# ETI CONCEPT

## Robert Stevenson has built what has to be the ultimate mains controller project.

There are a number of mains controllers on the market and indeed many have appeared as projects in the pages of electronics magazines such as ETI.

However, the ETI concept is different. As well as comparing favourably with the cost of commercial devices, the Concept (COst meter aNd Computerised Electronic Programmable Timer) has many extras.

This device is based around a timer with four output channels, each programmable with up to seven on and off times to occur on any day of the week. A 'countdown' facility turns on or off an output after a preset time of between 1 and 99 minutes.

A software lock is also provided. This disables all normal keyboard functions until a programmable four digit 'PIN' number is entered.

A battery-backed RAM memory stores the software key, the programmed times and so forth.

The Concept doesn't even end there. This device also has four isolated digital inputs. When enabled from the keypad, these can overide the programmed switching on each channel.

Unique to such controllers is the Concept's cost measuring facility. The total power drawn by appliances plugged into the Concept can be displayed at any time. The charge rate is programmable and so the accumulated cost or the projected cost for that usage over a period of a day or a week can also be calculated and displayed.

### Design Considerations

The initial design used no CPU. It consisted of a CMOS counter circuit with a DIP switch programmed rate multiplier and a couple of op-amps.

Although this was a potentially workable design, the cost seemed out of proportion to the facilities. A timer facility seemed the answer. Although basing the circuit around a timer

IC such as the TMS1121 is straightforward enough, cost and simplicity demand the timer and cost circuitry share the same display and this complicates matters considerably.

Eventually the Concept was based around a cheap 1MHz 6502 microprocessor and as few peripheral chips as possible.

The power measurement circuitry of the concept is directly connected to the mains. So, for safety reasons two separate power supplies are provided for this and the CPU board.

Multi-tapped transformers are both more expensive and inherrently less safe than two separate standard mains transformers.

### Construction

The Concept is straightforward to build. The major decision required is that of a case. The type used will be partly determined by the front panel arrangement (See Fig. 1) but more so by the number and type of output sockets required. Domestic mains sockets take up a lot of room on the case back panel.

Whatever case is chosen, make sure the two preset resistors on the power board are easily accessable when the whole device is assembled.

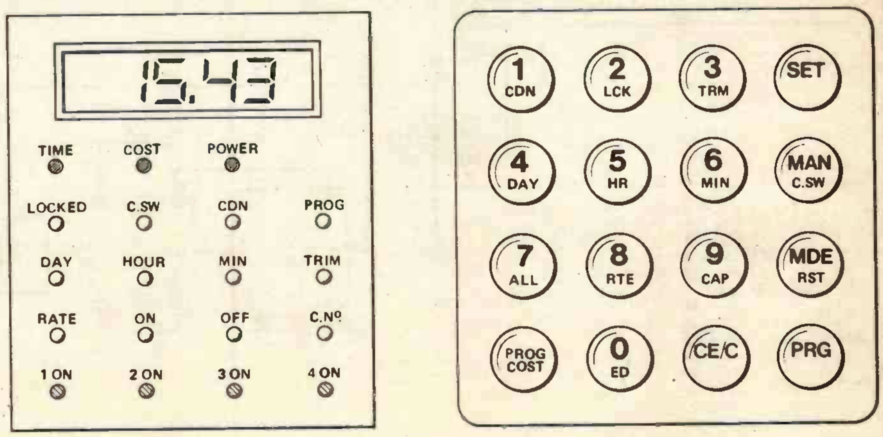



Fig. 1 The Concept front panel and keypad.

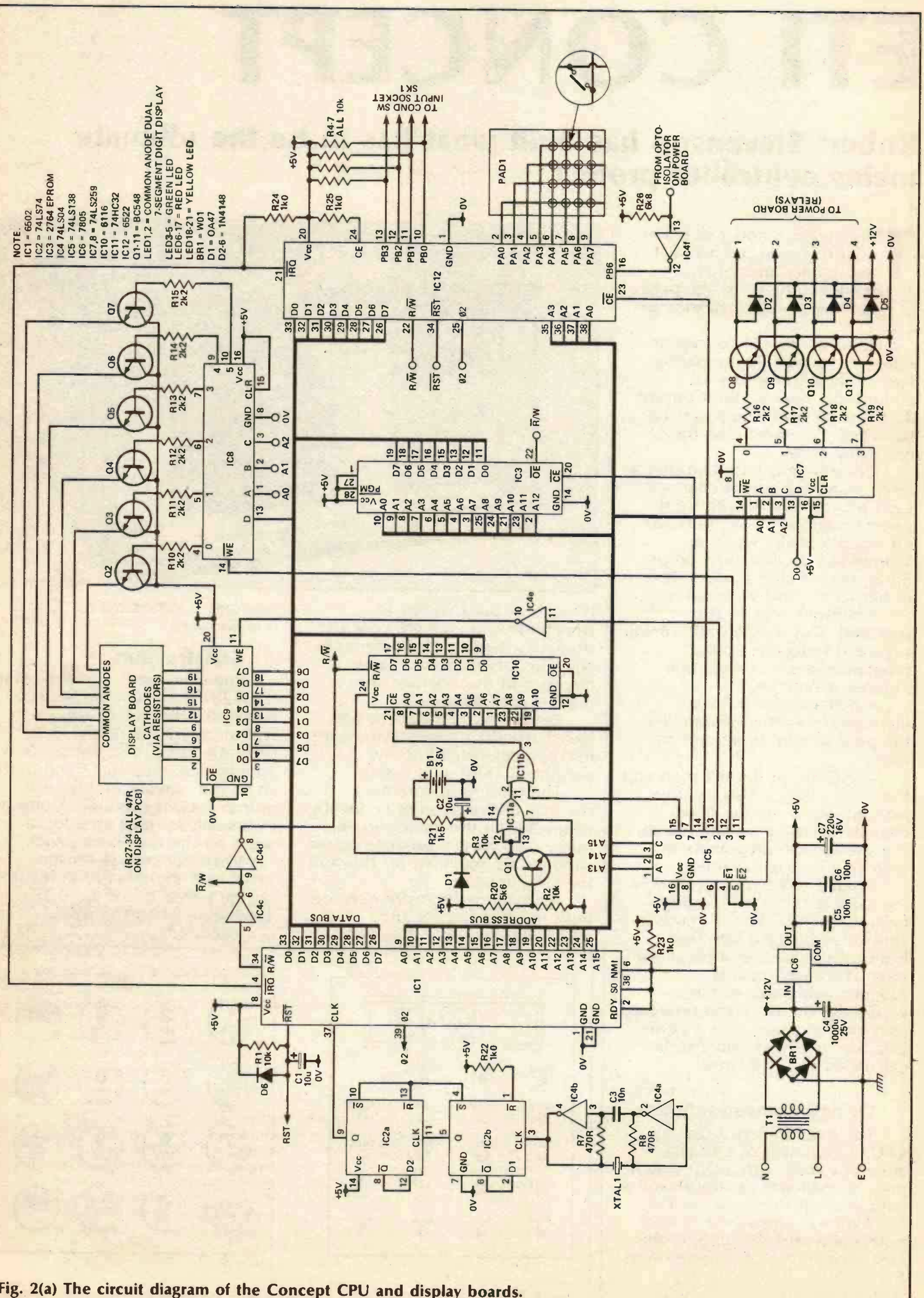



**Fig. 2(a) The circuit diagram of the Concept CPU and display boards.**

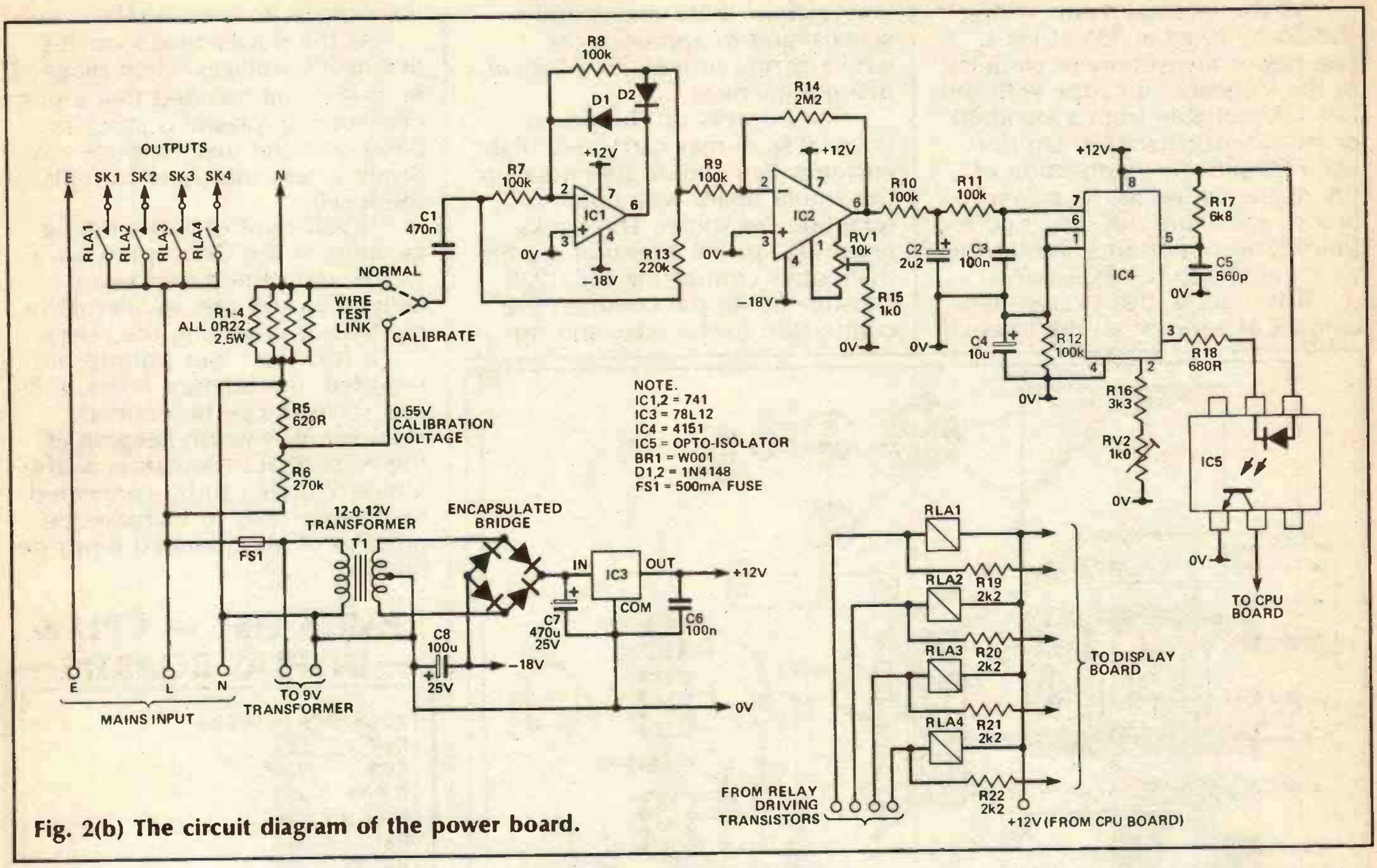



**Fig. 2(b) The circuit diagram of the power board.**

## HOW IT WORKS

Figure 2a shows the circuit diagram for the CPU board. The 7805 regulator (IC6) supplies the power. The unusually high value capacitors across the main 5V supply rail and the RAM supply (C7 and C2) ensure that any relay switching surges or mains 'brownouts' do not crash the processor.

The 74LS138 chip (IC5) performs the address decoding. The software resides in a 2764 EPROM which occupies the top 8K of memory. The battery backed RAM is located at the bottom of memory, from &0000 to &0800.

C1, R1, and D6 form a reset circuit that is used by the 6502 CPU and 6522 VIA. The processor requires a 1MHz clock signal and this is provided by IC2 and IC4. IC4a and b form a 4MHz crystal oscillator, the output of which is divided by IC2 to produce the 1MHz signal. The clock input of the 6522 is taken from the CPUs anti-phase clock output $\phi 2$ (pin 39).

The RAM select line from IC5 is ORed with a SUPPLY AVAILABLE signal derived from the transistor circuit of Q1. This OR gate arrangement ensures that the $\overline{CE}$ input of the RAM is held high when the main 5V supply rail is switched off. This puts the RAM in standby mode and prevents memory corruption.

D1 is a germanium device rather than a silicon type because it has a lower forward voltage drop which allows the RAM to work at very near the same voltage as the rest of the memory and provides an optimum charging potential for the NiCd battery.

The current consumption of the RAM and IC11 is very small — when fully charged, the NiCd battery has the capacity to preverve the contents of the RAM for at least a year.

The relay-driving transistors (Q8-11) are switched by the lower four outputs of an eight bit addressable latch 74LS259 (IC7). Diodes D2-D5 protect the transistors from inductive spikes when the relays are switched off.

The multiplexed LED display is driven by another addressable latch (IC8) via six transistors (Q2-7) which supply current to the common anodes.

The cathodes are connected via 47R resistors to IC9, which is an 8-bit D-type latch. The software latches a bit pattern into IC9 then switches on the appropriate anode driving transistor. Every 5ms the transistor is switched off, a new bit pattern is latched and the next transistor is turned on.

The 6522 VIA chip is the Concept's only input IC and it is used to generate interrupts which among many other things, form the basis for the software's real time clock.

The software contains a large proportion of interrupt service code, of widely varying priorities. The real time clock is the highest priority, followed by the display multiplexing routines. Lower priority routines include checking the programmed timer memories and scanning the inputs from the conditional switching port.

The keyboard is connected to the VIA I/O port A. Four lines of port B (PB0-PB3) are connected to the conditional switching socket SK1. Most 6522 applications utilise port B as a simple I/O port but the VIA has an internal counter which can be configured to count down every time PB6 is pulsed low. The Concept utilises this feature to provide a means of measuring the frequency of pulses from the power measurement circuitry. The frequency is directly proportional to the power consumption of the appliances connected to the Concept. The pulses come from an opto-isolator on the power boards (Fig. 2b). R26 pulls up the open collector of the isolator, and IC4f converts the signal to TTL specifications.

Power consumption is determined by measuring the AC current being supplied to the appliances. A very low value resistor, consisting of four 0.22R resistors in parallel, is connected in series with the neutral lead. The voltage drop across this resistor is amplified and precision rectified by two operational amplifiers, ICl and IC2. The output from the second amplifier is smoothed by R10, C2, R11 and C3.

RV1 provides a fine offset adjustment to zero the output and compensate for any circuit noise.

The smoothed output voltage, which varies from about 1mV to 5V, is connected to a voltage-to-frequency converter, IC4. The open collector output from this device is used to drive the opto-isolator. RV2 is used to calibrate the converter. Calibration sets the full scale frequency of the converter to ten times the power consumption in watts so a power consumption of 3000W produces a frequency of 30kHz.

All the internal mains wiring should be rated at 10A at least. The power measurement circuitry of the Concept can cope with the full 13A available from a standard domestic mains socket. Do not use PCB pins for connection of the mains wiring to the power board. These are not designed for these kind of currents. Solder the wire directly to the PCB track.

It is a good idea to use many colours of wire for all the internal connections (both mains and signals) and to approach the whole wiring process in a logical, planned manner.

Some tracks on the power board (Fig. 3) may carry very high currents. You should therefore tin the whole board with copious quantities of solder. The tracks requiring special attention are the thick ones connecting the 0.22R resistors (R1-4), the common live connection to the relay and the live output from each relay.

As the power board carries live mains voltages when plugged in, it is recommended that a piece of insulating plastic is stuck in place over the fuse (but not too firmly — you may have to replace the fuse!).

If you want only the timing facilities of the Concept (what a waste!) omit the power board altogether and use an alternative method of mounting the relays.

If less than four outputs are required, the relevant relays, LEDs and so forth can be omitted. However, it is worth keeping all the relay driver transistors as the 'unused' ones can be connected to another relay to increase the number of programmed times per output.

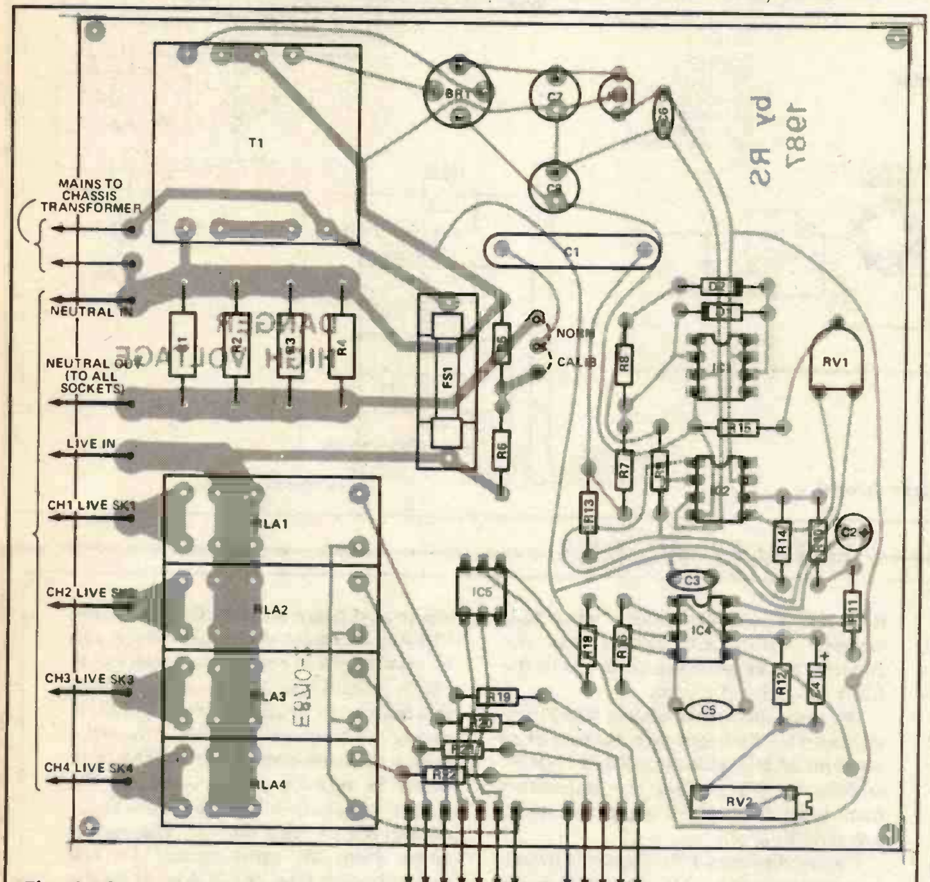



Fig. 3 The power board component overlay.

## PARTS LIST — POWER BOARD

| | |
|---|---|
| **RESISTORS (¼W 5% unless specified)** | |
| R1-5 | 0.22R 2½W |
| R5 | 620R 1% |
| R6 | 270R 1% |
| R7-12 | 100k |
| R13 | 220k |
| R14 | 2M2 |
| R15 | 1k0 |
| R16 | 3k3 |
| R17 | 6k8 |
| R18 | 680R |
| R19-22 | 2k2 |
| RV1 | 10k horiz. preset |
| RV2 | 1k0 multiturn preset |
| **CAPACITORS** | |
| C1 | 470n polyester |
| C2 | 2μ2 16V radial electrolytic |
| C3,6 | 100n ceramic |
| C4 | 10μ 16V axial electrolytic |
| C5 | 560p polystyrene |
| C7 | 470μ 25V radial electrolytic |
| C8 | 100μ 25V radial electrolytic |
| **SEMICONDUCTORS** | |
| IC1,2 | 741 |
| IC3 | 78L12 |
| IC4 | 4151 |
| IC5 | 6 pin opto-isolator |
| BR1 | W001 |
| D1,2 | 1N4148 |
| **MISCELLANEOUS** | |
| FS1 | 500mA fuse and PCB mount holder |
| RLA1-4 | 12V 16A relay |
| SK1-4 | 13A 3 pin mains sockets |
| T1 | 12-0-12 3VA PCB mount mains transformer |

PCB; connecting wire; mains cable; nuts and bolts.

## PARTS LIST — CPU & DISPLAY BOARDS

| | |
|---|---|
| **RESISTORS (¼W 5%)** | |
| R1-7 | 10k |
| R8,9 | 470R |
| R10-19 | 2k2 |
| R20 | 5k6 |
| R21 | 1k5 |
| R22-25 | 1k0 |
| R26 | 6k8 |
| R27-34 | 47R |
| **CAPACITORS** | |
| C1,2 | 10μ 10V tantalum |
| C3 | 10n ceramic |
| C4 | 1000μ 25V radial electrolytic |
| C5,6 | 100n ceramic |
| C7 | 220μ 16V radial electrolytic |
| **SEMICONDUCTORS** | |
| IC1 | 6502 |
| IC2 | 74LS74 |
| IC3 | 2764 EPROM |
| IC4 | 74LS04 |
| IC5 | 74LS138 |
| IC6 | 7805 |
| IC7,8 | 74LS259 |
| IC9 | 74LS373 |
| IC10 | 6116 |
| IC11 | 74HC32 |
| IC12 | 6522 |
| Q1-11 | BC548 |
| LED1-2 | common anode dual 7-segment digit display |
| LED3-5 | green LED |
| LED6-17 | red LED |
| LED18-21 | yellow LED |
| BR1 | W01 |
| D1 | OA47 |
| D2-6 | 1N4148 |
| **MISCELLANEOUS** | |
| PAD1 | 16 key switch pad |
| T1 | 9V 20VA mains transformer |
| XTAL1 | 4MHz crystal |
| SK1 | 5 pin DIN socket |
| B1 | 3.6V PCB mounting NiCd battery. |

PCBs; case; connecting wire; keypad connector; IC sockets; T05 heatsink for BR1; nuts and bolts.

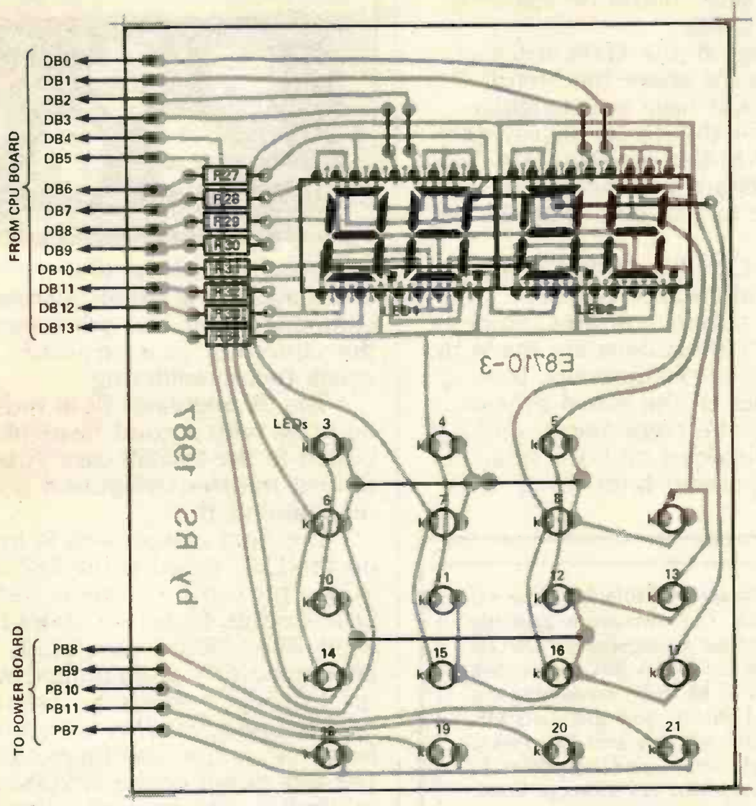
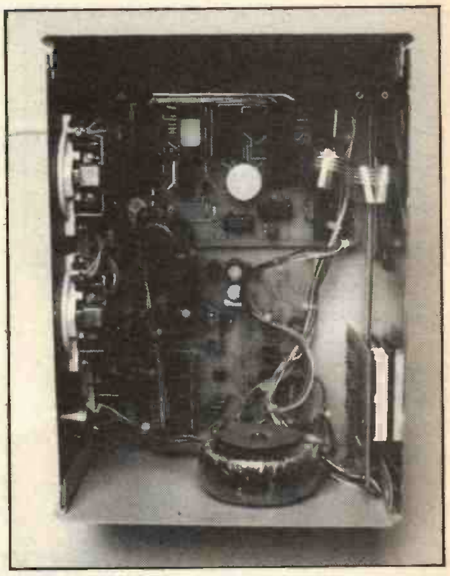
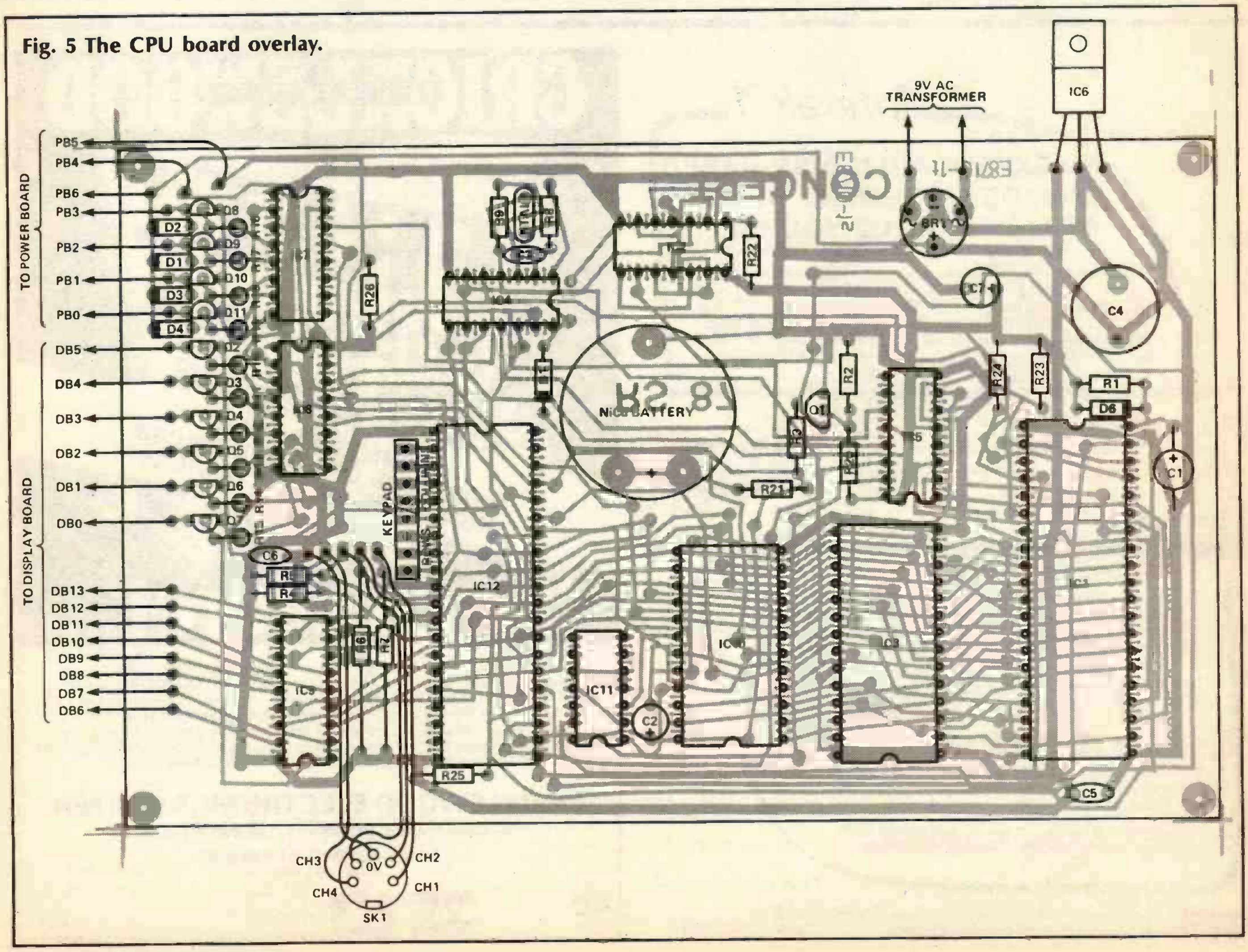


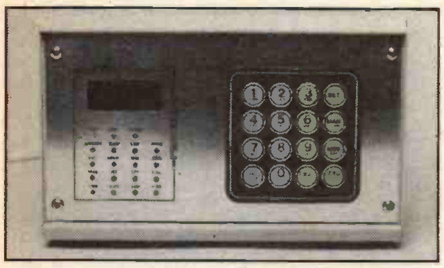

Fig. 4 The overlay for the display board.



The insides of the Concept prototype. Panel mounting mains sockets were chosen for the prototype because they take up less room on the back panel than normal pattress-mounting sockets. Alternative design, non-standard sockets could also be used to make the Concept more compact. Make sure the two calibration preset pots on the power board (RV1 and RV2) are easily accessible when the whole unit is assembled, as they are here.

Fig. 5 The CPU board overlay.



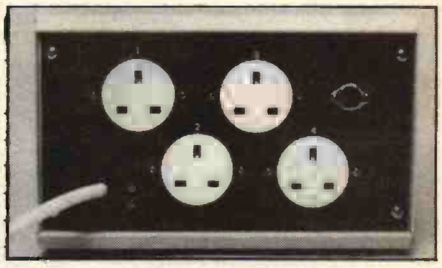


The display board (Fig. 4) contains the 19 display LEDs and the two dual digit 7 segment displays. The latter should not be directly soldered to the board but mounted in 'soldercon' type sockets.

Note that three links are required underneath the digital displays and should be soldered in first of all.

Solder all the LEDs at the same height above the board. The case should have a rectangular cutout for the digital display and 19 holes drilled for the LEDs. The display board will then sit in position, largely held there by the LEDs.

The CPU board (Fig. 5) is double sided and requires through connection pins. Some through connections are made by the leads of components. Look at both sides of the board as you solder in the components and if a pad is provided on both sides of the PCB, solder both sides.



Note that all the ICs, electrolytics and other polarised components are *not* orientated the same way. Take care and check before soldering.

The 5V regulator (IC6) must be fitted with a good heatsink or bolted to the (metal) case. A blob of heat transfer compound is also recommended.

The final component to install on the CPU board is the EPROM (IC3). This can be either a 2764 or 27128 and an IC socket should be used. The EPROM should, of course, be first programmed with the Concept's operating system. Programmed EPROMs are available from the author (see Buylines). The hex dump of the EPROM and calibration and operation details will be given next month.

**ETI**

## BUYLINES

**Despite its complexity, the vast majority of the components used in the Concept are easily available from usual sources.**

**The prototype used case 501-597 from Electromail (Tel: (0536) 204555). The PCB mounting transformer for the power board also came from Electromail (part 207-835) as did the relays (part 346-269).**

**Any 4x4 keypad may be used or one made up from individual key switches.**

**The PCBs are available from the ETI PCB service. The software is available from the author. A programmed EPROM is available for £15. A BBC micro disk (specify 40 or 80 track) containing the source and object code also costs £15. Both EPROM and disk cost £20. Please address all orders and enquiries to Robert Stevenson, 229 Vicarage Road, Leyton, London E10 7HQ.**