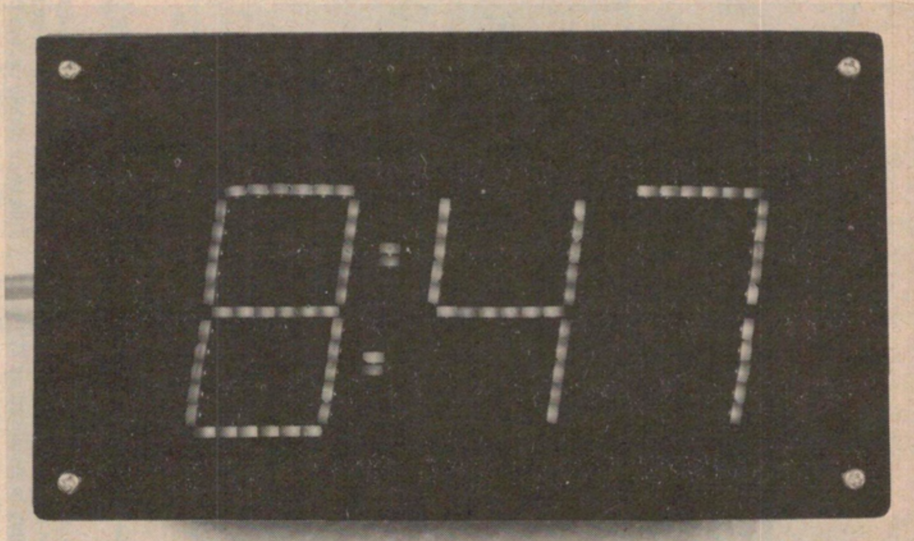
Digital clock features huge display

Here's just the thing for the kitchen, workshop, garage or shack — anywhere in fact, you need a digital clock that just can't be missed!

Barry Wilkinson



ISN'T IT just what you've always wanted — a digital clock with a decent sized display? Seeing the time at a glance is convenient in many situations and that's just what this clock has been designed for. The display features three seven-segment digits for the 'minutes units', 'minutes tens' and 'hours units' plus a single column '1' for the 'hours tens' displays. Each segment in the individual displays is made up of a string of LEDs connected in series. Each vertical segment contains five individual LEDs, while each horizontal segment contains six. Overall height of the display is around 60 mm.

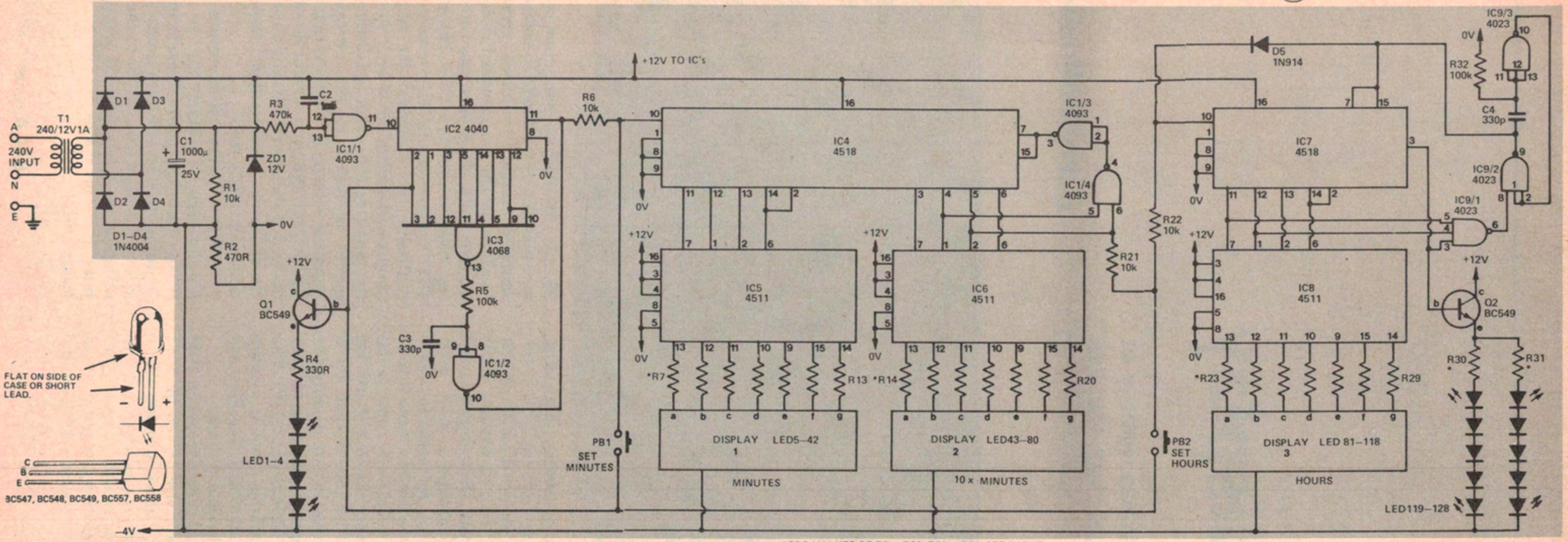
We used rectangular LEDs as they provided by far the best looking display compared to the more familiar round LEDs. Suitable rectangular LEDs are made by a number of manufacturers and are readily available through a variety of suppliers. A 'flashing colon' between the hours and minutes digits is provided to reassure you that the clock is going! However, as a binary divider clocking from the mains is used to drive the clock, a one-second output is unfortunately not available and so the next best output was chosen. This proved to be a division of 32 and thus, from 50 Hz, a pulse every 1.56 seconds is obtained and this is used to flash the colon.

Design

There are a number of interesting aspects to the design of this digital clock. For a start, conventional CMOS binary dividers have been used in preference to one of the special clock divider chips. The latter are very handy, no doubt about that, but they are incapable of driving a large sized display like the one used here. Firstly, the voltage drop across each segment of the multi-LED display varies depending on the type and colour of LED used. Whilst we have used red LEDs, which have a voltage drop of around 1.6 V each, red or yellow LEDs may be used and these have around a 2.1 V drop each. The Philips rectangular LEDs type CQX10-2 are red but have a voltage drop of 2.1 V too while some of the new 'high efficiency' LEDs also exhibit a 2.1 V drop. This means that, for a horizontal segment in our display the maximum voltage drop may be as high as 12.6 V (six LEDs times 2.1 V). The clock chips available cannot readily cope with this but CMOS decoders can be arranged to do what we want.

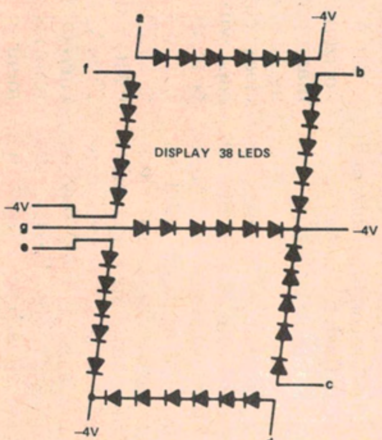
You will notice from the circuit that the LED segments are driven by 4511 CMOS decoders which provide up to 25 mA per segment, with the actual current being determined by current limiting resistors. The current per segment in our circuit is limited to around 20 mA. However, the maximum voltage across CMOS is limited to 15 volts and a supply of around 18 volts was necessary to allow for the drop across the display segment plus the drop across the limiting resistor and the 1.5 V lost in the 4511 output circuit. To overcome this difficulty, we stabilised the negative supply rail for the CMOS to 12 volts and the negative side of all the display segments is taken to the *unregulated* negative supply. The zener action of the LEDs (i.e: there is no current flow below about 1.4 volts per LED) the outputs of the 4511s are never 'pulled' below their negative supply rail.

To obtain a 'clean' 50 Hz square wave for accurate clocking, the ac input (taken from the power transformer) is 'squared-up' by a 4093 two-input NAND gate. This device is similar to the 4011 except that it has Schmitt trigger inputs and this helps to prevent false triggering. ▶



*FOR VALUES OF R7 – R20, R23 – R31, SEE TABLE.

NOTE: rectangular LEDs have one lead longer than the other. The longest lead is the anode.



A total of 38 LEDs are used in each seven-segment display. Each of the vertical segments uses five LEDs, while the horizontal segments use six.

HOW IT WORKS ETI-564

The power supply is simply a 12 V output transformer, full-wave rectified and filtered by C1. The IC supply is stabilised by ZD1 to 12 volts. For timing, the ac voltage is coupled to the input of IC1/1 via R3, with C2 providing some filtering to prevent false counting. The value of R3 protects IC1/1 against input damage as the ac voltage exceeds the supply rails of the ICs. IC1 is a 4093, which is a two-input NAND gate, similar to the 4011, except that it has Schmitt trigger inputs, and this helps to prevent false triggering with the output of IC1/1 being a clean 50 Hz square wave.

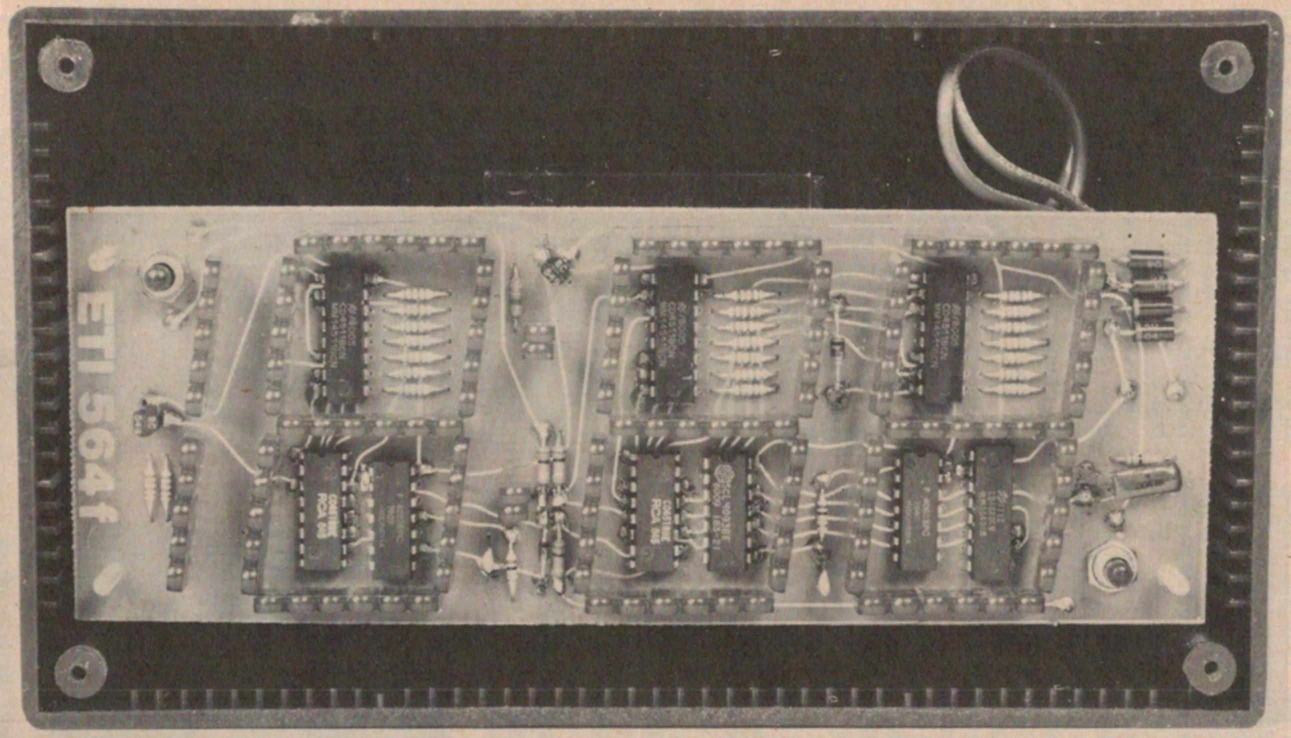
As the first digit is the minutes display, a division of 3000 is needed. For this IC2, 3 and IC1/2 are used. IC2 is a 4040 which is a 12-stage binary divider. The outputs of the 4th, 5th, 6th, 8th, 9th, 10th and 12th stages are decoded (when all are high) and the counter reset at that time to provide a division ratio of 3000 (binary 101110111000). This is detected by IC3 whose output gos low on that number. After a short delay (about 30 us) due to R5/C3 the output of IC1/2 will go high, resetting IC2. This immediately causes the output of IC3 to go low but, again due to R5/C3, the output of IC1/2 will remain high for about 20 us, ensuring correct resetting and the clocking of the minutes counter.

An output of IC2 (pin 2) is used to drive the colon and to provide the clock for the fast set modes. Unfortunately, exactly one second is not available using a binary divider so we chose the 1.56 second (50/32) output.

The output of IC1/2 (a 20 us pulse once per minute) clocks IC4 which is a dual decade (10) counter. The first half is used as a ÷10 and its output is decoded by IC5 to give the minutes display. The second half is clocked by the output of the first (10 minutes) and is decoded by IC6 to display the tens of minutes. As time has yet to be decimalised (!), we have to reduce the second half from ÷10 to ÷6. This is done by IC1/4 which detects when the 2nd and 3rd outputs are high (binary 0110) and resets it to zero.

The third output is used to clock the hours counter, IC7. This, like IC4, is a dual decade counter with the first half being decoded by IC8 and the second being clocked by the output of the first. As only a simple "1" is needed for the tens of hours (12 hour clock) no decoder is necessary, only a buffering transistor. IC9 is used to decode when IC7 reaches decimal 13 (0001 0011 binary) and this triggers a monostable formed by IC8/2,3. This is used to reset IC7 to zero hours, but, as there is no zero hour in the 12 hour system we need a reset to "1". This is done by the diode D5, which pulls pin 10 high for the duration of the reset pulse and allows it to fall back again — a few microseconds (delayed by stray capacitance) after the reset pulse, clocking it on to 1.

Fast setting is done simply by injecting, by the use of push buttons, the 1.5 second pulse directly into the minutes or hours counters.



The pc board patterns are on page 137

PARTS LIST — ETI-564

Resistors all ¼W, 5%

R1,R6,R21,R22	10k
R2	470R
R3	470k
R4	330R
R5, R32	100k
R7 - R20	see Table 1
R23 - R31	see Table 1

Capacitors

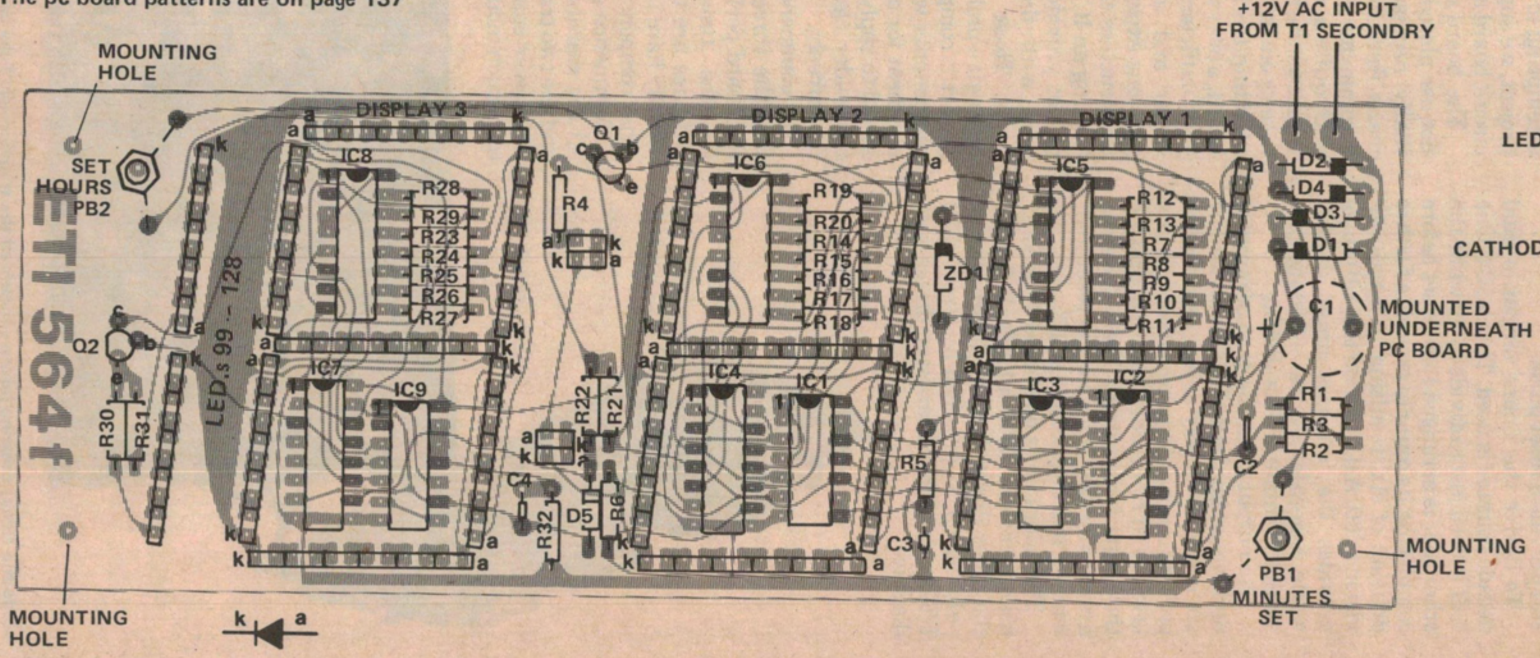
C1	1000u, 25 V pc electro
C2	4n7 polyester
C3 C4	330p ceramic

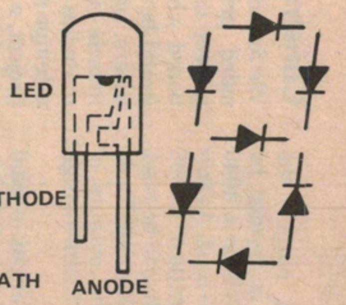
Semiconductors

IC1	4093
IC2	4040
IC3	4068
IC5, 6, 8	4511
IC9	4023
Q1, Q2	BC549
D1-D4	1N4004
D5	1N914
ZD1	12 V, 400 mW zener
LED1-128	LEDs (see text)

Miscellaneous

Two push-button switches; transformer 240 V to 12 V at 1 A; sheet of polarised plastic; pc board ETI-564, case to suit; nuts, bolts etc.





Overlay diagram, looking from the components side. Note that this is a double-sided pc board. ▶

To derive a 'minutes' output, the 50 Hz mains frequency is divided by 3000. To perform this division a 4040 12-stage binary counter is used. As this provides a total division ratio of 1:4096 (2^{12} = 4096) the counter has to be reset once it reaches the 3000th count. To do this we detect when the outputs of stages 4, 5, 6, 8, 9, 10 and 12 are all high and provide a reset pulse.

To derive the 'hours' output, a dual decade counter is used. This is IC4. One half is used just to divide by 10 while the other half is arranged to be reset before completing its count to provide a further division of six, resulting in a total division of 60. A decoder on the ÷10 stage provides the 'minutes units' display while a decoder on the ÷6 stage provides the 'minutes tens' display.

The output from the tens-of-minutes divider (second half of IC4) is divided by six in the same way as just described to provide the 'hours units' output and this is followed by decade counter to provide the 'hours tens' output. These divisions are provided by IC7 which is reset to '1' when it reaches a count of '13'.

The hours units display is derived by a decoder from the first half of IC7 as for the other digits, but the 'hours tens' is only ever a '1', provided by a row of 12 LEDs. A buffer transistor drives this display.

Construction

We found it necessary to use a double-sided printed circuit board for this project to avoid a large, cumbersome board which we feel sure you'd agree would be rather unattractive. To avoid ulcers, premature greying of the hair, muscle tremors and other assorted maladies that may develop from attempting to completely handwire this project, we suggest you obtain a printed circuit board as specified.

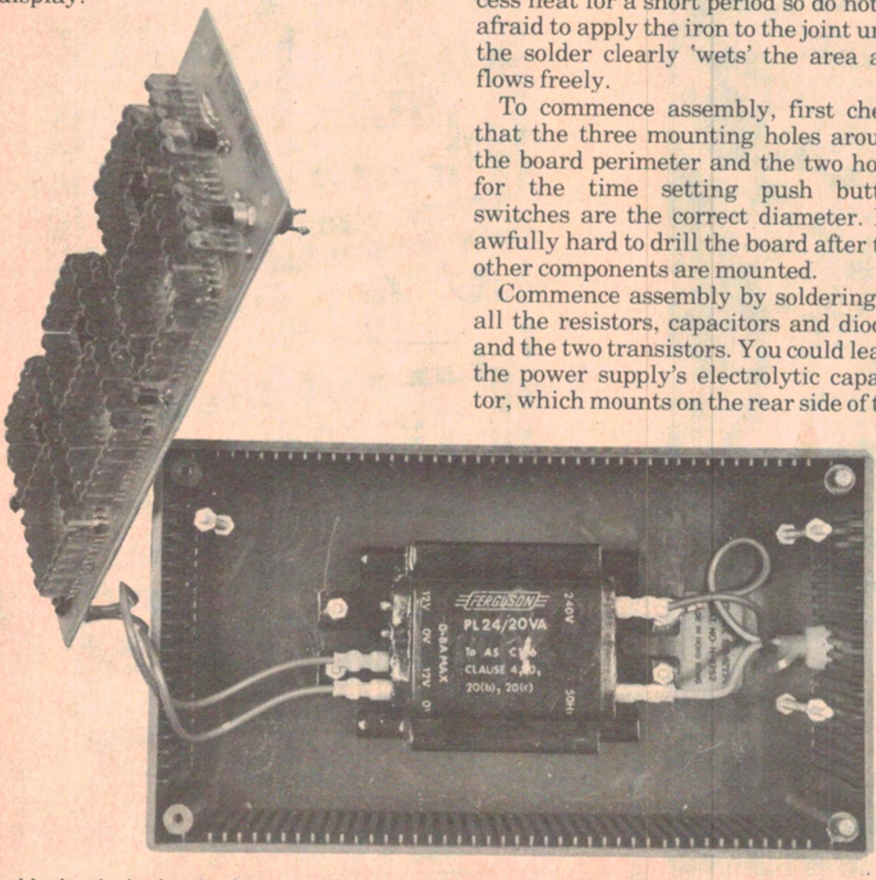
The board used in our prototype did not use plated-through holes as it is not really necessary. However, there are many fine tracks on the board and we recommend you use a soldering iron with quite a small tip. When soldering tracks on the top side of the board where a component lead connects to a corresponding track on the underside of the board, always ensure that you heat the joint sufficiently to get a good flow of solder and avoid a dry joint. From previous experience we find that many constructors tend to be afraid of overheating an IC or other components and do not provide enough heat for a good joint with the result that dry joints occur. These may work initially but often give problems some time after the project is completed and in use. Modern components will readily withstand excess heat for a short period so do not be afraid to apply the iron to the joint until the solder clearly 'wets' the area and flows freely.

To commence assembly, first check that the three mounting holes around the board perimeter and the two holes for the time setting push button switches are the correct diameter. It's awfully hard to drill the board after the other components are mounted.

Commence assembly by soldering in all the resistors, capacitors and diodes and the two transistors. You could leave the power supply's electrolytic capacitor, which mounts on the rear side of the board, until all the other components are assembled if you wish. Take care with the orientation of the diodes, paying particular attention to the component overlay. Note that different value ballast resistors are required, according to the type (and thus the voltage drop) of LEDs chosen. Refer to Table 1 for the appropriate values.

As CMOS ICs are used, take care when inserting them that you handle the devices with due care. Carefully remove them from their packaging, taking care not to handle the pins — pick them up with your thumb and forefinger grasping the ends of the package, not the pins. Make sure you have them correctly oriented before inserting them in the board. Also ensure that you put each IC in its correct place and on the correct side of the board too! Sockets cannot be used for the ICs as many of the pins are soldered on both sides of the board.

With the LEDs used in our prototype (Siemens LD80-2 and Philips CQX10-2) we first taped the groups for each segment together. To do this, lay a group of five or six LEDs down, anodes or cathodes all facing the same way, butt their heads against a straight edge and run a strip of tape first over one side, then the other. This makes assembly much easier. Having done this, insert the LEDs into the board. The LEDs we used have a shoulder or 'step' in their leads a few millimetres from the base. We pushed the LEDs down onto the pc board until this shoulder stopped them going any further. The outside lead of each segment array was soldered and then each group checked for align-



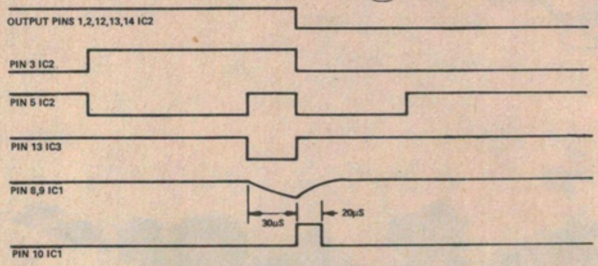
Inside the clock, showing how we mounted the transformer. Take care with the mains wiring.

Setting the time

1. Switch on.
2. Press the minute button (the right hand one) until the minutes display is correct. To prevent multiple pulsing due to contact bounce, the button should be pressed and released when the colon is **OFF.**
3. Set the hours in a similar manner to the minutes (left hand button). If the minutes display is less than 40, again operate the button when the colon is **OFF.** If the minutes display is 40 or more, operate the button when the colon is **ON.**
4. An easy way to set the clock to the *exact* time is to first set it some 20 - 30 seconds fast by the push buttons, then compare it to a known time standard (you might use Telecom or a radio time signal for this). Turn off the power for the exact time *difference* and the clock will cease counting. The large filter capacitor will hold its charge long enough to store the last time, for up to a few minutes, until the power is turned back on. When the time signal equals the clock display, turn the clock on.

TABLE 1: Value of ballast resistor for the LEDs

RESISTOR	1.6V LEDs	2.1V LEDs
R7, 10, 13, 14, 17	180R	150R
R20, 23, 26, 29	180R	150R
R8, 9, 11, 12, 15, 16	270R	180R
R18, 19, 24, 25, 27, 28	270R	180R
R30, 31	270R	180R



Waveforms around IC2 and IC3.

ment before soldering the other leads.

The rectangular LEDs specified measure 2.5 mm wide by 5 mm long. If you elect to use conventional round LEDs, the miniature 3 - 4 mm diameter types should be used. Many of the larger sized round LEDs will not fit this pc board as they have a shoulder around the base of the unit that measures 6 mm diameter, preventing the close packing possible with the other types.

Once you have the LEDs mounted and soldered in place, the two push button switches may be mounted. Short lengths of tinned copper wire are run from the switch lugs to the adjacent pads on the pc board.

At this stage, if you are satisfied everything has been mounted correctly, the board may be tested — *but give it another thorough check first!* In particular, look for solder 'bridges' between IC pins or across closely-spaced tracks as well as possible dry joints.

Simply apply 12 Vac to the two pins marked on the board overlay and see that the clock operates as it should. Try the 'hours set' and 'minutes set' buttons to see that they have the required effect. If all is not well, switch off and re-check the component placement and orientation, check for dry joints, etc.

We mounted our clock in a convenient plastic 'jiffy' box measuring 196 x 113 x 60 mm. The PL12/20VA 'low height' transformer is screwed to the rear of the box. The mains lead enters one side through a cable clamp. The pc board is mounted on three 58 mm long bolts with nuts positioned at a distance from the rear of the case determined by the height of the transformer.

To drill the case, first mark the position of the holes for the pc board mounting bolts. Use the pc board as a template, laying it face down on the outside rear of the case. It's probably best to do this before loading the board. Failing that, measure the position of the holes and accurately mark them on the case. Use the photographs here as a general guide.

The board is not located centrally between the two long sides of the case. The upper edge of the board is located about 30 mm from the top side of the box. Ensure that the board does not foul the inside mounting flutes or pillars. If all is well, drill the holes and check that the board mounts properly.

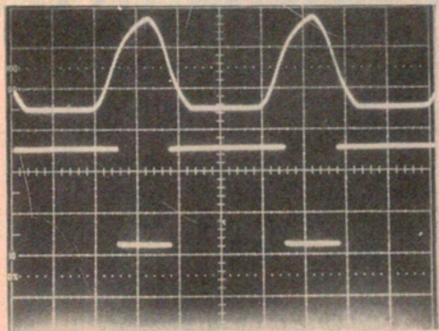
Next, mark the position of the mounting bolts for the transformer, which is located under the board. Drill these and check that the transformer will mount without fouling anything. It should, there's plenty of space. The hole for the mains cable clamp should be located and drilled next.

The front panel may now be tackled. A large rectangular cutout is made in the front panel, just larger than the display. A piece of circularly polarized plastic is cut to the *outer dimensions* of the case, using the case as a template. As we chose red LEDs, we bought a piece of red plastic. For other colour LEDs, use grey. This plastic is available through Polaroid Australia. Lay the case face down on the piece of plastic and scribe around the edge. Remove the case and carefully cut around the scribe mark. Next, place the panel over the piece of plastic and mark where the four panel mounting holes are located, then drill them. Two further holes have to be drilled in the plastic panel to permit access to the time setting push buttons. You're going to have to use a little judgement in locating these, but they don't have to be located all that accurately, just such that a match can be inserted to depress the buttons.

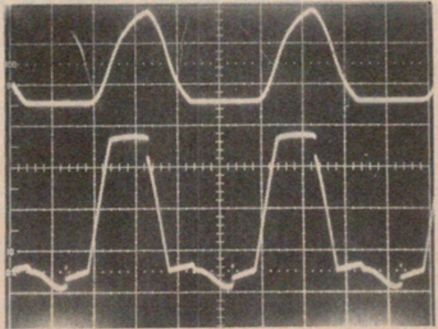
The plastic may now be glued carefully to the panel, or stuck on with double-sided sticky tape. As the clock dissipates some ten watts, ventilation is necessary. The easiest way to provide this is to stack some washers behind the front panel, on the mounting screws, such that the panel stands out from the case about 2 mm.

Now the clock may be finally assembled. Mount the mains transformer and secure the three pc board mounting bolts. Attach the mains cable and clamp then wire up the transformer primary and secondary. An earth lug should be mounted under one of the transformer mounting bolts and the mains cable earth soldered to it. A piece of cardboard, about 80 mm by 50 mm, should be stuck to the top of the transformer with a piece of double-sided tape. This is to insulate the rear of the pc board from the transformer case.

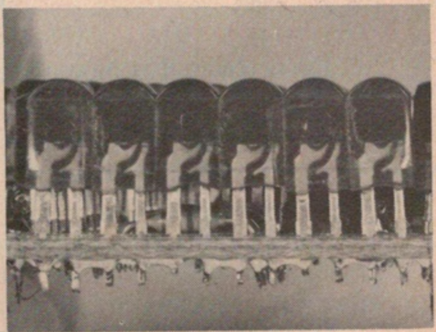
The nuts to locate the rear of the pc board should now be put on the mounting bolts and the pc board carefully secured in position. Make sure the board is held securely without it bending. Mount the front panel, plug in and you're ready to set the time! ●



Waveforms around IC1. At top is the waveform on the input, bottom shows the output.



Top waveform shows the input to IC1/1, lower trace shows the ac input to R3.



How the LEDs were mounted. The 'shoulders' on the leads are butted against the pc board.