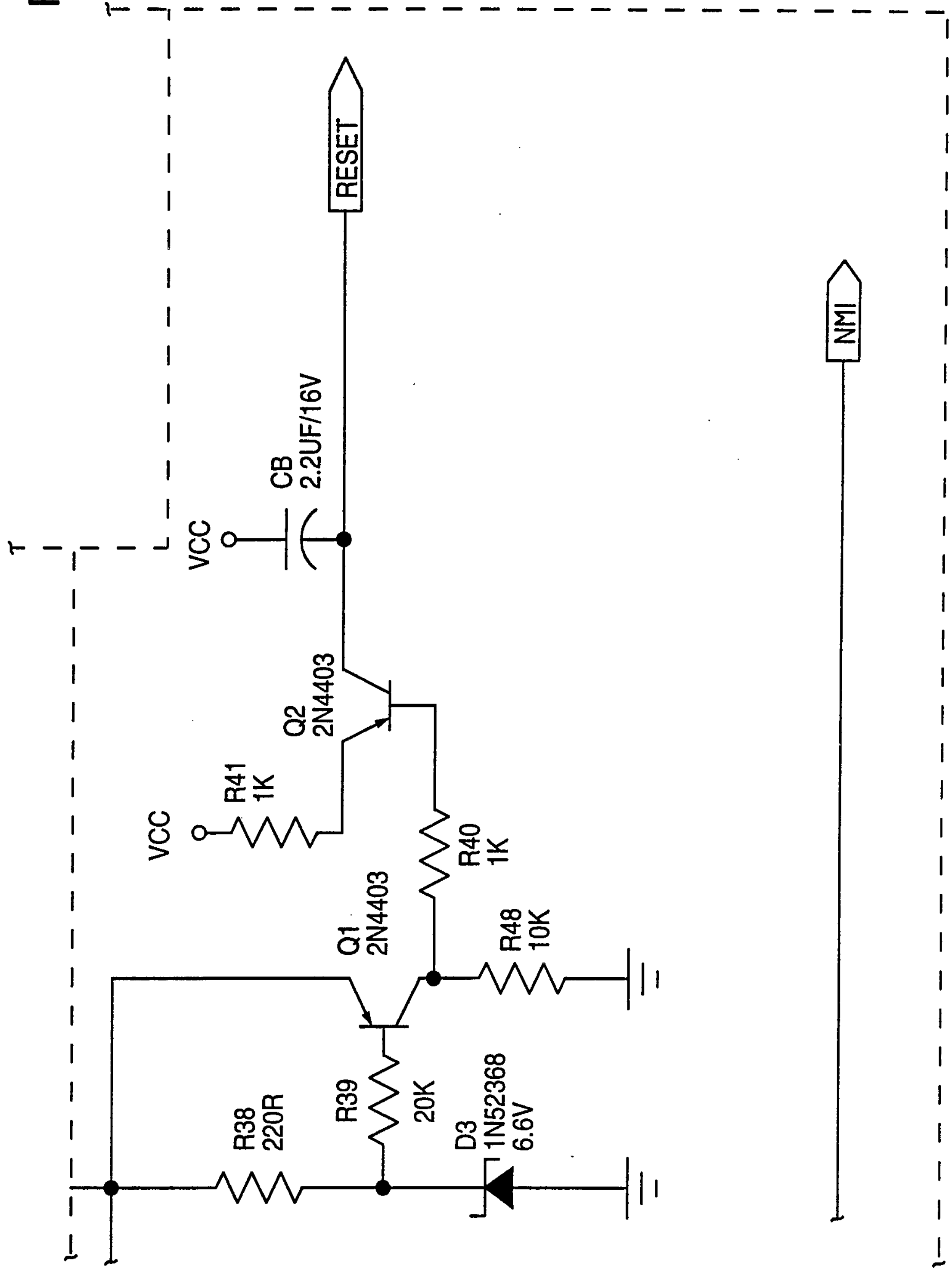
R2
10K
D1
1N52378
8.2V
R1
220R
T15
AC GND

FIG.3C.

FIG.3D.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NMI
CB
2.2UF/16V
VCC
Q2
2N4403
R41
1K
VCC
R40
1K
Q1
2N4403
R48
10K
R39
20K
R38
220R
D3
1N52368
6.6V

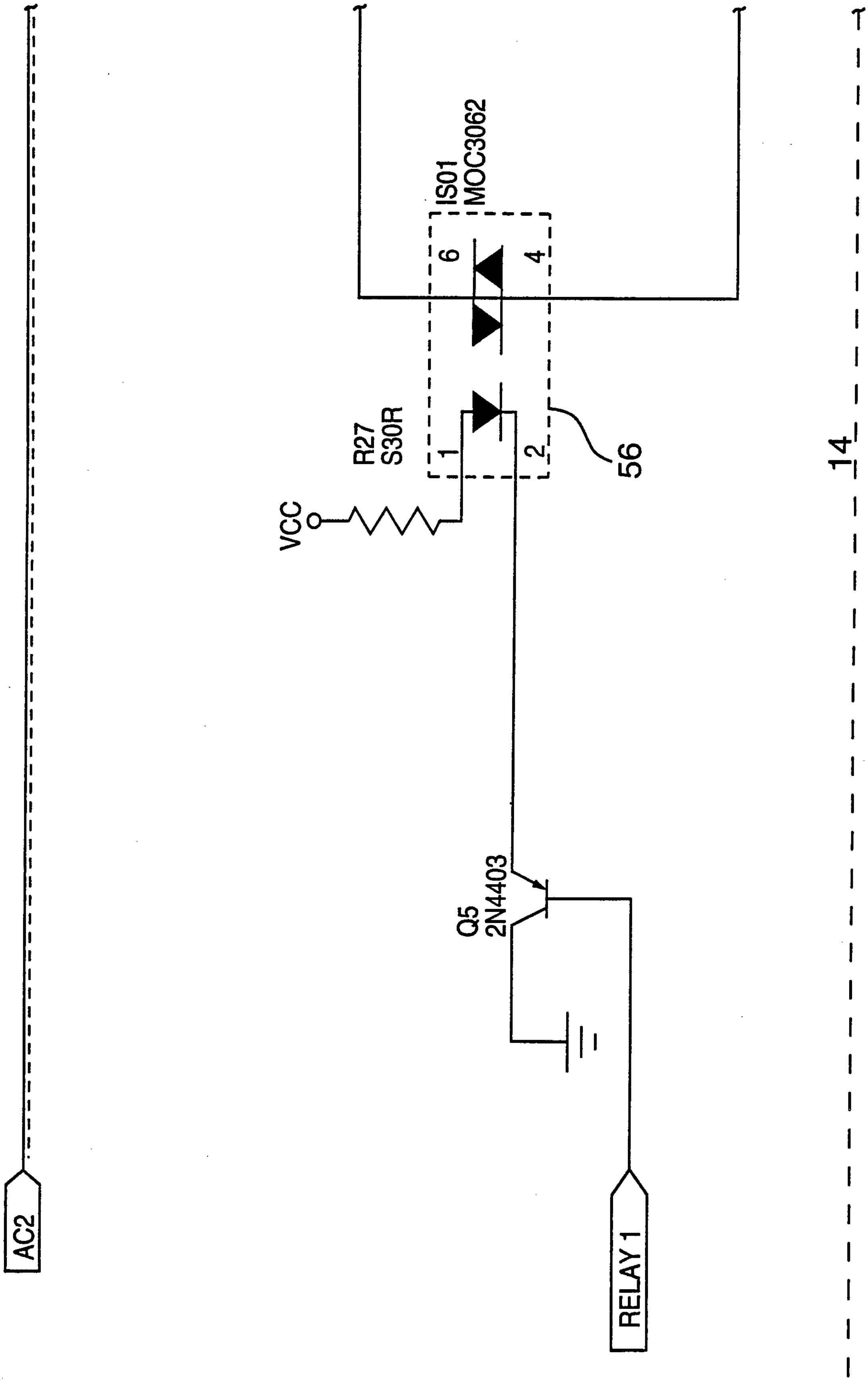


FIG.4A.

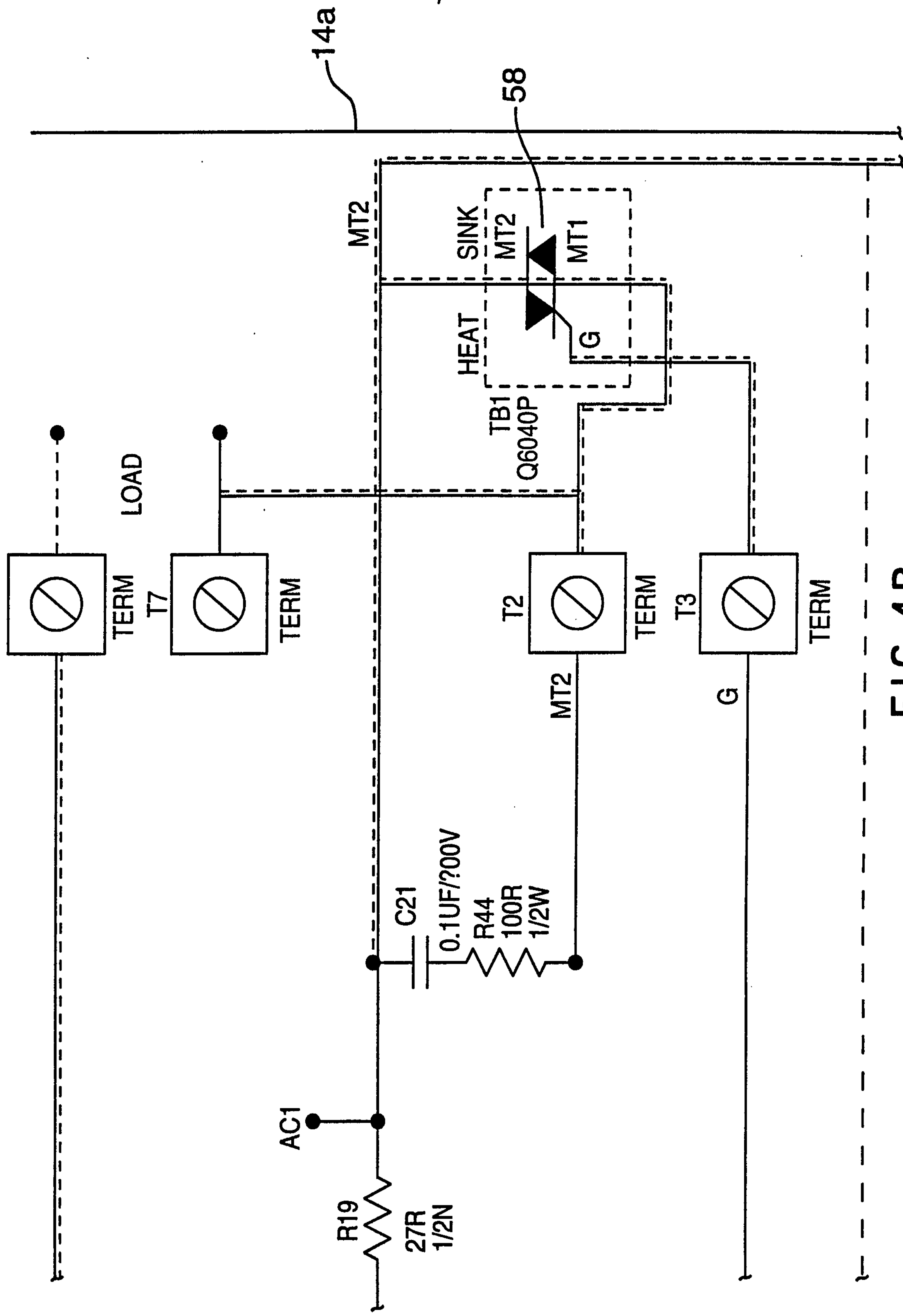

14a
58
MT2
SINK
MT2
MT1
HEAT
G
TB1
Q6040P
LOAD
TERM
T7
TERM
T2
TERM
T3
TERM
MT2
G
C21
0.1UF/?00V
R44
100R
1/2W
AC1
R19
27R
1/2N

FIG.4B.

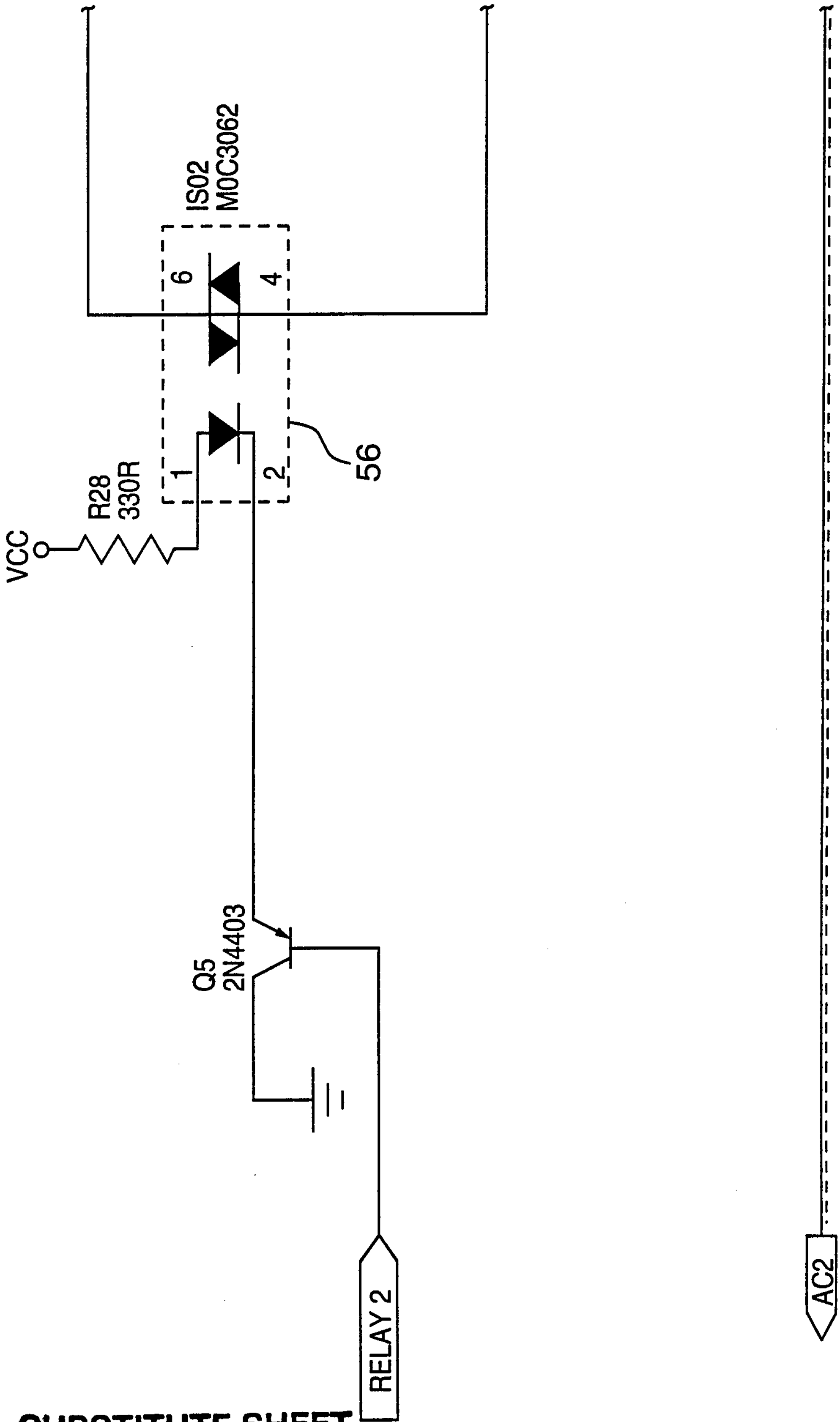
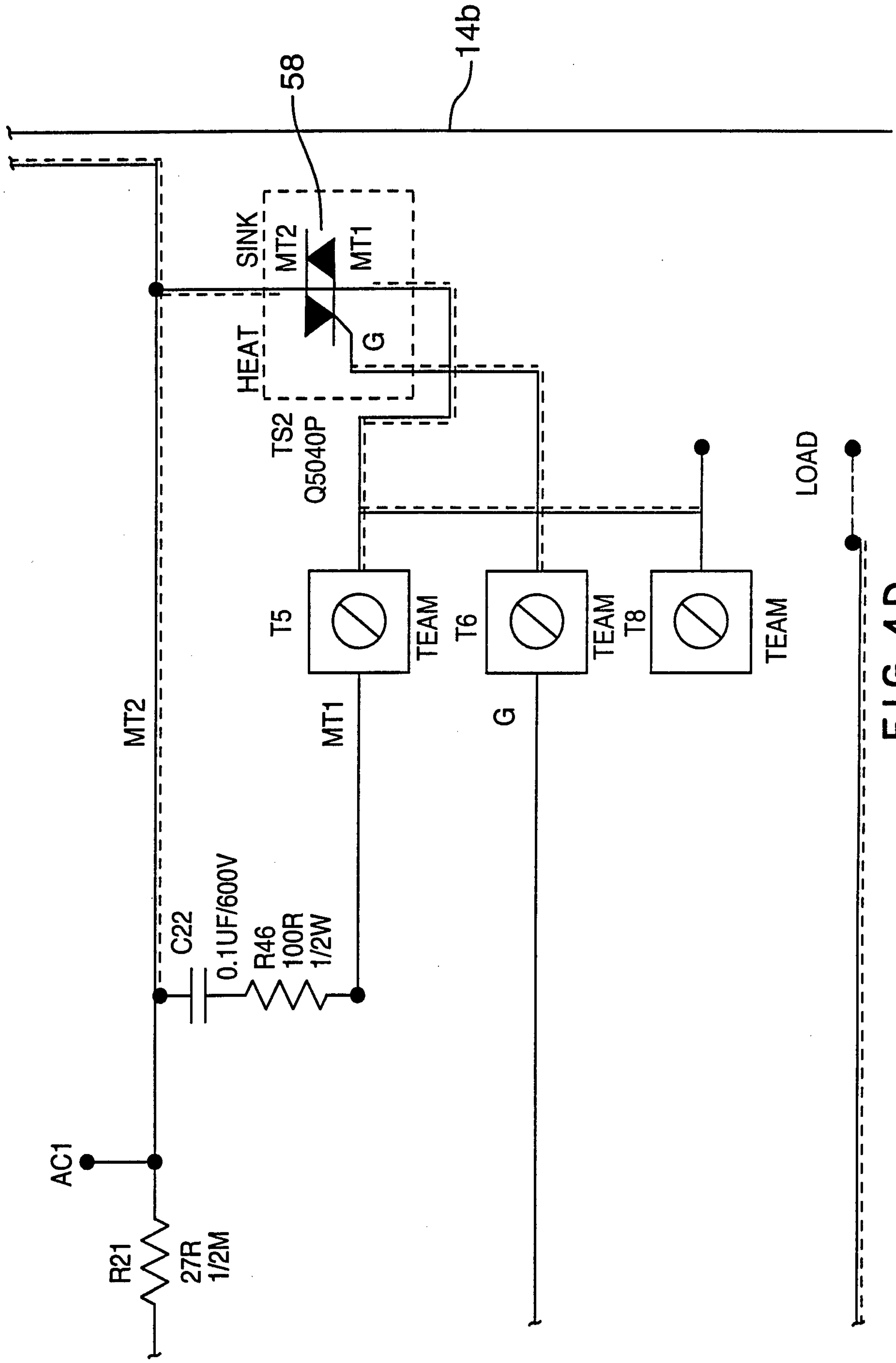


FIG.4C.


14b
58
SINK
MT2
MT1
HEAT
G
TS2
Q5040P
LOAD
T5
TEAM
T6
TEAM
T8
TEAM
MT2
MT1
G
C22
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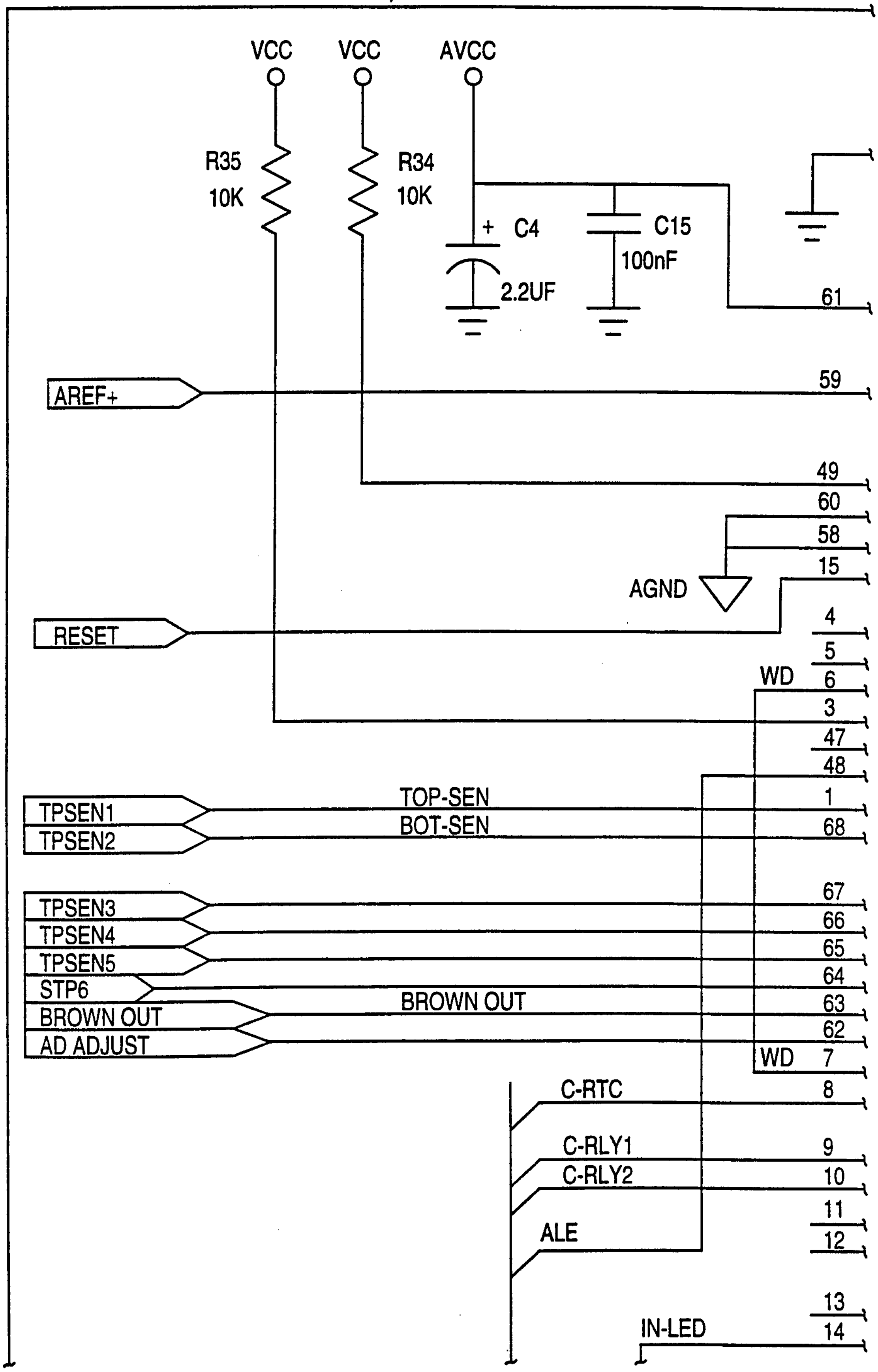
R46
100R
1/2W
AC1
R21
27R
1/2M

FIG.4D.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VCC
AVCC
R35
10K
R34
10K
+ C4
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C15
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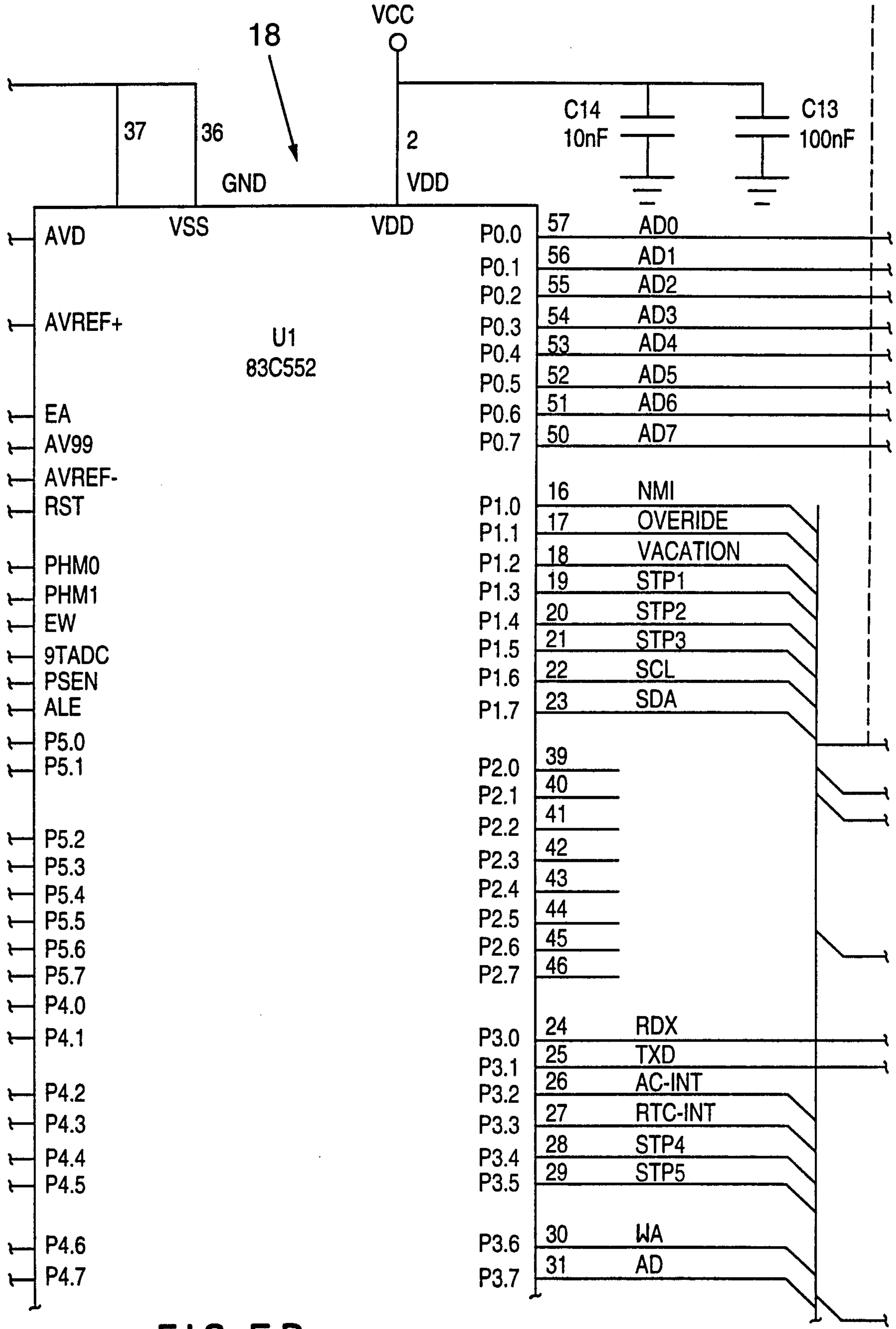
61
AREF+
59
49
60
58
15
AGND
RESET
4
5
WD 6
3
47
48
TPSEN1
TPSEN2
TOP-SEN
BOT-SEN
1
68
TPSEN3
TPSEN4
TPSEN5
STP6
BROWN OUT
AD ADJUST
BROWN OUT
67
66
65
64
63
62
WD 7
C-RTC
8
C-RLY1
9
C-RLY2
10
ALE
11
12
13
IN-LED
14

FIG. 5-A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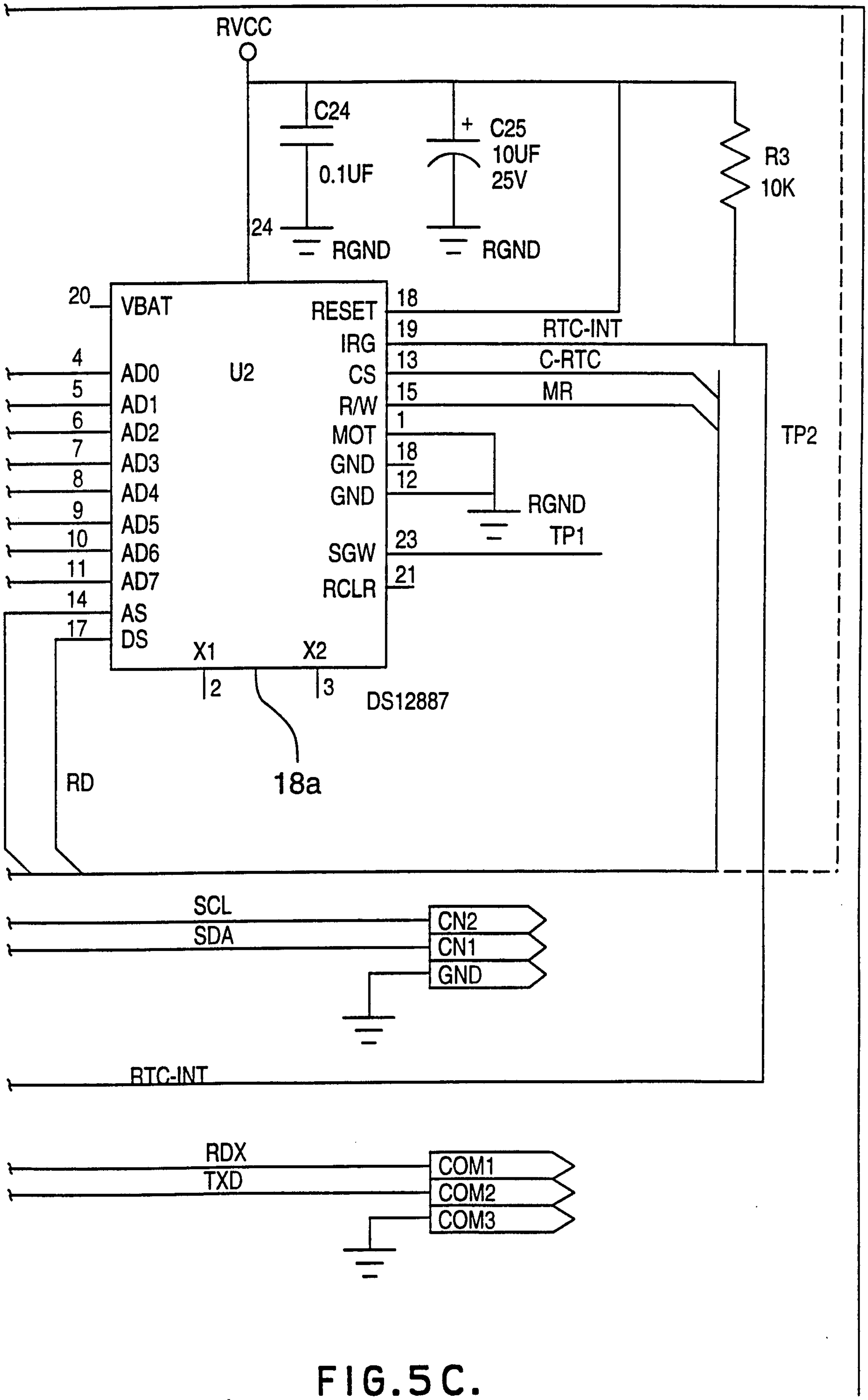
36
2
GND
VDD
C14
10nF
C13
100nF
AVD
VSS
VDD
AVREF+
U1
83C552
EA
AV99
AVREF-
RST
PHM0
PHM1
EW
9TADC
PSEN
ALE
P5.0
P5.1
P5.2
P5.3
P5.4
P5.5
P5.6
P5.7
P4.0
P4.1
P4.2
P4.3
P4.4
P4.5
P4.6
P4.7
P0.0 57 AD0
P0.1 56 AD1
P0.2 55 AD2
P0.3 54 AD3
P0.4 53 AD4
P0.5 52 AD5
P0.6 51 AD6
P0.7 50 AD7
P1.0 16 NMI
P1.1 17 OVERIDE
P1.2 18 VACATION
P1.3 19 STP1
P1.4 20 STP2
P1.5 21 STP3
P1.6 22 SCL
P1.7 23 SDA
P2.0 39
P2.1 40
P2.2 41
P2.3 42
P2.4 43
P2.5 44
P2.6 45
P2.7 46
P3.0 24 RDX
P3.1 25 TXD
P3.2 26 AC-INT
P3.3 27 RTC-INT
P3.4 28 STP4
P3.5 29 STP5
P3.6 30 WA
P3.7 31 AD

FIG.5B.



RVCC
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C25
10UF
25V
R3
10K
24
RGND
RGND
20
VBAT
RESET
IRG
CS
R/W
MOT
GND
GND
SGW
RCLR
U2
AD0
AD1
AD2
AD3
AD4
AD5
AD6
AD7
AS
DS
X1
X2
DS12887
18a
RD
RTC-INT
C-RTC
MR
TP2
RGND
TP1
SCL
SDA
CN2
CN1
GND
RTC-INT
RDX
TXD
COM1
COM2
COM3

FIG.5C.

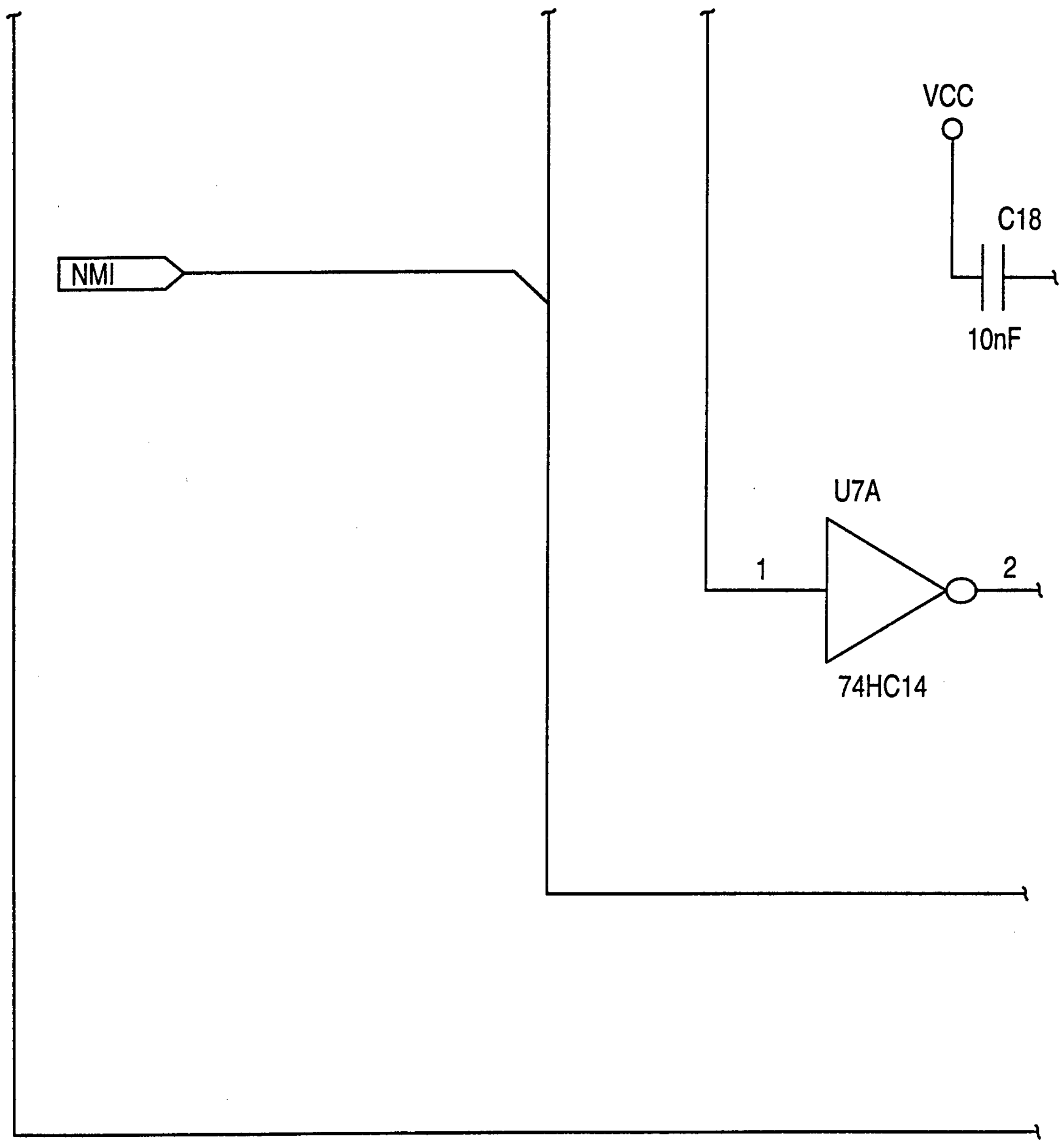
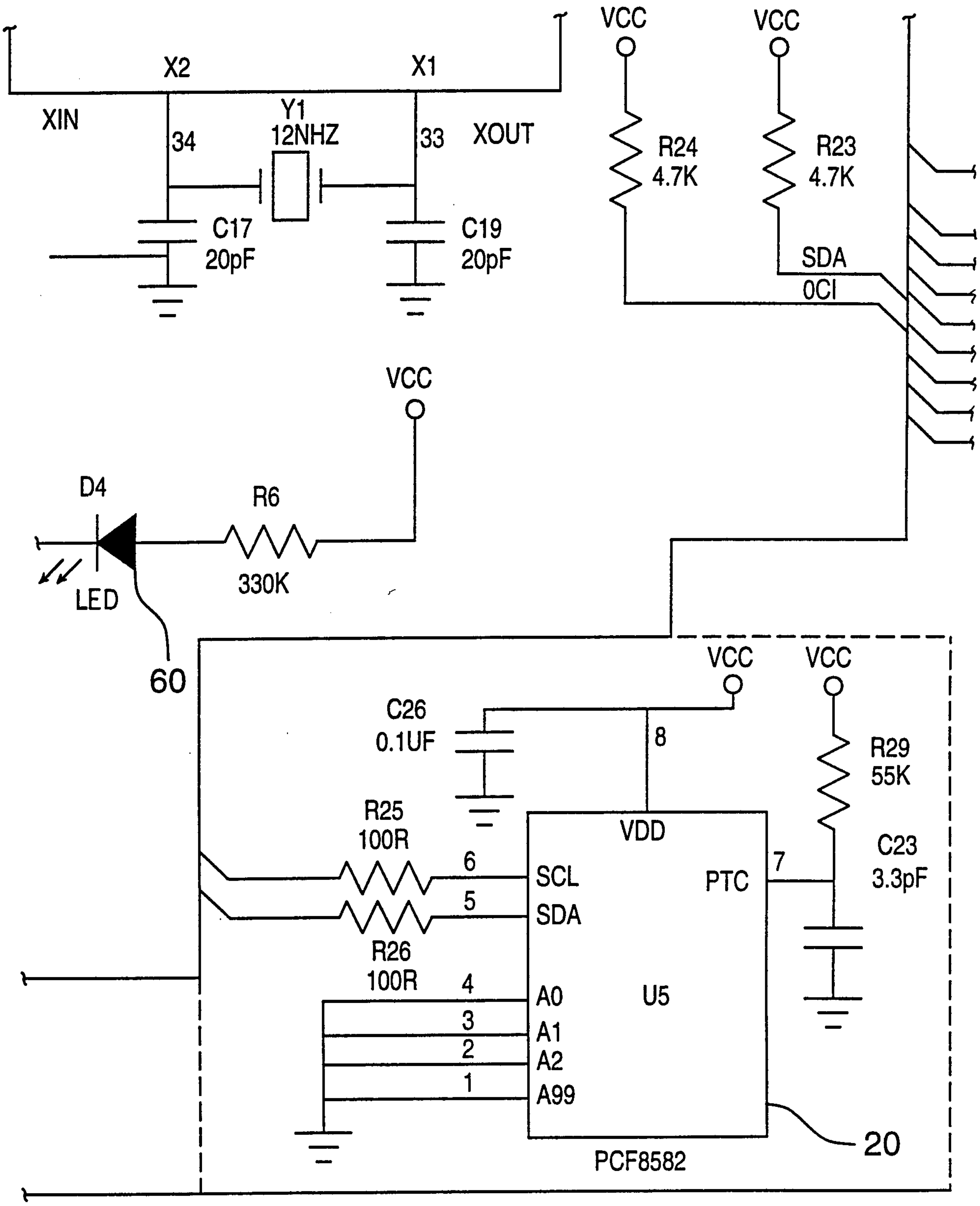


FIG.5D.


X2
X1
XIN
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Y1
12NHZ
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XOUT
C17
20pF
C19
20pF
VCC
R24
4.7K
VCC
R23
4.7K
SDA
0CI
VCC
D4
R6
330K
LED
60
VCC
VCC
C26
0.1UF
8
R29
55K
R25
100R
VDD
C23
3.3pF
6
SCL
PTC
7
5
SDA
R26
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A0
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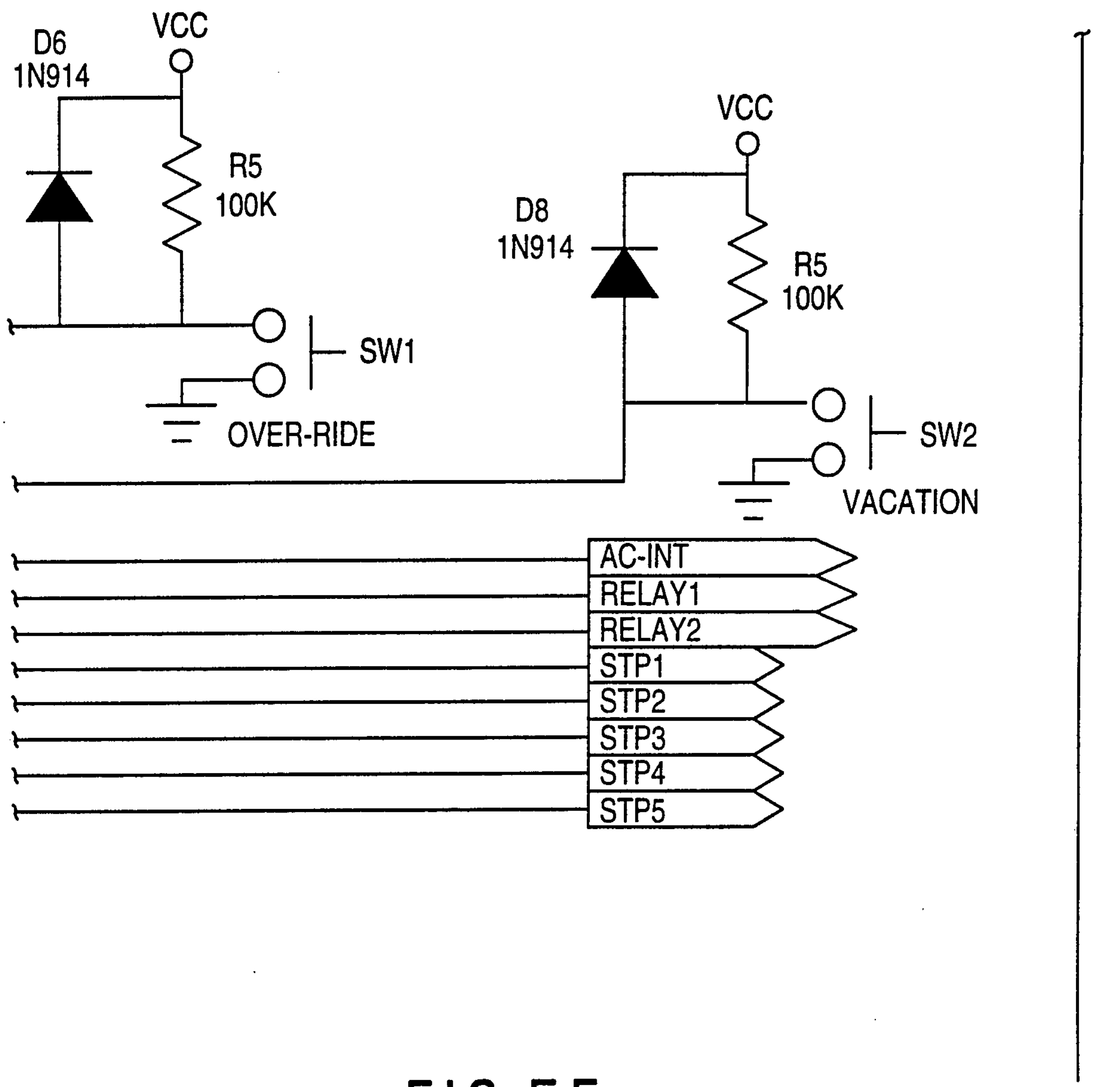
20
PCF8582

FIG.5E.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VCC
R5
100K
SW1
OVER-RIDE
VCC
D8
1N914
R5
100K
SW2
VACATION
AC-INT
RELAY1
RELAY2
STP1
STP2
STP3
STP4
STP5

FIG.5F.

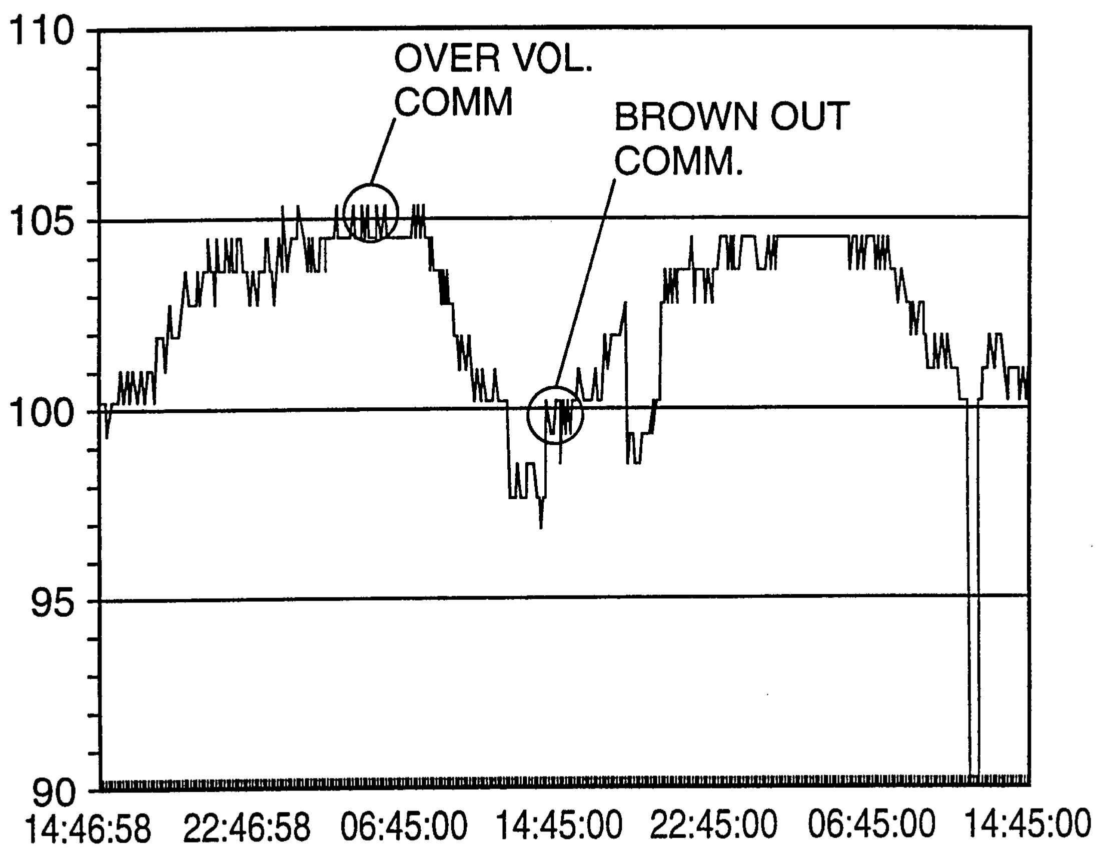
110
105
100
95
90
OVER VOL.
COMM
BROWN OUT
COMM.
14:46:58
22:46:58
06:45:00
14:45:00
22:45:00
06:45:00
14:45:00

FIG.6.

INTERNATIONAL SEARCH REPORT

International application No. PCT/CA 95/00077

A. CLASSIFICATION OF SUBJECT MATTER

H 02 J 3/14

According to International Patent Classification (IPC) or to both national classification and IPC 6

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G 05 F,H 02 J,H 05 B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE, C, 3 212 765 (LICENTIA) 13 October 1983 (13.10.83), the whole document. --	1,3, 18,19
A	US, A, 5 168 170 (K. HARTIG) 01 December 1992 (01.12.92), abstract; column 1, line 5 - column 2, line 26; claims (cited in the application). --	1,7
A	US, A, 5 115 491 (M. PERLMAN) 19 May 1992 (19.05.92), the whole document. --	14
A	US, A, 4 978 833 (J.T. KNEPLER)	14

[x] Further documents are listed in the continuation of box C.

[ ] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 May 1995	24.05.95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	MEHLMAUER e.h.

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	18 December 1990 (18.12.90), abstract; claims. --	
A	US, A, 4 413 189 (D. BOTTOM) 01 November 1983 (01.11.83), abstract; column 1, line 5 - column 2, line 51; claims; fig. 1,2. --	1,3,7, 9
P,A	EP, A, 0 597 322 (I.M.C. ELETTRONICA) 18 May 1994 (18.05.94), the whole document. --	1
A	EP, A, 0 561 255 (MITSUBISHI) 22 September 1993 (22.09.93), abstract; column 3, line 15 - column 4, line 15; claims; all fig.. --	1,14
P,A	WO, A, 94/06 191 (DOSANI) 17 March 1994 (17.03.1994), the whole document. --	1,14, 15,16
A	WO, A, 92/16 041 (ECONOLIGHT) 17 September 1992 (17.09.92), abstract; page 1, lines 5-11; claims. ----	1,7

ANHANG

zum internationalen Recherchenbericht über die internationale Patentanmeldung Nr.

ANNEX

to the International Search Report to the International Patent Application No.

ANNEXE

au rapport de recherche international relatif á la demande de brevet international n°

PCT/CA 95/00077 SAE 104117

In diesem Anhang sind die Mitglieder der Patentfamilien der im obengenannten internationalen Recherchenbericht angeführten Patentdokumente angegeben. Diese Angaben dienen nur zur Unterrichtung und erfolgen ohne Gewähr.

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The Office is in no way liable for these particulars which are given merely for the purpose of information.

La présente annexe indique les membres de la famille de brevets relatifs aux documents de brevets cités dans le rapport de recherche international visée ci-dessus. Les reseignements fournis sont donnés á titre indicatif et n'engagent pas la responsibilité de l'Office.

Im Recherchenbericht angeführtes Patentdokument Patent document cited in search report Document de brevet cité dans le rapport de recherche	Datum der Veröffentlichung Publication date Date de publication	Mitglied(er) der Patentfamilie Patent family member(s) Membre(s) de la famille de brevets	Datum der Veröffentlichung Publication date Date de publication
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