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TECHNICAL REPORT

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A MONITOR UNIT FOR AUTOMATICALLY LOGGING POWER LINE DISTURBANCES

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S U M M A R Y

A portable monitor system has been developed for automatically gathering data on the quality of electrical mains supplies. The equipment will store the number of times overvoltages or undervoltages occur in a chosen period, and will give a breakdown of the data into five disturbance-duration categories, plus an indication of the accumulated disturbance time.

The equipment is self-contained and requires no attention during the monitoring period, making it particularly useful for remote or unmanned sites.

Up to 100 000 excursions outside the preset thresholds can be tallied in any one period. The unit will continue to acquire and store data through extended mains failures for virtually the shelf life of its internal battery.

Approved for Public Release

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1. INTRODUCTION

There are a number of serious limitations associated with a conventional chart-recorder approach to mains monitoring. Besides requiring periodic attention and being vulnerable to mechanical failures, the problem of supplying power to the recorder during mains failures has to be considered. Also the amount of paper required to give adequate resolution to record the occurrence of even moderately short disturbances is a severe drawback. A simple chart-recording system will produce useful data on only a fraction of its total record length, since even poor quality mains can be expected to have a reliability figure better than 99%, and the data recovered will require a large amount of analysis and reduction. The chart recorder is certainly not a viable proposition for an installation which is to be unmanned for a long period of time.

The mains monitor system described here was developed for the role of gathering data for a statistical analysis of the quality of the electrical mains supply at a remote and unmanned site; this was necessary in order to specify a suitable Uninterruptible Power Supply (U.P.S) prior to the installation of critical electronic equipment. It has none of the limitations of the chart-recorder technique and has been field-tested over a period of many months in a tropical environment.

The unit is compact, light and portable. It is normally powered from the mains supply, but in the event of extended mains failures (regardless of their frequency of occurrence or duration), will retain the data for a period approaching the shelf-life of the Monitor's internal battery.

The data which can be collected using the Monitor relates to the number and duration of overvoltage and undervoltage deviations from the normal mains voltage. The unit allows for the selection of a wide range of thresholds for overvoltages and undervoltages.

With minor circuit modifications (detailed in Appendix III), the data stored in the Monitor can be retrieved automatically by a computer.

Photographs of the unit are shown as figures 1, 2 and 3.

1.1 General description (refer to Block Schematic figure 4)

The mains supply to be monitored is connected via a filter and an isolation transformer to two detectors in parallel, one for overvoltage and the other for undervoltage. These detectors supply suitable logic levels to drive counters either directly or via programmable timers. The thresholds of the detectors can be preset in the range -25% to +100% of the nominal mains voltages (115 V or 240 V).

The mains disturbances are logged in terms of their type (overvoltage or undervoltage) and duration (e.g. > 1 second, > 5 minutes etc.) by the counters 1 to 7 (5-decade counters). The timing for the categorisation and measurement of disturbance duration is derived from a one minute clock. The clock is arranged to achieve 30-second resolution for the measurement of disturbance duration.

The overvoltage counter, number 1, keeps a running total of the number of times the mains goes over the preset threshold voltage. The undervoltage counter, number 2, performs the same function for undervoltages.

Counters 3 to 6 must be assigned, via timers 3 to 6, to either the overvoltage or the undervoltage option by switches on the rear panel. The switched option increases the versatility of the instrument since it allows users to concentrate on overvoltage or undervoltage data depending on their particular interest.

Counter 3 tallies the number of times the mains is disturbed for periods in excess of 1 second. This counter is incremented via a fixed 1 second timer (timer 3). The 1 second period was chosen to provide a record of the number of times a typical unprotected regulated d.c. power supply would drop out due to undervoltages on the monitored mains.

Counter 4 will respond to disturbances of a duration greater than any period preset in timer 4 (between 1 and 9 minutes), via a BCD switch on the rear panel. The period must be a whole number of minutes. The preset period is implemented by a programmable timer which derives its timing from the one minute clock. If the disturbance exceeds the programmed time, the counter is incremented by 1.

Counters 5 and 6 perform similar functions to counter 4, except that the programmable delays can be anywhere between 1 and 99 minutes.

The Accumulated Time counter (7) stores the number of minutes (up to 99 999) that the mains has been disturbed in the monitored period. Either overvoltage or undervoltage time can be measured in any period, and the option is selectable by a rear panel switch.

A system of multiplexing is used to display the contents of any required counter whilst disabling the others.

The internal battery ensures that the Monitor remains fully functional during mains failures and that no data is lost.

A detailed circuit diagram is shown in figure 5.

There was no requirement, in the original specification for this unit, to monitor impulsive disturbances (less than say 2 ms duration), but with some straightforward additions this could be done. It would require the provision of a high-pass filter at the input to remove the mains frequency component, and a detection system to allow the impulsive disturbances to be logged as a function of their polarity and energy or amplitude as required.

1.2 Applications

Some areas where the Monitor may prove useful are:

(a) The gathering of statistics to facilitate the specification or design of Uninterruptible Power Supplies, (a practical example is given in Section 4).

(b) The gathering of statistics to determine the suitability of Mains Voltage Regulators for protecting critical loads. For example, the output of a Mains Regulator could be monitored directly. Alternatively the thresholds of the Monitor could be set to the upper and lower input voltage limits of a Mains Voltage Regulator, and statistics gathered.

(c) The testing of Uninterruptible Power Supplies and Mains Voltage Regulators to check their adequacy.

(d) For anticipating the reliability of a mains supply prior to installation of equipment.

(e) To monitor overvoltage surges on diesel alternator outputs used in field installations.

(f) For the unattended monitoring of mains voltage in a critical equipment installation. Note: In installations where a computer is available automatic retrieval of the Monitor data is possible; modifications to allow this are suggested in Appendix III.

(g) As an aid in the diagnosis of mains-caused equipment malfunctions (in real time if necessary).

An example of how the Monitor Unit can be used might be in making a decision on what type of Uninterruptible Power Supply (U.P.S) would be best suited for a particular installation. A typical commercial U.P.S. may have capacity options of 5, 30 or 60 minutes. If these three periods are programmed into the timers associated with counters 4, 5 and 6 respectively, the Monitor Unit's undervoltage and overvoltage thresholds are set to correspond with the U.P.S. input voltage limits, and the supply is monitored for a reasonable time, an accurate picture can be drawn of the expected mean time between failures for the three options (i.e. the number of times the capacity of the U.P.S. has been exceeded, resulting in a loss of mains voltage to the critical load).

The data sheet for a commercial U.P.S. is reproduced in Appendix II.

An account of an actual field application of the Monitor will serve to illustrate another of its possible uses.

Random errors were occurring in a digital system which was being operated on a regulated mains supply. The Monitor, set to measure undervoltages, was first connected to the raw mains, and this proved to be relatively disturbance-free (in the short term at least). The Monitor was then placed on the regulated mains, and it was found that glitches were occurring at a rate of approximately 10 per hour, with occasional undervoltages exceeding 1 second duration. The 1 second undervoltages were seen to correlate with the errors in the digital system and the fault was quickly located in the mains regulator itself - a motor driven variac type. The wiper was found to be making intermittent contact with the track.

2. DETAILED CIRCUIT DESCRIPTION

2.1 Overvoltage and undervoltage detectors (refer figures 4, 5 and 6)

A peak (rather than r.m.s. or average) detecting system has been adopted in this unit in the belief that the acquired data will have more validity and relevance in terms of the effect of mains disturbances on the behaviour of modern power supplies using capacitor-input filters.

The mains voltage is applied to isolating transformers T1 and T2 arranged so that either a nominal 115 V or a 240 V line can be monitored by selecting the appropriate configuration. The arrangement is such that each transformer is normally required to work at only half its nominal primary voltage rating, thereby preventing the possibility of non-linear operation due to core saturation for overvoltages up to 200% of the nominal line voltage.

The secondary voltage is full-wave rectified and fed to two parallel adjustable voltage dividers (R26, R27 and R28, R29). The potentiometer R27 presets the overvoltage threshold and R29 the undervoltage threshold. The overvoltage threshold setting is such that the series zener diode (V8) will conduct when the preset threshold is exceeded, passing a series of pulses to transistor V20, causing it to switch on and off with a repetition rate of twice the mains frequency. This causes filter capacitor C38 to discharge, allowing the 74C914 Schmitt trigger (IC12a) to change state, producing a transition from logic low to high at the output. The logic high will be present for the duration of the mains overvoltage.

A low-pass filter, formed by C36 and R37, further attenuates fast transients on the mains (some filtering is already achieved in the mains filter) precluding the possibility of spurious overvoltage counts. The diode V18 is a safeguard against excessive reverse base-emitter voltages occuring in V20.

The values of R39, R41 and C38 are chosen to allow a fast attack time for the detection system (2 ms) and a slow decay time (around 200 ms).

The hysteresis inherent in the Schmitt trigger limits the sensitivity of the circuit to prevent erratic operation when the threshold is just reached by an overvoltage. This hysteresis has the effect of allowing the monitor to ignore extremely small (<1%) variations in mains voltage.

A transistor/zener configuration was chosen as the voltage comparator element in this system mainly because it takes very little current from the supply. Also it does not require an extra rail voltage (in contrast to the more orthodox voltage reference/comparator configuration).

The undervoltage detector, comprising R28, R29 and V9 etc., is similar in design to the overvoltage circuit already described. An undervoltage of a duration less than one half of a mains cycle (as distinct from an impulsive undervoltage as defined in Section 1.1) is not detectable other than by extremely sophisticated means and has not been attempted in this design. The value of the time constant at the input of the Schmitt trigger is chosen to give an attack time slightly greater than the period of one 50 Hz mains cycle, thus precluding the possibility of spurious counts occurring due to mains waveform distortion.

The potentiometer R29 is used to set the required threshold for an undervoltage such that the zener diode V9 is conducting (in pulses), giving a high level at the output of the Schmitt trigger in the normal and overvoltage condition. When an undervoltage occurs, the zener will stop conducting and the Schmitt trigger output will go low. Inverting gates (IC's 13a and 13c) at the outputs of the two Schmitt triggers allow true and complemented outputs to be derived from each detected overvoltage and undervoltage. The "undervoltage" and "overvoltage" signals are combined to generate a "disturbance" signal at the output of the gate IC13d.

Transistors V23 and V24 drive front-panel LED's indicating the presence of an overvoltage (OVERVOLTS LED, V25, illuminated) or giving an indication that neither the overvoltage nor undervoltage threshold has been reached (OK LED, V26, illuminated). No LED is allocated to indicate the presence of an undervoltage, since in the event of a prolonged mains failure, the drain on the internal batteries would be excessive. However the presence of an undervoltage can be deduced by noting that neither of the two LED indicators are illuminated.

2.2 One minute clock (refer figures 4 and 7)

The astable multivibrator (IC14) is a type 4047, and has a period of 1 minute (set with the network R69, R70 and C40). Its function is to provide an accurate time-source to facilitate the categorisation of overvoltages and undervoltages as a function of their duration (e.g. > 1 minute, > 5 minutes, etc.), and to increment the Accumulated Time counter as required. The clock is designed such that its frequency has a low sensitivity to its supply voltage (dF/dV), maintaining a substantially constant period with decreasing battery voltage.

When an undervoltage or overvoltage is detected, the "disturbance" signal enables the astable IC14. In parallel with the enable line is a delay network (R68 and C41), connected to the reset input. This allows the reset (logic low to pin 9) to be released, when a disturbance is detected, only after the enable has been applied for 2 ms. This guarantees the initial state of the astable output and also safeguards against the possibility of a transition occurring immediately the enable is applied. All Programmable Timers are incremented by the positive-going edge of the clock output, and the Accumulated Time counter by the negative-going edge.

When an undervoltage or overvoltage is detected, the clock output will stay high for 30 seconds then effect the transition to low. However, should the mains return to normal before this transition takes place, the clock output state will not change, and the disturbance will be recorded as zero minutes in the Accumulated Time Counter.

When a disturbance is between 30 seconds and 90 seconds long, the Accumulated Time Counter will be incremented by one at the 30 seconds negative transition of the clock output. The disturbance, in this case, will add one minute to the total accumulated time. This explanation applies for the first 1 minute pulse, but it can be seen that the rounding-off effect holds for disturbances of any length, giving a resolution of 30 seconds for duration measurements.

For disturbances of less than 1 minute the programmable timers will not be incremented. Up to 30 seconds no change in the clock output state occurs. Between 30 seconds and 1 minute the programmable timers will be reset immediately the disturbance ends, i.e. 2 ms before the clock is reset due to the delay network R68 and C41. This rounding-down effect applies for all disturbances whatever their duration.

2.3 Programmable timers (refer figures 4 and 7)

Three programmable timers (or delays) are able to be set by rear-panel BCD switches (BCD 1 to 5), and there is a fourth delay permanently set, by hard wiring, to 1 second.

The one second delay (timer 3) is achieved by the network IC12d, V17, R35, C34 and IC12e. The Schmitt trigger (IC12d), is fed from either the undervoltage or overvoltage detector output, as selected by switch S15 on the rear panel. If the disturbance is less than 1 second in duration, capacitor C34 will not discharge sufficiently to allow a change of state to occur in IC12e, and counter 3 will not be incremented. If the disturbance is in excess of 1 second duration, a change of state occurs, and counter 3 will be incremented by 1. At the end of the disturbance, diode V17 will become forward biased allowing the charge to be rapidly restored to C34. The 1 second period was chosen to represent that time beyond which a mains operated power supply, such as is found in typical electronic equipment, would drop out with an undervoltage condition.

Timer 4 consists of a programmable down-counter, IC11 (type 4522), and is used to preset delays in the range 1 to 9 minutes in 1 minute increments. The desired time interval is set by the BCD switch connected to the parallel inputs (pins 5, 11, 14 and 2).

To explain the operation assume that:

(1) the BCD lines to IC11 are set for 6 minutes delay,

(2) the associated counter (4) is set to monitor overvoltages,

(3) an overvoltage of a duration in excess of 6 minutes is detected on the mains.

The one minute clock will start and its output will decrement the programmable counter via the clock input (pin 6). Simultaneously, the overvoltage detector output will enable the counter via the parallel enable input (pin 3). The counter will decrement by one, with the arrival of every positive-going edge from the one minute clock until, after 6 minutes, it will have decremented to zero. At this point the decoded zero output (pin 12) will go high, causing IC4 (a five-decade counter type 4534B) to increment by 1, recording the fact that an overvoltage of greater than 6 minutes duration has occurred. At the same time, IC11 will be disabled until the disturbance has finished, since the logic high at the decoded zero output is also connected to the inhibit (pin 4).

The pull-down resistors R1 to R4 have been made purposely high to minimise current consumption, and the capacitors C7 to C10 are to provide a degree of noise immunity.

The operation of the other two programmable timers (5 and 6) is identical except they are each comprised of two cascaded 4522's and are therefore programmable between 1 and 99 minutes in 1 minute increments.

2.4 Counters and display (refer figures 4 and 8)

The 4534B (IC's 1 to 7) is a five-decade ripple counter which has its respective decade outputs time-multiplexed using an internal scanner. The BCD outputs of each decade are selected by the scanner and appear on the output pins 17 to 20. The selected decade is indicated by a logic high on the appropriate digit select pin. Both BCD and digit-select outputs have tri-state controls, providing an open circuit when these controls are high. This feature allows the BCD outputs of all seven counters to be parallelled (the BCD data bus) and also the digit-select lines (the digit-select bus), facilitating time-multiplexing of the contents of any one of the counters into the display. Any counter can be chosen to have its contents displayed by positioning the DISPLAY switch (S12a) to supply the necessary logic low (to pins 15 and 21) to enable the counter. The BCD and digit-select lines in the selected counter will output normally, while on all other counters these lines will be held at high impedance.

The counters have been allocated as follows:

IC1 Total number of overvoltages.

IC2 Total number of undervoltages.

IC3 Number of overvoltages (or undervoltages) of duration longer than 1 second.

IC4 Number of overvoltages (or undervoltages) of duration longer than X, where X is a whole number of minutes programmable between 1 and 9.

IC5 Number of overvoltages (or undervoltages) of duration longer than Y, where Y is a whole number of minutes programmable between 1 and 99.

IC6 Number of overvoltages (or undervoltages) of duration longer than Z, where Z is a whole number of minutes programmable between 1 and 99.

IC7 Accumulated time of overvoltages (or undervoltages), up to 100 000 minutes /(69 days).

Note:- Counters 3 to 7 are assigned to either overvoltage or undervoltage operation by switches on the rear panel.

The internal scanners of the counters are clocked (via pin 10) by the output of a free-running 600 Hz oscillator (IC12C, R36 and C35). The BCD output lines of each counter therefore produce time-multiplexed outputs of the five digit count, and these are used to drive a BCD to 7-segment decoder (IC20).

The decoder output is connected through resistors to the parallelled segment inputs of four of the numeric displays.

Due to the multiplexing arrangements, zero blanking can only be achieved in the most significant digit, and this has been implemented by the provision of a second 7-segment decoder (IC21) dedicated to the one numeric display. It is necessary to turn on one numeric display at a time at the scanning rate, and this is achieved by using the digit-select outputs to control the zero volts connection to each display. Peripheral drivers IC18, IC8 and IC9 are used to switch the common cathode connections of the 7-segment displays to zero volts when they are required to be activated, and the switching action is controlled by the output on the digit-select bus. At any instant, therefore, only one digit select line is high and only one numeric display is activated.

Should the mains voltage become extremely low, or fail completely, it is necessary to make all the BCD and digit-select lines go to their high impedance state. This will prevent current being sourced from these lines into the peripheral IC's which are supplied from the mains-derived +5 V rail. This is done by the network associated with V22, IC12f and IC19d. While sufficient reservoir voltage is available to maintain +5 V regulated output, the transistor V22 will be saturated with its collector providing a logic low to the Schmitt trigger input (IC12f), the output of which is inverted by the gate IC19d. This will provide the necessary logic low to the wiper of the DISPLAY switch (S12a), and sets the conditions for normal operation. When the +5 V regulator voltage differential becomes marginal, the collector of V22 will go high, forcing the BCD outputs and digit select lines into their high-impedance state. This allows the BCD outputs (BCD data bus) and seven-segment decoder inputs to be pulled high by resistors R43 and R46, and the digit select bus to be pulled low by R87 to R91. This condition results in the segment outputs going low and the common cathodes (of the displays) going open circuit, blanking the display. However, the shedding of the display current allows the reservoir capacitor voltage to rise sufficiently to unblank the display. The result is a rapid oscillation between the two states, allowing the display to function, at reducing brilliance, down to the lowest possible mains voltage.

By momentarily putting pin 2 of any of the 5-decade counters to a logic high the counter will reset to zero. When a reset is required, the appropriate counter is selected by the DISPLAY switch S12 and the two RESET push-button switches (S13 and S14) on the front panel are pushed simultaneously to pass the high from R78 through the switch S12b to pin 2 of the selected counter. The two series switches are intended to prevent accidental reset operation.

2.5 Accumulated time counter (refer figures 4 and 8)

The type 4534 counter, IC7 is dedicated to producing a running total of the time the mains has spent in either the overvoltage or undervoltage condition; the overvoltage or undervoltage option is selected by the switch (S19) labelled '7' on the rear panel. A disturbance of less than 30 seconds duration will not be included in the accumulated total (see One Minute Clock above). Up to 100 000 minutes (approximately 69 days) of accumulated disturbance time can be recorded.

The circuit comprised of IC19a, 19b, 19c, C27, R21 and V27 is designed to increment the Accumulated Time counter through pin 4 as required, and to prevent the counter responding to disturbances of less than 30 seconds duration. Since any short (less than 30 seconds) disturbances will appear, for their duration, as high logic levels on pin 1 of IC19a, it is necessary to invert and differentiate the one minute clock pulse. This will maintain a logic low at pin 2 of IC19a, preventing the Accumulated Time counter from incrementing each time a (selected) disturbance occurs.

The one minute clock output is buffered and inverted by IC19c, the output of which is differentiated by C27 and R21. The diode V27 prevents negative-going peaks from possibly damaging the gate IC19a.

When a disturbance exceeding 30 seconds occurs, the detector will pass a high logic level to pin 1 of IC19a (a NAND gate) for the duration of the disturbance. The other input (pin 2) is fed from the inverted differentiated clock output. After 30 seconds from the start of the overvoltage or undervoltage the clock output will make a transition to low and the resulting positive-going pulse will be passed to pin 2 of the NAND gate (IC19a). This will cause the output of the gate to go momentarily low, which in turn will be passed via IC19b to the counter IC7 which will then increment 1. Disturbances of any duration will be measured and recorded with 30 seconds resolution as explained in Section 2.2 (One minute clock).

2.6 Power supplies (refer figures 4 and 9)

(a) Mains filter

Inductors L1 and L2, with C1 to C4 form a conventional low-pass filter designed to remove any radio-frequency interference and impulsive disturbances from the input to the Monitor Unit.

(b) +5 V and +B V supplies

There are two supply rails in the Monitor Unit. One is derived from a +5 V regulator and is marked +5 V: the other is from a 6 V battery and is marked +B V.

The mains normally powers the whole system, but in the event of a mains failure the battery will automatically supply current to all the essential data-gathering circuitry

Dry cells were chosen for use in the Monitor Unit because their useful life will be many years; they are universally available and are inherently reliable. Alkaline or carbon zinc types are recommended.

Trickle charged nickel cadmium cells were rejected because experience has shown that they are less reliable than dry cells, particularly in a situation where they are subject to continuous trickle charge and virtually no discharge. Also it is considered desirable in critical systems that testing of nickel cadmium cells be carried out at (typically) three-monthly intervals. In a remote site application this is not possible.

The transformers T3 and T4 are configured by the 115 V/240 V switch (S2) to accept either mains voltage. It should be noted that this switch simultaneously configures the isolation transformers (T1 and T2) in the same fashion. The secondary voltage is full-wave rectified and filtered by V2 and C28 before being passed to the regulator which supplies +5 V, and also (via R22 and V3) to two large reservoir capacitors, C31 and C32, across which is a 5.6 V zener diode (V10). This is the +B V line and it is connected to the battery via the diode V11. As long as the mains voltage is normal, V11 will stay non-conducting and the battery will not pass current. If the mains voltage drops drastically, or fails completely, the charge on C31, C32 will slowly drop to the point where V11 will conduct and the battery will start to supply current, thus effecting a smooth transfer to battery operation.

If the mains has failed and it is required to turn on the numeric indicators momentarily, this can be done by pressing the DISPLAY ON BATT(ery) switch S5, a biased toggle switch in series with the +5 V supply. This facility is also necessary for carrying out full functional checks on the Monitor Unit. Pressing switch S5 will open-circuit the normal +5 V rail and connect in its place a voltage derived from the battery, allowing the numeric indicators to come on. As a safety precaution, the connection can only be maintained as long as the battery voltage is adequate. The Protection Circuit around V5, V6 and V7 is designed to perform this task. When the battery voltage falls below 4.7 V the voltage at the base of V7 will be reduced to the point where the transistor is cut off. This will effectively remove the forward bias from V5, cutting it off completely. The battery line to the numeric indicator circuitry is thus open-circuited, and also the 'Display on Battery' protection circuit itself will no longer draw current from the battery.

The transistors V15 and V16 are arranged to give an indication of the state of the internal battery. When the biased BATTERY VOLTAGE - TEST switch (S6) is depressed momentarily, the battery voltage is passed via a zener diode (V14) and R30 to the base of transistor V15. If the battery is healthy, base current will flow in V15 causing it to turn on, and the LED V12 (BATTERY VOLTAGE - OK) will become illuminated. Under these conditions the base voltage of V16 is held low and this transistor is turned off. Conversely, if the battery voltage is low, V15 will be turned off, causing base current to flow in V16 and illuminating V13 (BATTERY VOLTAGE - FAILING).

Should the BATTERY VOLTAGE - TEST switch be operated with the mains off when the battery is at the end of its useful life (voltage as low as 3 V) the data will still be saved, since the voltage on the reservoir capacitors will be adequate to support the counters while the switch is momentarily depressed.

3. OPERATION AND ADJUSTMENTS

3.1 Front panel controls and displays

(a) DISPLAY Switch (S12)

This eight position rotary switch allows any one of the seven data counts to be displayed on the numeric indicators, and also has an OFF position which leaves the display blank.

The card to the left of the switch is used to list the parameters pertaining to each position, since these are preset variables.

(b) DISPLAY ON BATT(ery) Switch (S5)

This is a biased toggle switch which must be pushed if the numeric display is to be used while the mains is off. It will only turn on the display if the battery voltage is greater than 4.7 V (see Section 2.5(b), Power Supplies).

(c) RESET Push Switches (S13 to S14)

The counters in the Monitor Unit can only be reset one at a time. To reset any one of the seven counters to zero, the contents of the counter are first selected for display using the DISPLAY switch (S12), then both RESET switches are depressed simultaneously. Under certain conditions (e.g. no mains voltage and internal battery failing) the display will remain blank, and the reset function will be inoperative. A simple rule therefore applies - if the display can not be seen then the counter can not be reset.

(d) BATTERY VOLTAGE - TEST Switch (S6)

This is a biased push switch and is used to test the condition of the internal battery, lighting up the appropriate LED (either OK or FAILING).

(e) MONITORED VOLTAGE Indicators (V25, V26)

These two LED's, one marked OK and the other OVER VOLTS give a real-time indication of the state of the mains voltage being monitored. If the mains voltage is in the window between the overvoltage and undervoltage thresholds then OK will be illuminated. If an overvoltage is present then OVER VOLTS will be on. If neither

LED is alight then an undervoltage condition exists.

3.2 Rear panel controls

(a) VOLTAGE SET Potentiometers (R27 and R29)

These are screwdriver adjustable multi-turn potentiometers labelled OVER (R27), and UNDER (R29). They are used to set the undervoltage and overvoltage thresholds over a range of -25% to +100% about the nominal mains voltage (115 V or 240 V).

(b) MAINS Switch (S1)

This single-pole switch is in series with the active lead of the mains supply to the Monitor Unit. It can be used to simulate mains failures if required.

(c) BATTERY Switch (S4)

This is used to open-circuit the line from the internal battery, for purposes of transportation, storage and testing etc.

(d) COUNTERS OVER-VOLTS and UNDER-VOLTS Switches (S15 to 19)

The switches are each labelled with a number which corresponds to the numbers on the front-panel DISPLAY switch (S12) and they allow the individual counters to be switched to log overvoltages or undervoltages as required. These switches, along with S1 and S4 ((b) and (c) above) have been protected from inadvertent operation by guard plates.

(e) SET TIME MINUTES Switches (BCD 1 to 5)

These are miniature screwdriver-switchable BCD switches and are labelled 4, 5 and 6. These numbers correspond with the DISPLAY switch (S12) labelling. They are used to set the programmable timers.

Switch 4 can be set to program the time delay for counter 4 to any whole number of minutes between 1 and 9. There are two switches associated with the label 5, and they are to program the time delay for counter 5. These can be set to any whole number of minutes between 1 and 99. The least significant digit is on the right.

The two switches (BCD 4 and 5) under label 6 will program the time delay for counter 6 to any whole number of minutes between 1 and 99.

(f) 240 V/115 V SW(itch) (S2)

This is located behind the removable battery supply compartment cover and is clearly labelled. The switch should be set to correspond with the nominal mains voltage before the Monitor Unit is connected.

(g) Fuse

The Monitor Unit is protected by a 250 mA miniature glass cartridge fuse.

(h) SPARES (1 to 6)

Some of these have already been allocated as follows:

Socket 1. 0V.

Socket 5. Internal Battery Supply (switched).

Socket 6. Internal Battery Supply.

Sockets 2, 3 and 4. Spares.

Sockets 5 and 6 can be used for measuring battery current, and the Spare sockets might possibly be used for bringing out connections suitable for monitoring parameters other than mains voltage.

3.3 Setting up procedure

3.3.1 Setting thresholds

The Monitor Unit is plugged into a variac which has been set, using an a.c. voltmeter, to the required threshold voltage. The VOLTAGE SET potentiometers on the rear panel are then adjusted whilst observing the MONITORED VOLTAGE LED's on the front panel. When setting the overvoltage threshold the potentiometer marked OVER is adjusted to the point where the OVERVOLTS LED comes on.

Setting the undervoltage threshold is similar. The variac is adjusted to the new threshold voltage and the potentiometer marked UNDER is set to the point where the OK LED goes out.

This method was found convenient in the original application, but a more flexible approach might be to use indicating-type multi-turn potentiometers which have been pre-calibrated using a technique similar to that described above.

3.3.2 Setting programmable timers

The required time, in minutes, can be set directly using the BCD switches on the rear panel. The BCD switches are clearly marked with their assigned counter numbers.

3.3.3 Selecting disturbance options

The undervoltage or overvoltage option for each counter is fixed by positioning the toggle switches (labelled 3 to 7) on the rear panel to OVERVOLTAGE or UNDERVOLTAGE as required.

4. INTERPRETING THE MONITOR DATA

Appendix I is a Monitor System Record listing a sample of data recovered from the Mains Monitor Unit installed at a remote site.

The preset thresholds are shown on top of the record, and the seven columns correspond with the DISPLAY switch positions on the front panel of the Monitor. In this sample, counters 3 to 7 were all switched to monitor undervoltages, and the preset periods were chosen to be 5, 30 and 90 minutes.

The data was recovered from the Monitor on an opportunity basis at intervals varying between one and thirty days. When necessary, of course, the Monitor can be left unattended for many months, but it can prove useful to update a record sheet from time to time. This procedure is an insurance against some catastrophe overtaking the Monitor, but more importantly, trends in the data which might show a time distribution can be highlighted.

If the record sheet is up-dated on a regular basis, it becomes possible to determine the absolute duration and approximate time of occurrence of each extended mains failure, allowing the use of normal statistical methods on the data.

The figures on the record sheet are, to some extent, self-validating. For example a study of this particular record shows the following:

(a) The running totals in each column are logically ascending with time.

(b) At any time, the total in column 7 (total number of minutes) can be sensibly correlated with the entry in column 4 (e.g. the last entry shows 85 minutes total accruing from 5 undervoltages of between 5 and 30 minutes duration).

(c) At any time the totals in column 2 are greater than or equal to those in 3, which are greater than or equal to those in 4, etc. up to column 6.

Although, in most cases, a monitoring period greater than 3 months would be considered desirable before confidently drawing conclusions, it is interesting to analyse the data on the record sheet. Out of a total of 92 undervoltages we find that:

30 (or 33%) exceeded 1 second duration.

5 (or 5.4%) were between 5 and 30 minutes duration.

0 (or 0%) exceeded 30 minutes duration.

25 (or 27%) were between 1 second and 5 minutes duration.

62 (or 67%) were of less than 1 second duration.

From the point of view of specifying an Uninterruptible Power Supply (U.P.S.) for this site, the data could be summarised as follows:

(1) An unprotected, regulated d.c. supply would have dropped out, on average ten times per month.

(2) A U.P.S. with 5 minute capacity would have failed to support the critical load more than once per month.

(3) A U.P.S. with 30 minutes capacity would have provided complete protection.

(4) The reliability of the mains is 99.93% for a threshold of 216 V taking into account the 85 minutes of undervoltage time in 3 months of monitoring. (This is calculated from the formula: Reliability = 100(1-Tu/P)% where Tu = Accumulated Undervoltage Time and P = Monitored Period).

5. MAINS MONITOR UNIT - SPECIFICATIONS

(1) Mains Supply: Nominal mains voltages 240 or 115 at 45 Hz to 65 Hz. Power required < 2 V A.

(2) Threshold Range about the nominal (240/115) voltage: -25% to +100%.

(3) Hysteresis in overvoltage and undervoltage detectors: 0.8% (2 V in 240 V) (approx.).

(4) Preset Thresholds - Stability with temperature: +0.07% per °C (approx.).

(5) Temperature Stability of One Minute Clock: -0.05% per °C (approx.).

(6) Operating Temperature Range: 0 to +50°C

(7) Internal Battery Type: D cells (four). Alkaline or Carbon Zinc.

(8) Battery Current: 75 μA during mains failures. 130 mA with DISPLAY ON BATT(ery). (Typical)

(9) Mains voltage below which the numeric indicators are automatically blanked: 200 V/100 V.

(10) Battery voltage below which the numeric indicators blank with DISPLAY ON BATT(ery): 4.7 V.

(11) Battery voltage below which battery FAILING indication is given: 4 V.

(12) Permissible battery replacement time before data is lost (with no mains supply): > 5 minutes.

(13) Overall Dimensions: 30 cm wide, 9 cm high, 34 cm deep.

(14) Weight: 3.8 kg (with batteries).

APPENDIX I

MONITOR SYSTEM RECORD

LOCATION	DERBY – WESTERN AUSTRALIA						
VOLTAGE THRESHOLDS	UPPER 250 VOLTS			LOWER 215 VOLTS			
	DISPLAY FUNCTION						
	Total number of overvoltages	Total number of undervoltages	Total number of UNDERVOLTAGES longer than 1s	Total number of UNDERVOLTAGES longer than 5 min	Total number of UNDERVOLTAGES longer than 30 min	Total number of UNDERVOLTAGES longer than 90 min	Total number of minutes UNDERVOLTAGE
DATE	1	2	3	4	5	6	7
22/9/78	0	0	0	0	0	0	0
26/9/78	4	0	0	0	0	0	0
27/9/78	94	6	0	0	0	0	0
2/10/78	110	7	1	1	0	0	17
4/10/78	218	49	1	1	0	0	17
11/10/78	290	50	2	2	0	0	24
24/10/78	499	50	2	2	0	0	24
16/11/78	1182	53	2	2	0	0	24
14/12/78	3045	92	30	5	0	0	85

APPENDIX II

SPECIFICATION OF COMMERCIAL U.P.S.

two systems to choose from . . .

DELTEC has two Uninterruptible Power Systems available which were designed to meet various installation and application requirements. The same considerations for MTBF and MTTR are incorporated in these systems where applicable.

The DSU Series system is available in power output configurations from 500 VA to 1500 VA. These units are small, compact systems completely "self-contained" including all basic UPS components. No facility or special installation preparations are required. Simply plug the UPS into an appropriate AC outlet and plug the critical load into the UPS.

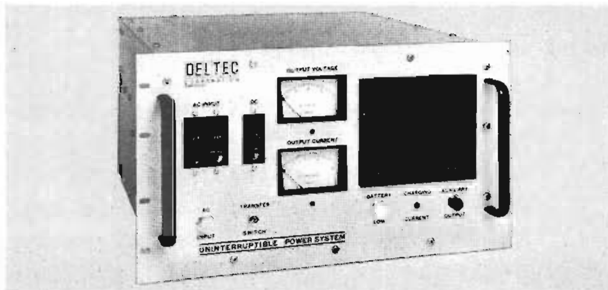
The 5000A Series UPS is the most advanced, modular constructed system available. These systems are available in power output configurations of 2000 VA to 37.5 KVA, 1Ø and 3Ø.

These are versatile systems which are easily adapted for specific customer requirements, i.e., input/output voltages, optional configurations, energy reservoir capacity and others. Due to the modular concept of assembly, short deliveries of most systems are available.

THE DSU SERIES

The DSU series is ideal for powering minicomputers and control systems. It is designed for rack-mounting, with modular circuit assemblies for minimum MTTR. The DSU series is supplied with Power Rectifier/Battery Charger, Battery (sealed Gel/Cell®) and DC/AC Static Inverter. Convenience circuit breakers, AC output voltage and current meters and status indicator lights with parallel contact closures are provided.

Options available with the DSU series are: Static Transfer Switch (4 ms), Frequency phase and synchronization, and additional rack-mount battery reservoir.



Model DSU 520

PERFORMANCE SPECIFICATIONS

INPUT
220 VAC, 1 phase 47-63Hz, ±10%. Others available.

OUTPUT

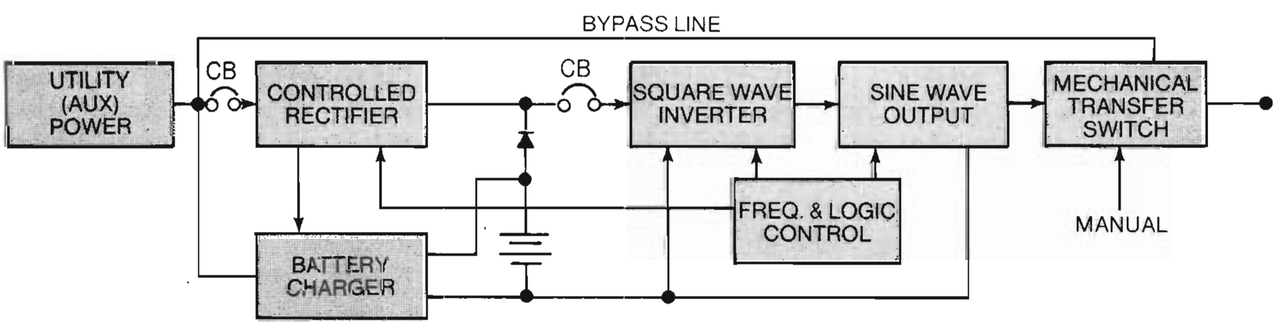
Voltage:	220 VAC, 1 phase standard, others available
Regulation:	5% Line and Load
Frequency:	50 Hz ±0.25%;
Wave Form:	Sine wave, 5% maximum harmonic distortion
Power Factor:	Accepts loads of 0.8 Lagging or 0.8 Leading
Meters:	AC Voltage and AC Current

GENERAL

Controls:	AC Power "ON-OFF"; DC Power "ON-OFF"
Indicators:	"AC INPUT" Amber; "BATTERY LOW" White; "AUXILIARY OUTPUT" Red; "CHARGING CURRENT" Blue, varying
Transfer Switch:	Less than 50 ms; optional ¼ cycle
Operating Temperature:	0°C to 55°C
Mounting:	483mm Rack
MTBF:	Greater than 20,000 hours

UNIT SPECIFICATIONS

	DSU 520	DSU 1020	DSU 1520
INPUT			
Current (max)	5	8	12
Connection	Terminal	Terminal	Terminal
OUTPUT			
Power	500 VA	1000 VA	1500 VA
Connection	Terminal	Terminal	Terminal
RESERVOIR POWER (Internal)			
Backup Time	5 min.	15 min.	10 min.
Recharge Time	6 hrs. 100%	6 hrs. 100%	6 hrs. 100%
PACKAGE			
Height (mm)	277	400	623
Width (mm)	432	432	432
Depth (mm)	508	508	508
Net Weight (Kgrm)	635	1160	1705
Optional External Battery Reservoir 277x433x508 (mm)	RP520 - 1 hr.	RP1020 - 40 min.	RP1520 - 30 min.



APPENDIX III

MODIFICATIONS REQUIRED FOR COMPUTER INTERROGATION OF MONITOR UNIT

(a) General

In situations where there are critical loads, computer monitoring of the mains can be useful. If a computer itself is part of the critical load, it is not possible to recover meaningful data relating to mains disturbances using the computer alone. When combined with a Monitor Unit however, the operation of the monitoring system becomes independent of disturbances and the Monitor data can be accessed retrospectively. Data collected using such a computer interrogation method can be envisaged as an automatic method of updating a Monitor System Record as illustrated in Appendix I and discussed in Section 4.

This feature will be included in a Monitor Unit soon to be assigned to a multiple computer field installation used in a critical data-gathering role, and will allow possible data anomalies to be correlated with mains disturbances.

(b) Circuit modifications

If a computer is to be used to recover the data by interrogating the Monitor the following modifications should prove adequate. Reference is made to the simplified schematic in this Appendix and to the main circuit diagram (figure 5). There are advantages, especially in the computer situation, in providing an extra counter to allow separate measurements of accumulated overvoltage and undervoltage times to be logged, and this extra facility can be implemented by including a position 8 on the DISPLAY switch (SW12).

(c) Computer output requirements

Five bits are needed. Bits 1 to 4 form the appropriate counter-select input code to allow selection of any of the eight counters. Bit 5 is a computer-generated scanning clock pulse for the Monitor Unit which replaces the function of the internal scanner clock.

To retrieve data from a particular counter, it has been shown (in Section 2.4 above) that it is necessary to place a logic low on the wiper of S12a (the DISPLAY switch). This function is transferred to the computer when the the proposed COMPUTER/MANUAL switch is set to COMPUTER. This switch could conveniently be located on the front panel of the Monitor Unit.

In the COMPUTER position, the ICA2e and ICA2f tri-state buffers are held in their high impedance state, effectively open-circuiting the wiper connection to S12a (normally a logic low) and the internal scanner clock output line. Simultaneously, the external scanning clock input is passed via a TTL/CMOS buffer (VA1) and tri-state buffer ICA3e to the scanner clock line. The inverter, ICA4a, holds tri-state buffers ICA2a to ICA2d, and ICA3a to ICA3e active when COMPUTER has been selected.

The Counter Select Inputs (bits 1 to 4) are 1 of 10 decoded by ICA1 (a 7441), the open collector facility of which, with associated pull up resistors, provides the necessary TTL/CMOS interface. The outputs of the decoder are passed via the tri-state buffers to the Counter Output Enable (tri-state) lines. Any of the eight counters can be selected by applying the appropriate number (1 to 8) in binary form to the Counter Select Input, with 0 being used to blank the display when the unit is not being interrogated.

(d) Computer inputs

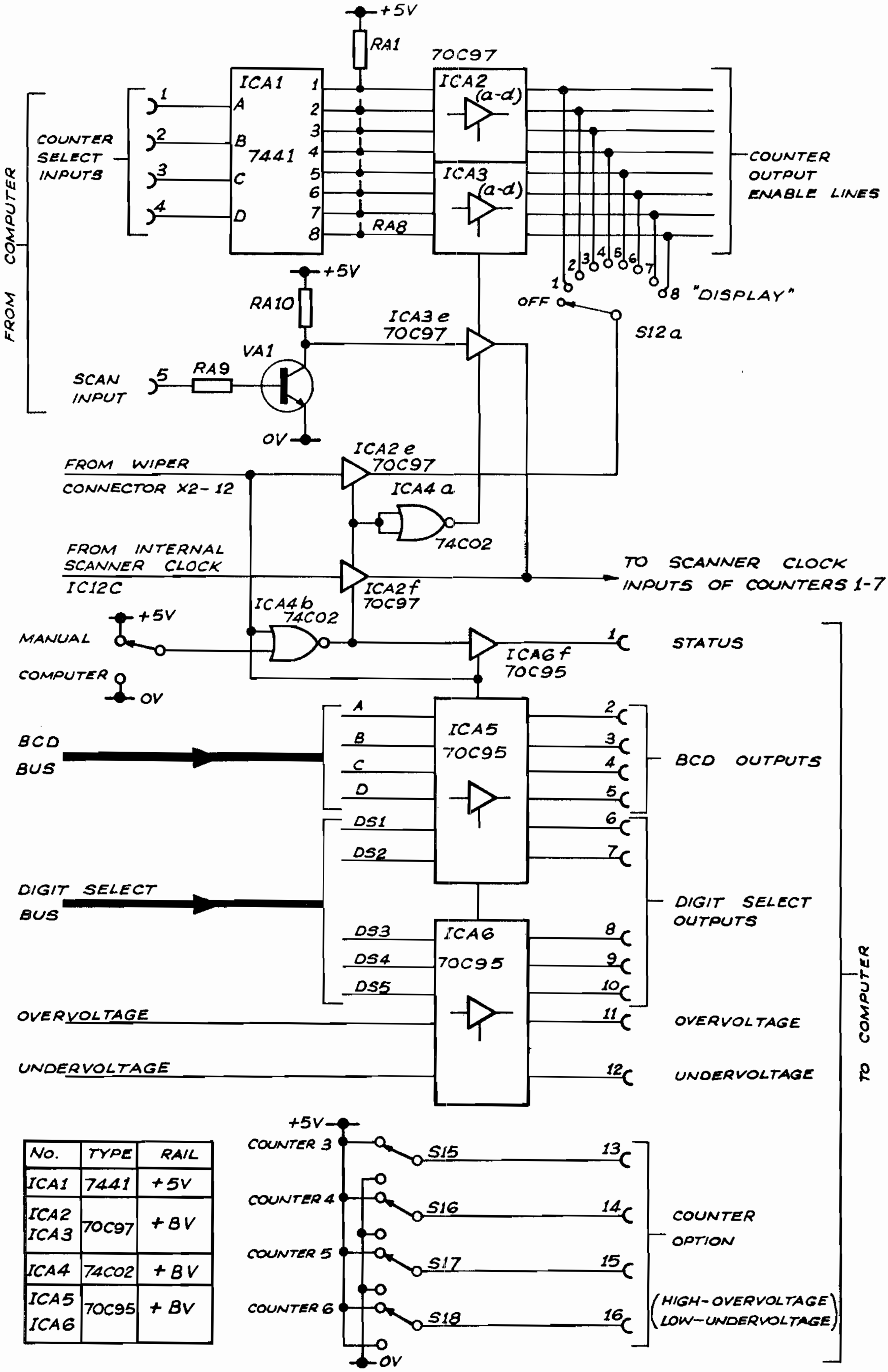
Sixteen bits are required. Bit 1 is a Status bit to identify the setting of the COMPUTER/MANUAL switch. Bits 2 to 5 comprise the buffered BCD data bus carrying the Monitor data. Bits 6 to 10 are the buffered digit-select lines, which (as explained in Section 2.4 above) will allow the computer to know which display digit is, at any instant, being represented on the BCD data bus. Bits 11 and 12 give the computer access to the Overvoltage and Undervoltage signals, thus allowing a degree of real-time monitoring of the mains voltage. Bits 13 to 16 allow the computer to assign the appropriate Overvoltage or Undervoltage label to the contents of each of the Counters 3 to 6. This can be achieved by switching a logic high or low, as appropriate, to bits 13 to 16, using the spare poles on S15 to S18 (the OVERVOLTS/UNDERVOLTS switches).

(e) Parameters not interrogated

The only other parameters required to completely define the configuration of the Monitor Unit are the settings of the Voltage Thresholds and Programmable Timers. The Voltage Thresholds are not available in digital form. The Programmable Timers' settings, although in digital form, are not considered sufficiently useful in the computer application to warrant the twenty necessary output bits which would allow them to be automatically examined; the data obtainable from the counters with Programmable Timers can be deduced from the Accumulated Time counters.

(f) Interface operation during mains failures

Should the mains supply to the Monitor Unit completely fail (or drop sufficiently to reduce the +5 V rail) when the system is in COMPUTER mode, the SW12a wiper signal will drive the output of ICA4b to a logic low and cause the Monitor to revert internally to MANUAL mode. This ensures that the display is blanked and that no invalid data is passed to the computer. At the same time, the SW12a wiper signal will drive the tri-state output buffers ICA5 and ICA6 into the high impedance state.



No.	TYPE	RAIL
ICA1	7441	+5V
ICA2 ICA3	70C97	+8V
ICA4	74C02	+8V
ICA5 ICA6	70C95	+8V

Figure III.1. Modifications for computer interrogation

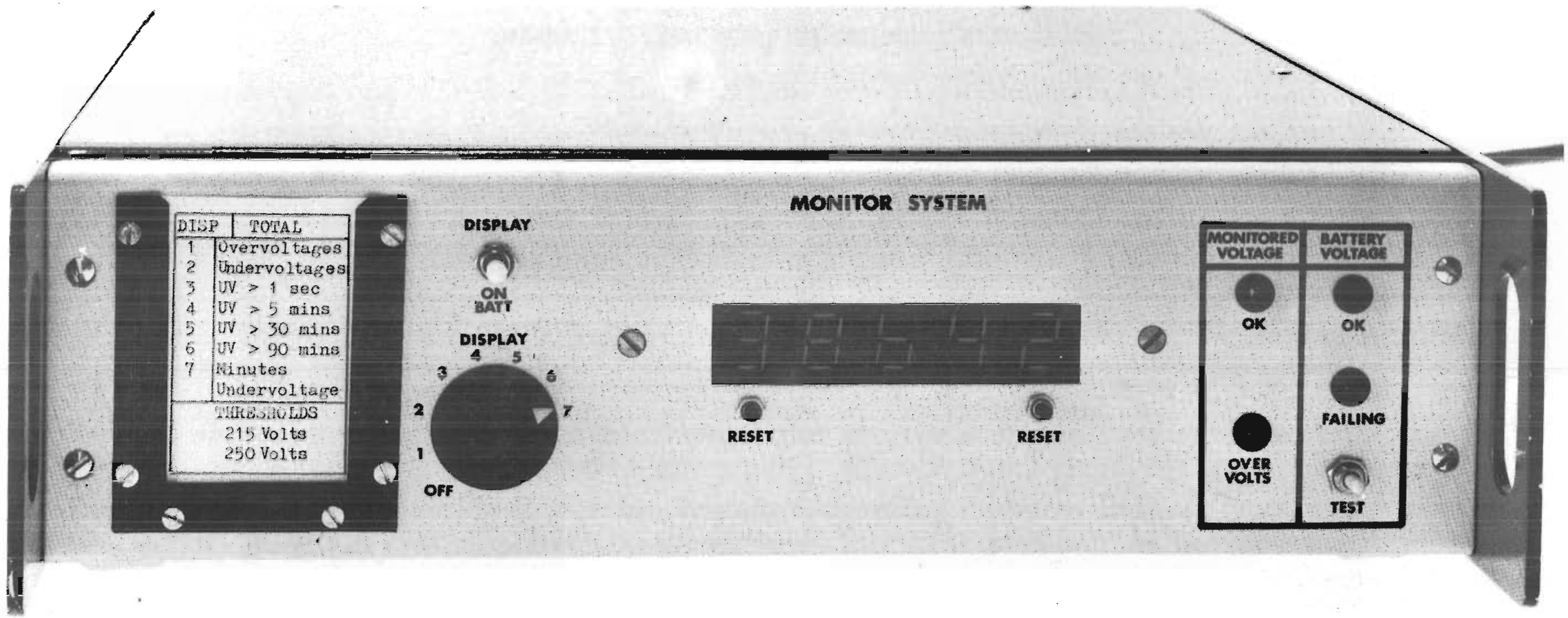


Figure 1. Photograph of Monitor (front view)

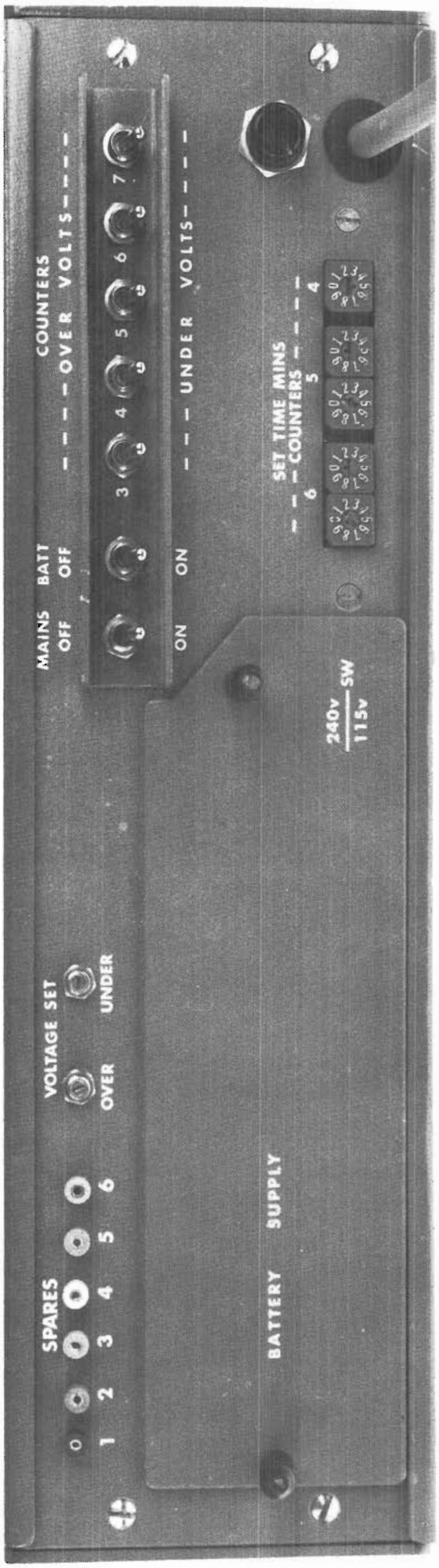


Figure 2. Photograph of Monitor (rear view)

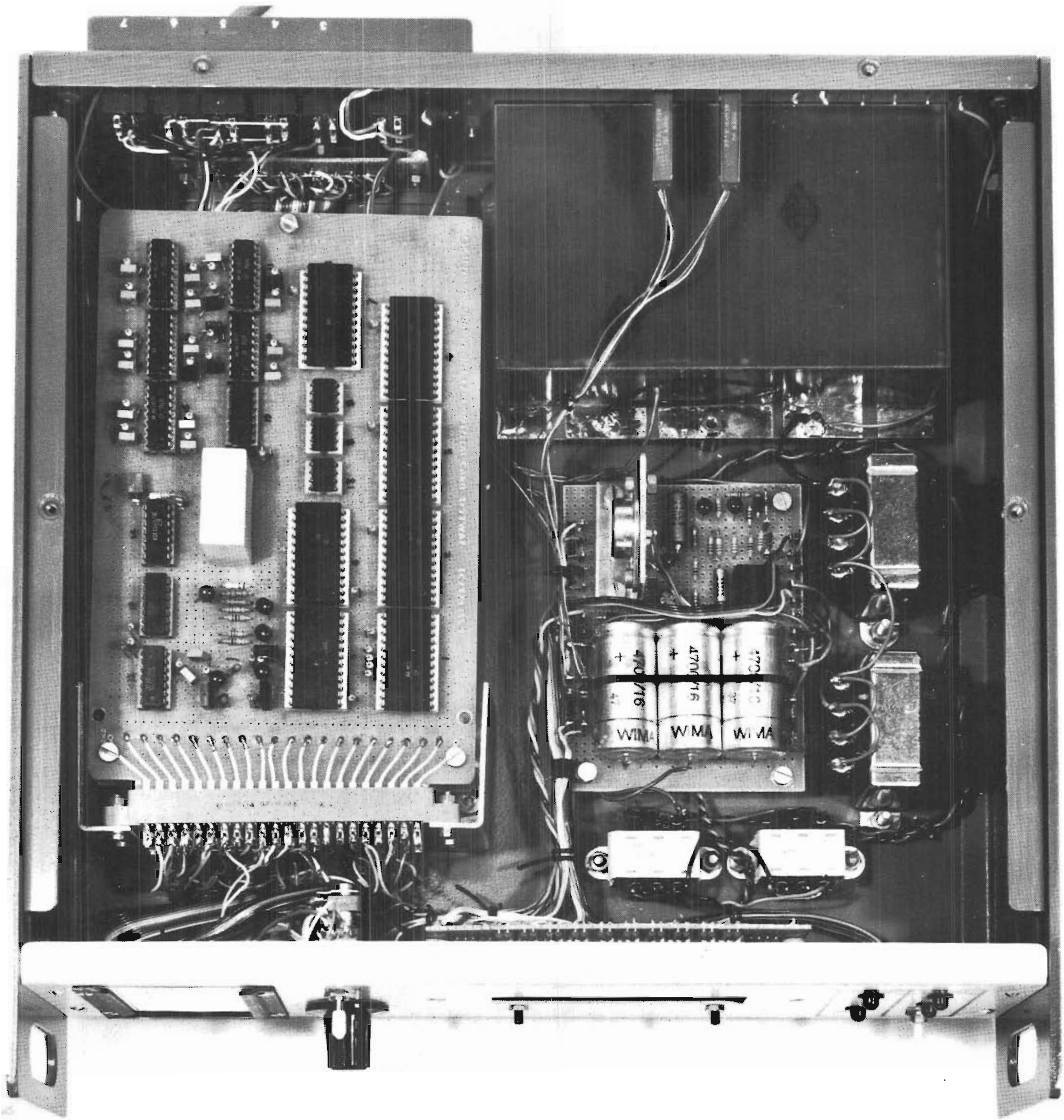


Figure 3. Photograph of Monitor (inside view)

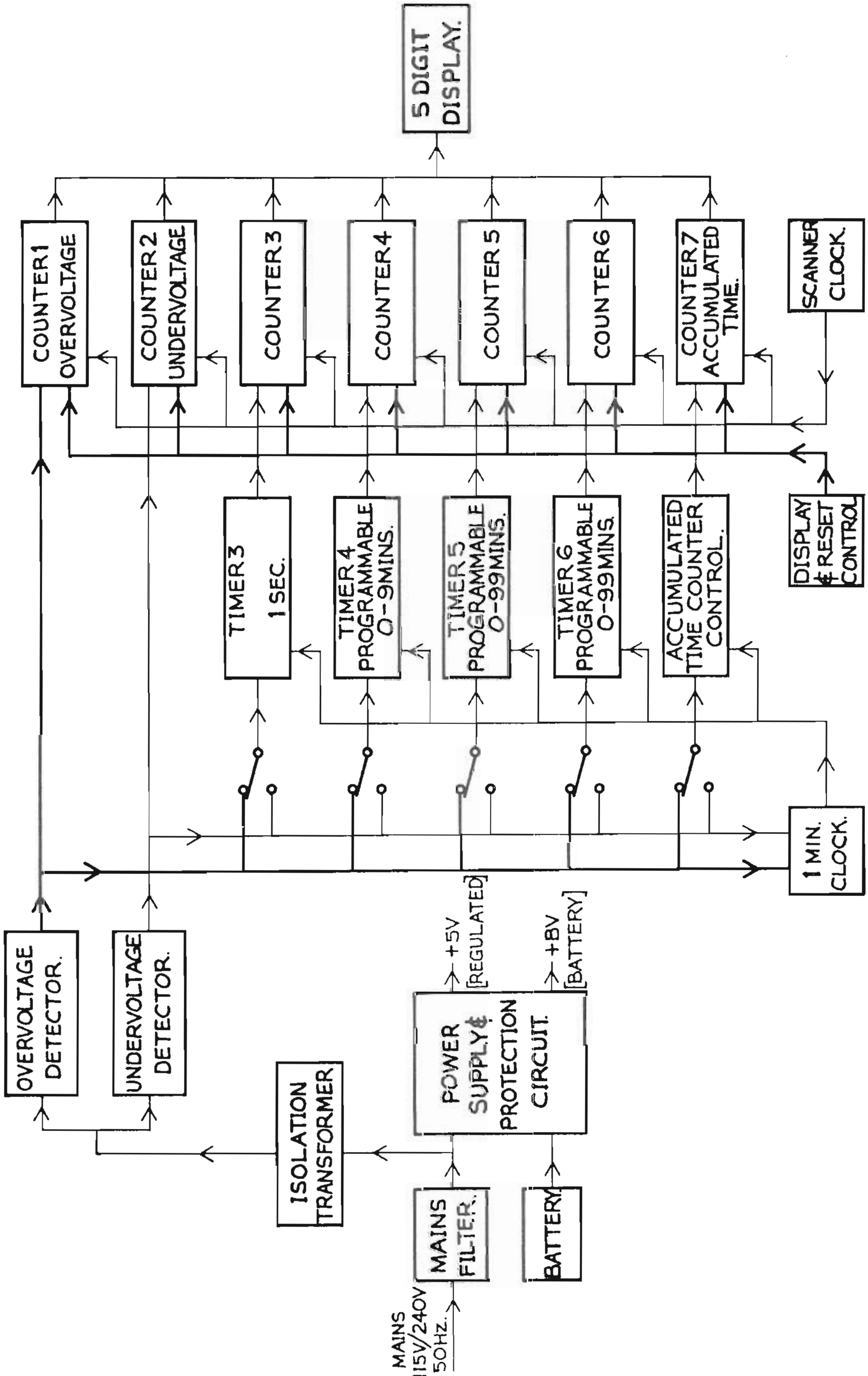
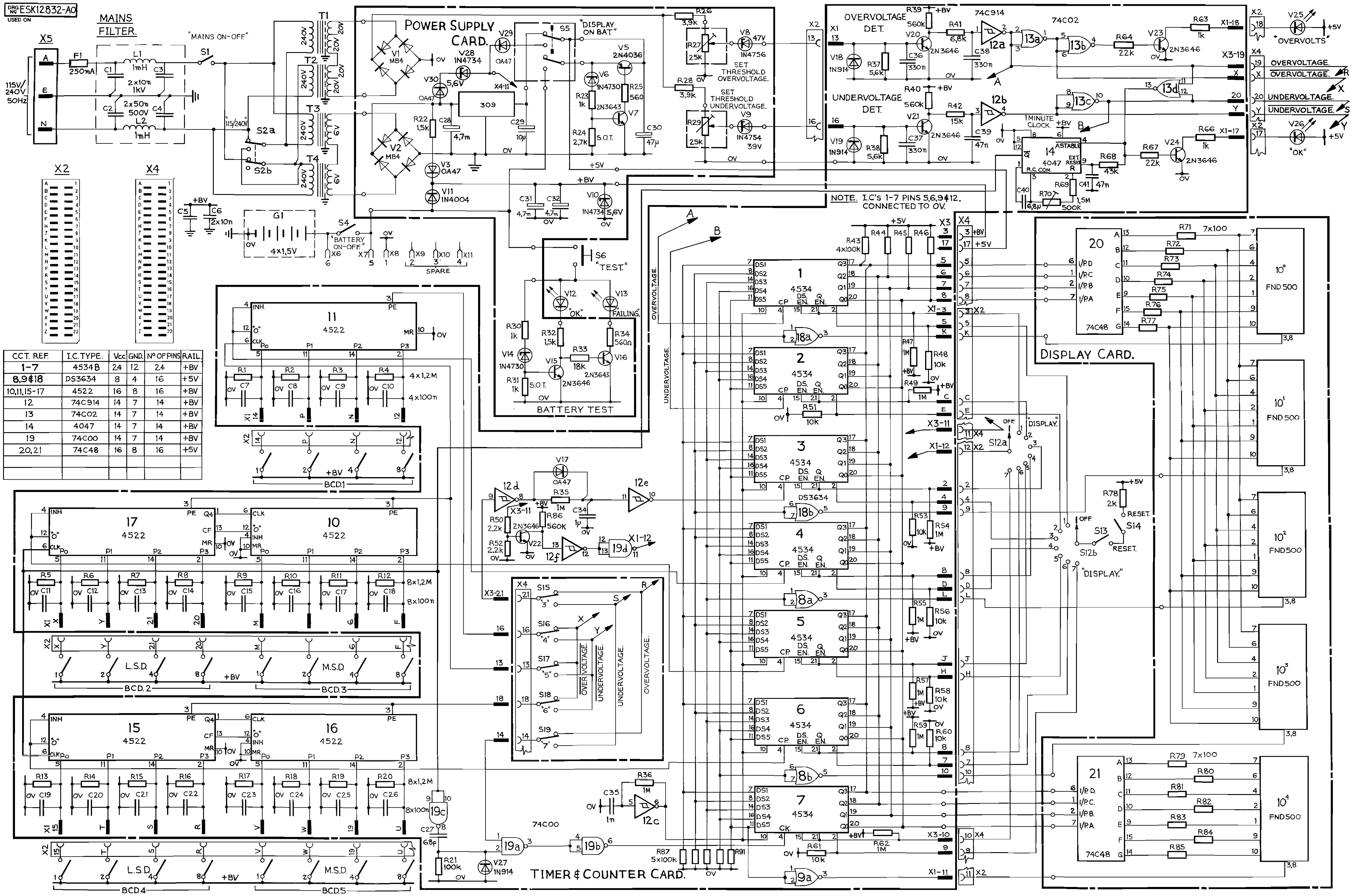


Figure 4. Block diagram of Monitor



CCT. REF.	I.C. TYPE.	Vcc	GND.	No OF PINS	RAIL.
1-7	4534B	24	12	24	+BV
8,9&18	DS3634	8	4	16	+5V
10,11,15-17	4522	16	8	16	+BV
12	74C914	14	7	14	+BV
13	74C02	14	7	14	+BV
14	4047	14	7	14	+BV
19	74C00	14	7	14	+BV
20,21	74C48	16	8	16	+5V

Figure 5. Schematic diagram of Monitor

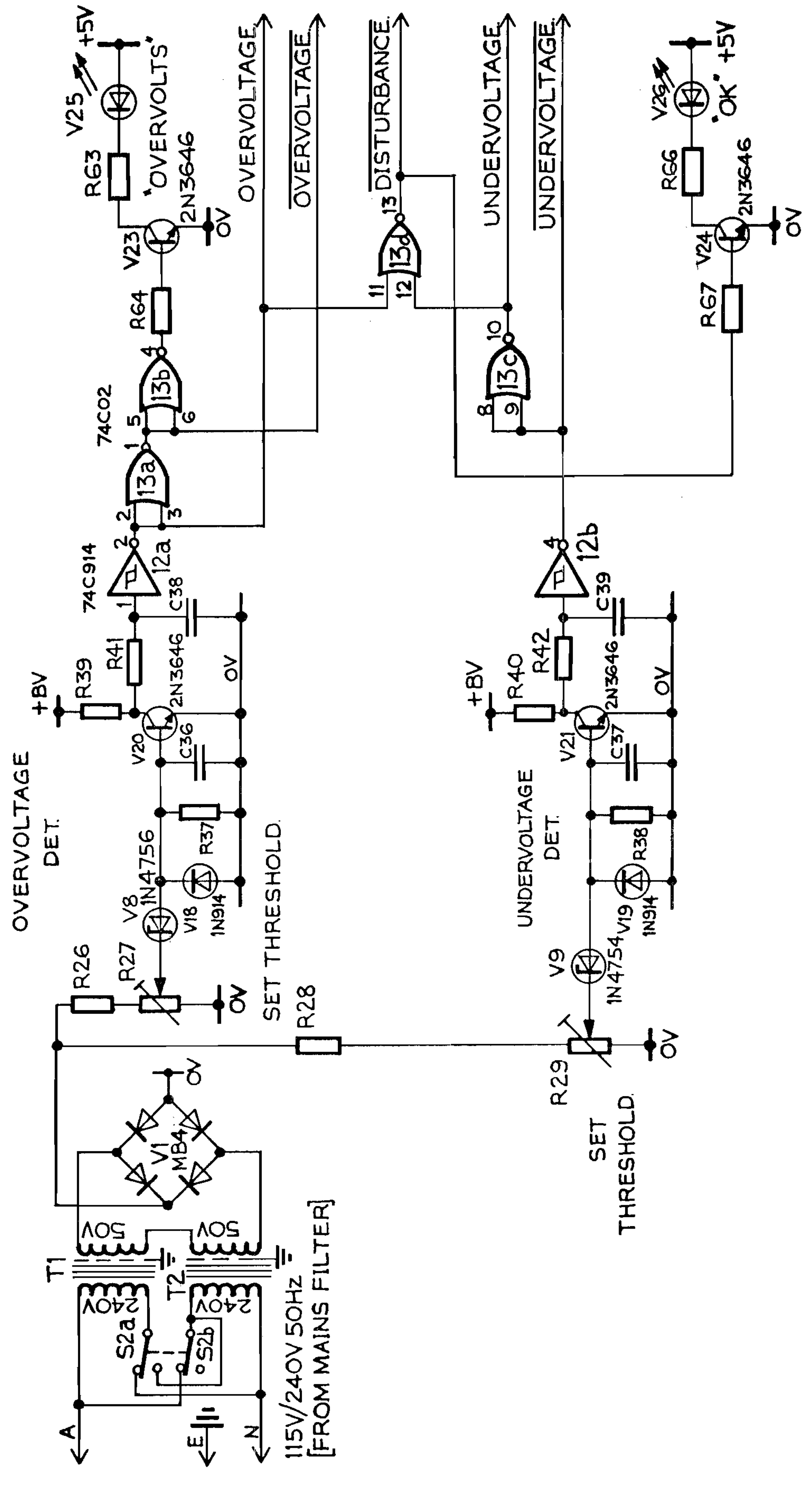


Figure 6. Overvoltage and undervoltage detectors (simplified schematic)

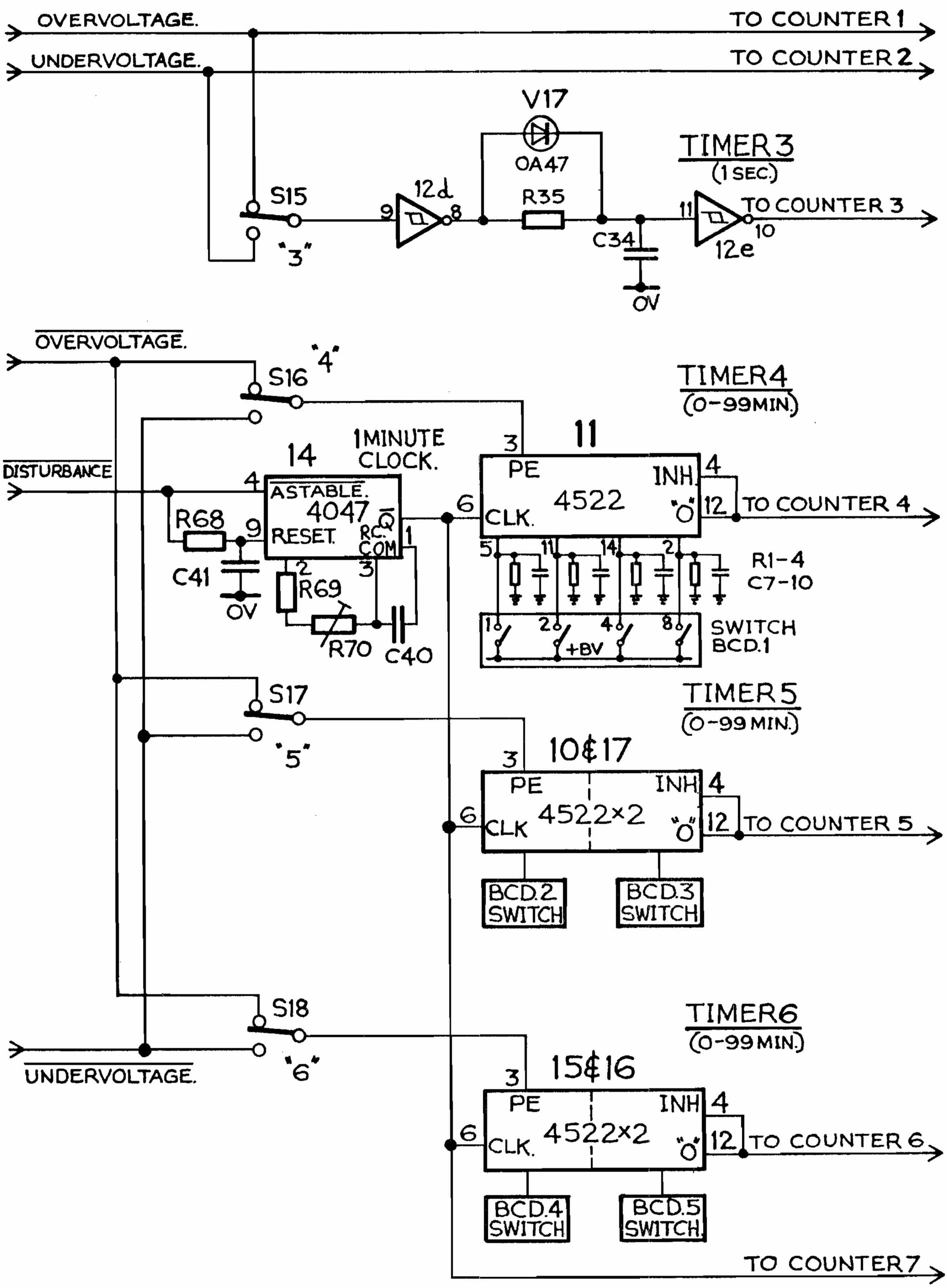


Figure 7. Programmable timers and 1 Minute Clock (simplified schematic)

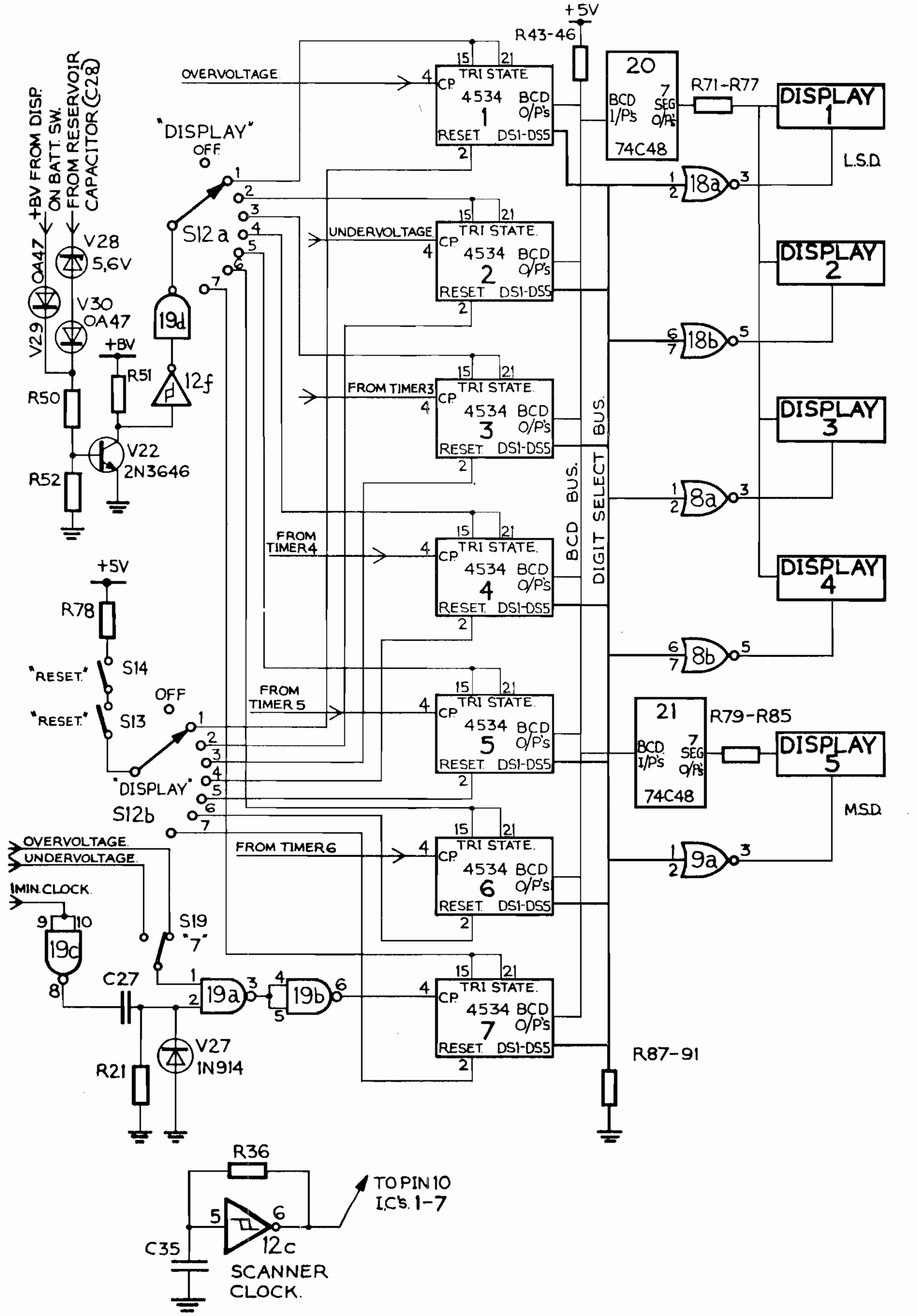


Figure 8. Counters and displays (simplified schematic)

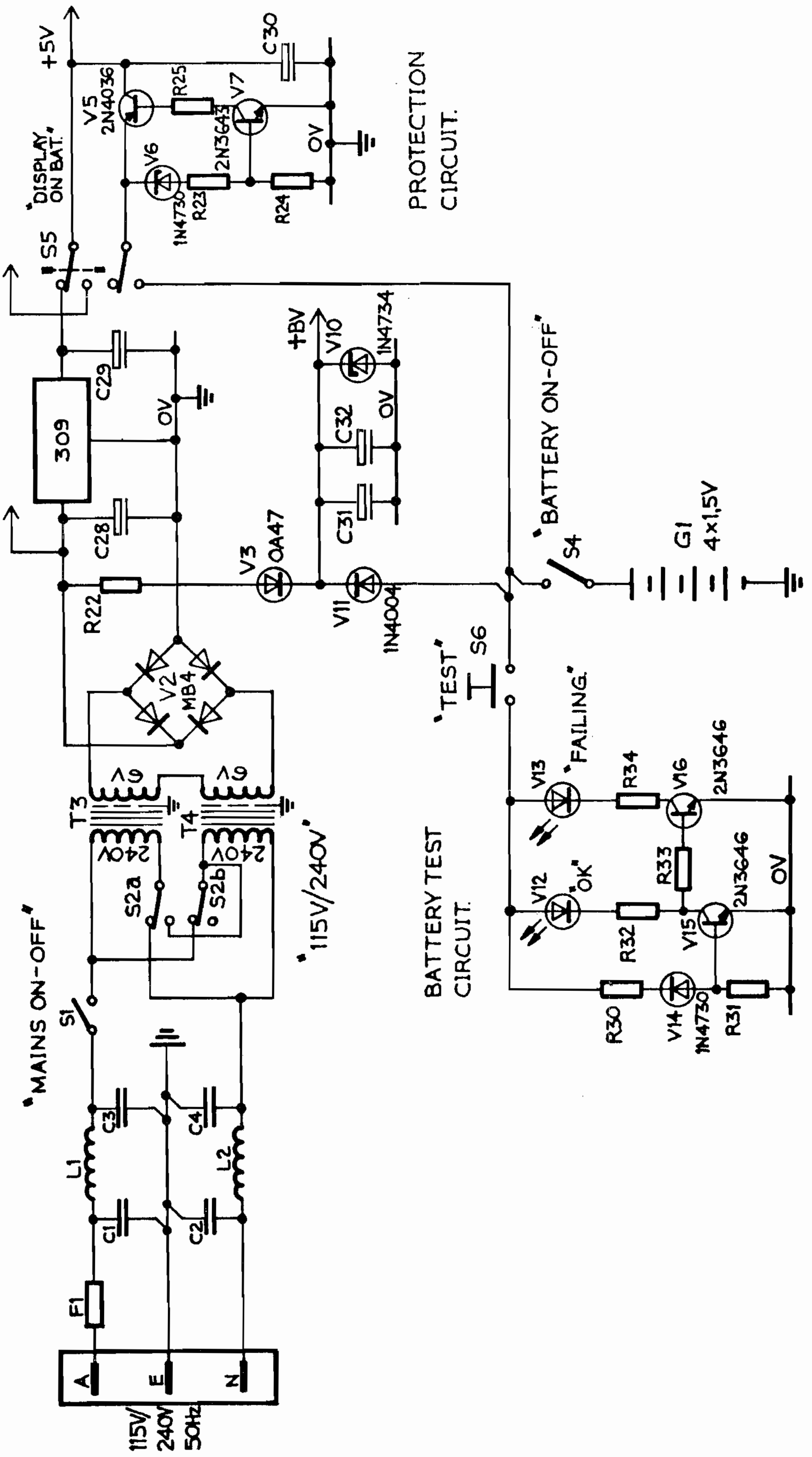


Figure 9. Power supplies (simplified schematic)

DOCUMENT CONTROL DATA SHEET

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A portable monitor system has been developed for automatically gathering data on the quality of electrical mains supplies. The equipment will store the number of times overvoltages or undervoltages occur in a chosen period, and will give a breakdown of the data into five disturbance-duration categories, plus an indication of the accumulated disturbance time.

The equipment is self-contained and requires no attention during the monitoring period, making it particularly useful for remote or unmanned sites.

Up to 100 000 excursions outside the preset thresholds can be tallied in any one period. The unit will continue to acquire and store data through extended mains failures for virtually the shelf life of its internal battery.

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