Mains Switching TIMER

by David Ponting

MAKING PRINTED CIRCUITS THROUGH THE PHOTOGRAPHIC PROCESS OF EXPOSING TO UV LIGHT THE SENSITISED SURFACE OF A COATED COPPER BOARD REQUIRES THE EXPOSURE TIME TO BE CAREFULLY CONTROLLED.

I have been making PCBs this way for many years now and have always set the exposure period with a mechanical, mains-driven timer. But my most recent board was spoiled by gross over-exposure caused by the not entirely unexpected failure of the somewhat ancient switch. It was clearly time to find a modern replacement.

This was surprisingly difficult. In fact I could not find a single commercial timer which would reliably and accurately control a piece of mains driven equipment for a period of time from a few minutes to an hour, and with an accuracy of +/- 1 second. It soon became clear that a switch with the particular features I needed was going to have to be homemade.

A number of recently published circuits I researched described timers with very accurate timing facilities but all of them involved the use of a microprocessor and/or a computer, pretty big sledge hammers to crack the nut I had in mind. In any case, how many of us have the finance, or even the

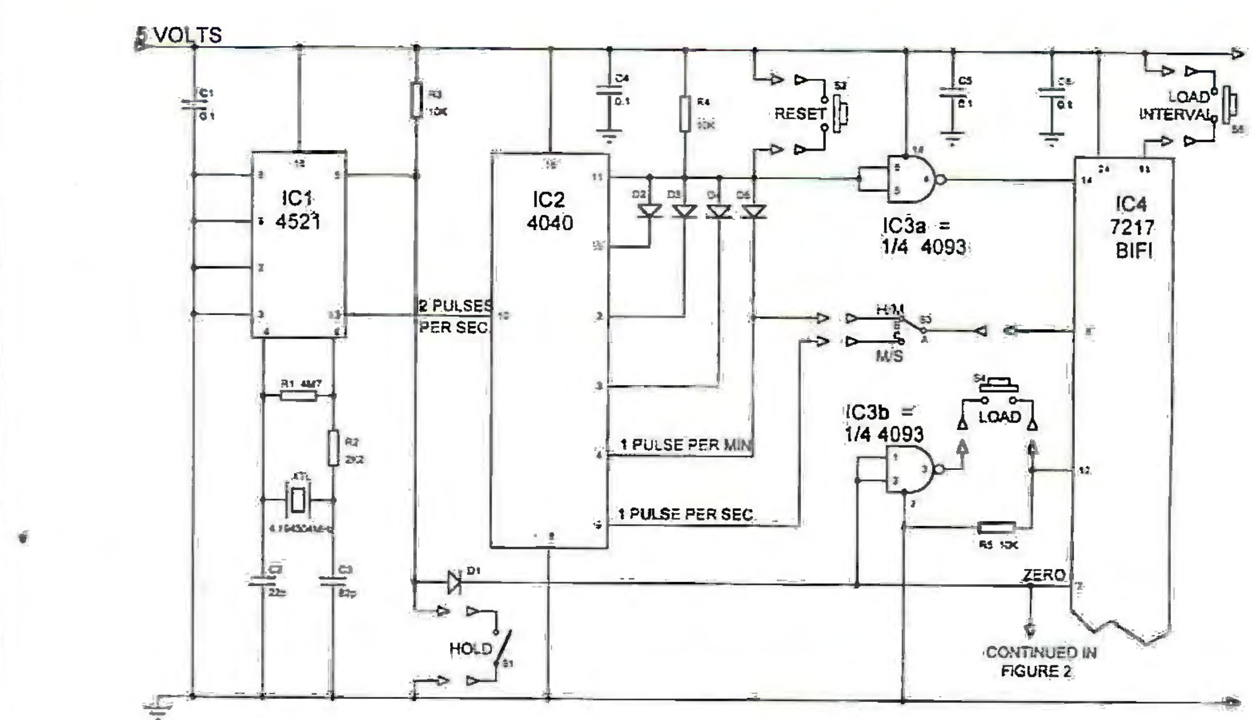


Figure 1. Timebase

room in our work area, to dedicate a computer to such a lowly task.

There had to be a simpler solution.

Looking through the various components' catalogues, I found that the 7217, an old but reliable workhorse timer IC, was still readily available. It seemed to be obtainable only in its 'BIFI' form but that was fine for my purpose since this designation means that the IC counts in sixties, and outputs its maximum count in the 5959 form rather than 9999.

So here was the foundation of a digital timer which could switch my UV light off after any exposure and have the accuracy and repeatability needed. Of course its use need not be limited to this single function. I foresaw many applications for a mains-switching timer.

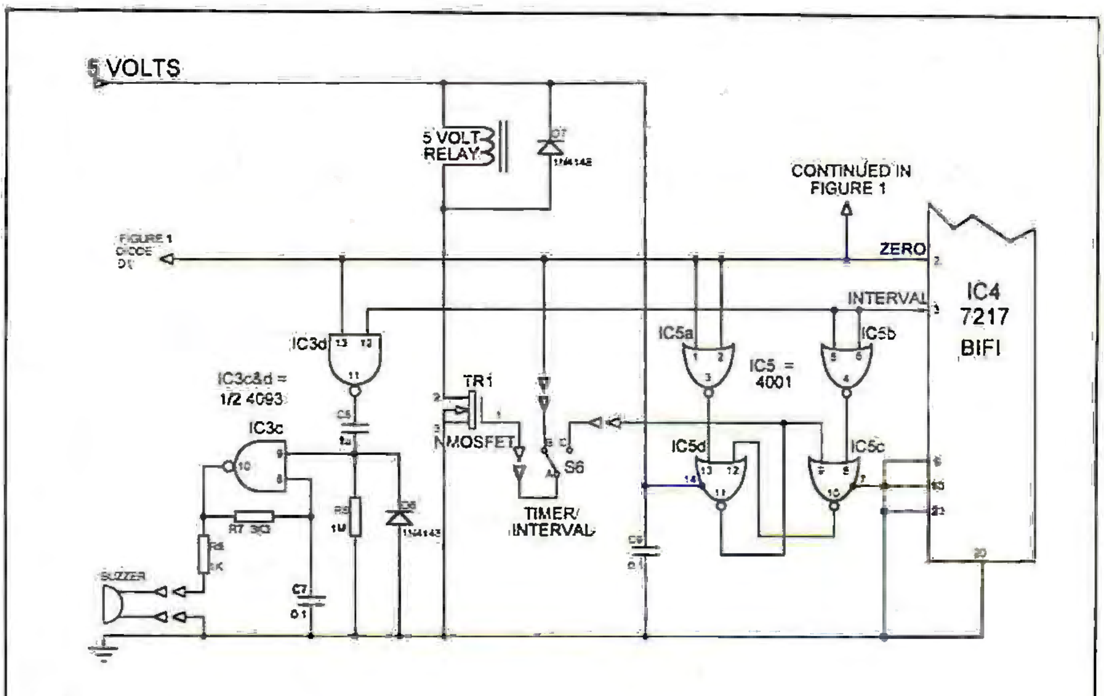


Figure 2. Control

How the circuit works

Pin 8 of the 7217 is its clock input and pulses at this pin are counted by the IC. Consequently the first thing needed is an accurate timebase to provide the necessary reference frequency. Such a timebase is shown in Figure1.

IC1 is a standard CMOS oscillator-and-divider chip which when used with a 4.194304 MHz crystal and wired as shown, will divide that frequency down to an output at pin 13 of two pulses per second. This is routed to IC2 pin 10, the clock input of a second divider chip. The output from pin 9 of this IC provides the input frequency divided by 2, which was all that was needed for my primary purpose.

However, to make the timer as universally applicable as possible, why not include as many additional features as feasible? This explains the further components around the rest of IC2's internal dividing chain which, when wired with the four diodes in the way shown, provides an output at pin 4 of the input frequency divided by 120. In other words IC2 outputs two signals: one pulse per second and one pulse per minute. The one-pole-double-throw switch S3 determines which of these provides the clocking signal into pin 8 of IC4.

All the internal counters of IC2 are reset

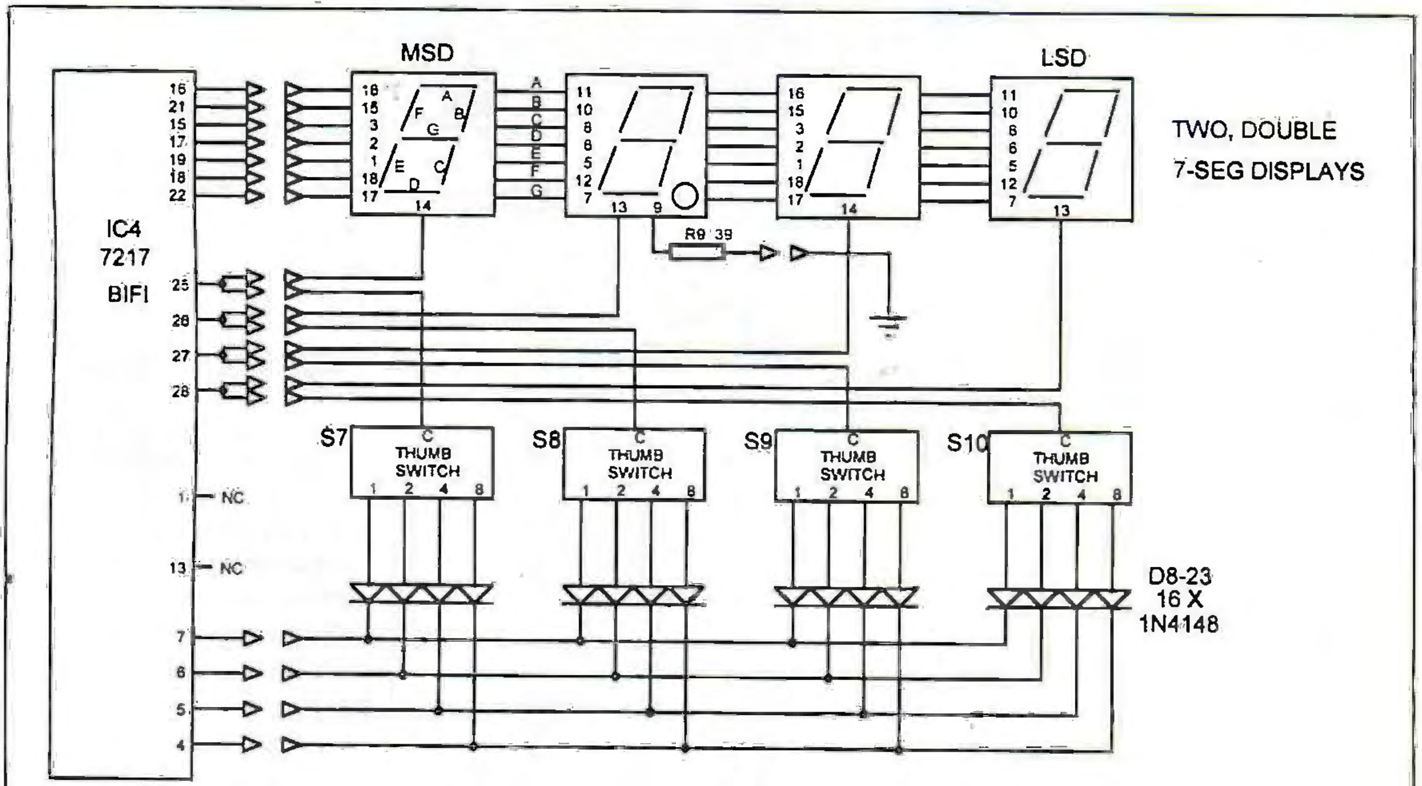


Figure 3. Set and display

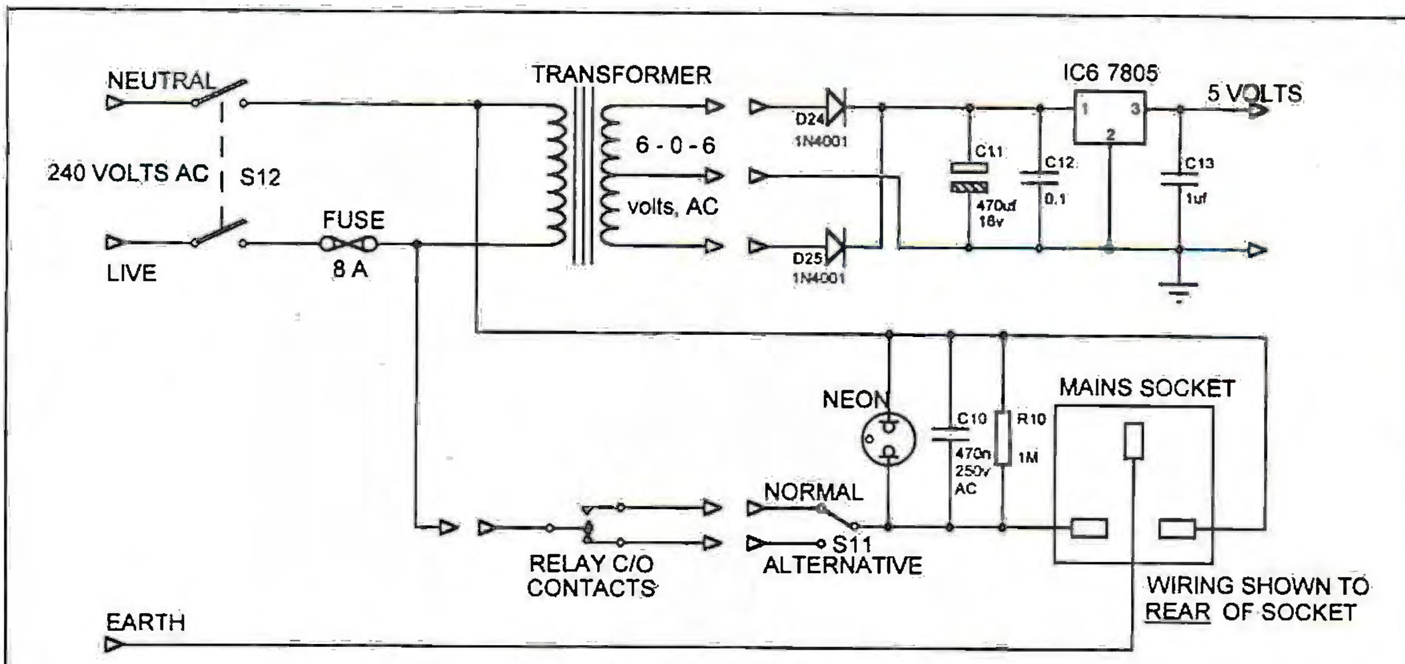


Figure 4. Power and mains switching

when its pin 11 (normally low via the diodes D2-5) is taken high. This happens when S2 is pressed. Whether pin 11 is high or low, its state is inverted by gate IC3a and routed to IC4 pin 14. This pin needs to be high when the 7217 is in its counting mode but resets all IC4's internal counters when taken low. So S2, with gate IC3a, provides a reset function for both IC2 and IC4.

On/off switch S1 resets IC1 by taking pin 5 low when the output of half-second pulses stops. But this switch has no effect on the current count of IC2, other than to hold that count exactly where it is. Releasing S1 will restore the output of IC1 and the count on IC2 will continue from where it was. So this switch produces a HOLD function for the timer.

Pin 2 of IC4 is marked ZERO and is one of the two major outputs from the 7217. The output at this pin is high all the time IC4 is counting down and only when the count reaches 00.00 does it go low. The purpose of diode D1 now becomes clear. While IC4 pin 2 is high, IC1 outputs 2 pulses per second. But when IC1 pin 5 is pulled low via D1 as the 7217 pin 2 goes low at 00.00, IC1 is reset and held so. Consequently all counting stops with the display at 00.00 and the timer is then 'at rest'.

Other than noting that gate IC3b

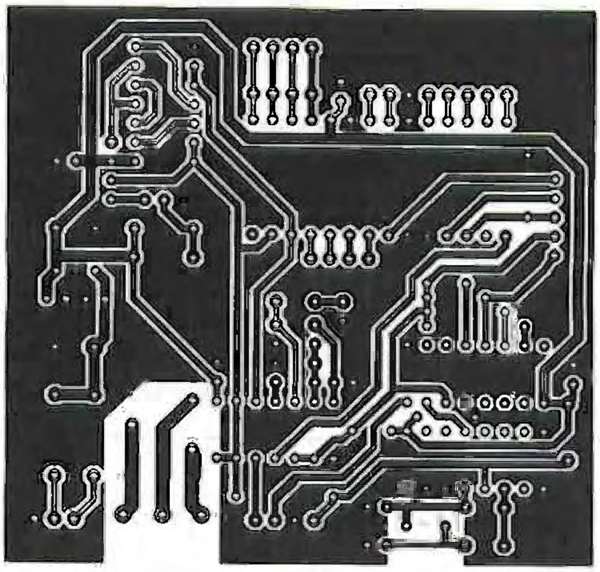


Figure 5. PCB track layout

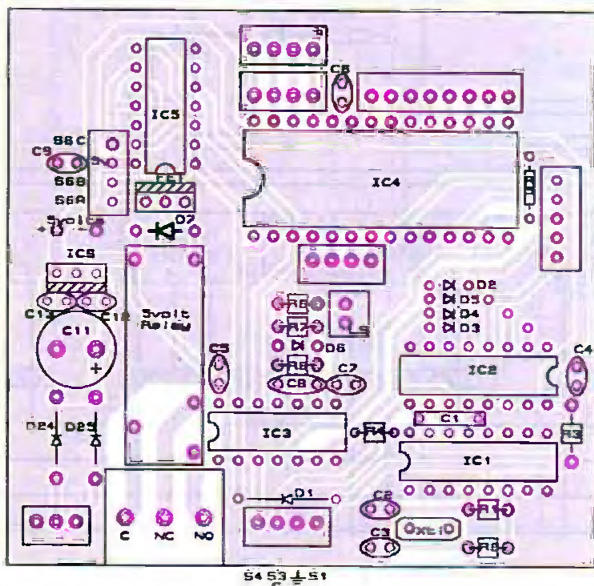


Figure 6. Component positioning

is wired as an inverter and hence the output at its pin 3 is always in anti-phase with the state of IC4 pin 2, let us delay discussion of switches S4 and S5.

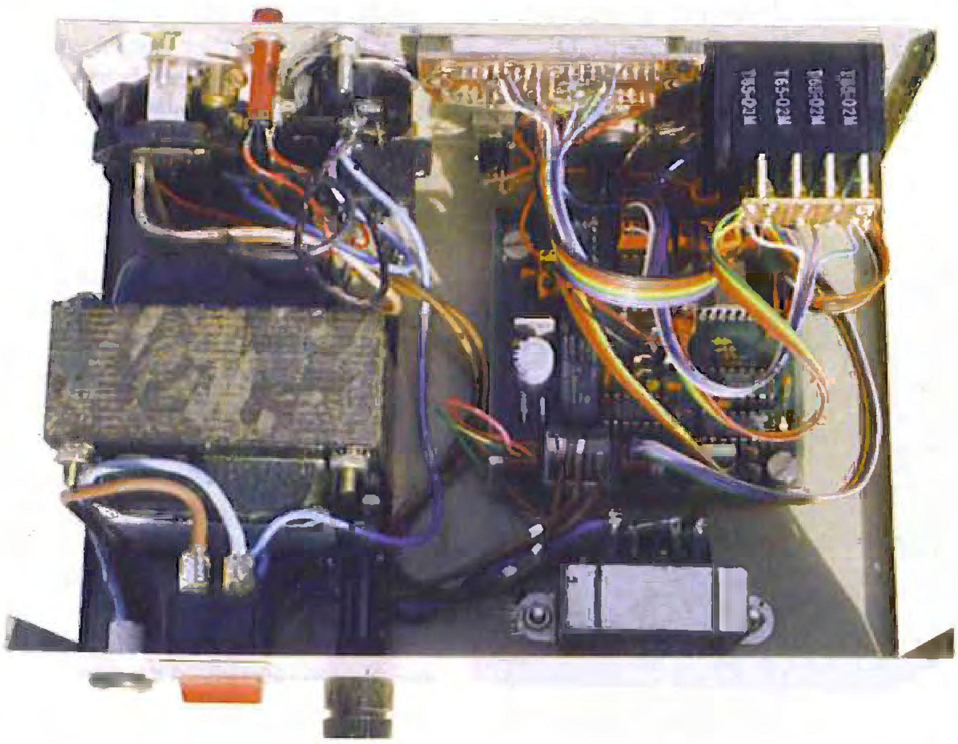
Figure 2 shows some more of the control and output features. IC4 pin 3 is marked INTERVAL and is the second major output of the 7217. Normally a timer is expected to switch something on at the start of a timing period and switch it off at the end. Pin 2 provides this function. But the INTERVAL output at pin 3 allows a different switching sequence.

In the INTERVAL mode it is possible to choose a moment between the start and finish times when IC4 pin 3 changes state to provide an interim switching point. With the timer running or at rest, this INTERVAL pin is usually high. But when the chosen intermediate setting is reached during countdown, pin 3 goes low for just the length of one input pulse.

Now let us consider the effect on gate IC3d of the outputs from pins 2 and 3 of IC4.

After the timing period starts, both inputs of gate IC3d will be high and hence its output is low. When the 'INTERVAL' moment is reached, the input at pin 12 of the gate will go low, the output high and gate IC3c pin 9 (which had been low) will go high and remain so until capacitor C8 has charged via R8. The time-constant of these two components is about 1 second and consequently IC3c is gated on for this time. As this gate with its components is configured as an oscillator, a burst of around 4KHz will reach the buzzer which will sound for about 1 second. Some time later the output of IC4 pin 3 will return high, the output of gate IC3d will go low and C8 will be discharged via D6. The buzzer will not sound again until IC4 pin 2 goes low at the end of the timing period.

The outputs of IC4 at pins 2 and 3 also control gates IC5a and b. The whole of IC5 is configured as a SET/RESET flip-flop with the output normally low from linked pins 9 and 11 of the combination. But if the 'INTERVAL' facility is being used this output will be set high when IC4 pin 3 goes high at the intermediate moment during the timing period, and it will remain high until reset by IC4 pin 2 going low at the end of the cycle.



S6 provides the choice between the two timing modes. With pole A switched to B, the N-MOSFET, TR1, is on whenever IC4 pin 2 is high. In this position TIMER is being used; the relay is pulled in at the beginning of the set period and released at the end. But if pole A is switched to C, the INTERVAL mode is being used. Now the relay will not pull in until the interim point is reached and it will remain energised from then until the timer times out.

All of this may seem a little confusing now but should become clearer when the method for setting the on and off times is explained.

IC4 pin 9 controls the storing of the count, pin 10 the direction of counting and pin 23 the blanking or otherwise of the display. In this application they should all be wired low.

Figure 3 is the 'other side' of the 7217, showing connections to the setting switches and the displays. Four thumb switches are used to select the various times, and two, double, 7-segment, common-anode displays show the progress of the countdown towards 00.00.

When the unit is used in its TIMER mode, the period for which the load is to be switched on is set on the thumb switches and then loaded into the 7217's main register by taking IC4 pin 12 high (see Figure1). The LOAD switch, S4, can only take this pin high if the output of gate IC3b is high; this will only be so when the timer is 'at rest' with the ZERO pin 2 low. Immediately the LOAD switch S4 is closed, the thumb switch settings will appear on the display, the relay pulls in, and the countdown starts. At 00.00 the buzzer will sound and the relay drops out.

The INTERVAL mode is more easily explained with an example. Let us suppose that it is now 11am and we are going out until the evening. While we are away, we want a device switched on at 14.30 and be left on for three hours, switching off therefore at 17.30. So the timer which we will set running as we leave at 11.00 is to switch off completely at 17.30 having run for a total of 6 ? hours. But before we load 06.30, we should first set the thumb switches to 03.00, the interval during which the device is to be on. This setting is then loaded into the 7217's second register by taking IC4 pin 11 high via switch S5. (Note that nothing appears on the display to tell you that this interval has been stored, but it has). Then, when the full running time of 06.30 is set and loaded with S4 as we leave home, the countdown will start but without immediately switching on the device. In fact, 3 ? hours will pass before it is 14.30 and only then will the mains socket be switched live. At that moment the countdown will display as 03.00 and therefore the device will stay switched on for the required 3 hours.

It should be noted that when an INTERVAL time has been loaded into the 7217 by closing S5, this period remains in memory either until a new INTERVAL time is entered or the register is cleared by switching mains to the timer off and then on again. Consequently once an INTERVAL time is stored, the unit is always operating in the INTERVAL mode. If the timer seems to be buzzing at odd moments or timing erratically, clear its registers by switching the unit off then on again.

Both the displays and the thumb switches are multiplexed and IC4 pins 25, 26, 27 and 28 function as both inputs and outputs. The diodes connected to the thumb switches isolate the output of each as they are scanned and loaded but of course no such isolation is necessary for the displays. R9 lights the appropriate decimal point.

IC4 pin 1 provides a CARRY signal if a second 7217 were to be used and pin 13 allows the speed of the scanning oscillator to be varied. In this application both these pins should be left unconnected.

Figure 4 shows the power supply and mains switching. Little needs to be said about the 5 volt supply which is standard in every way. If a perfectly smoothed 5 volts DC cannot be achieved at a full load of about 100 mA, it may be necessary to use a transformer with a greater output voltage than 6-0-6 volts AC.

The mains-switching circuit does require some comment. Mains Live is switched by the relay's change-over contacts but these outputs are again switched by S11. In the NORMAL switch position as shown in the diagram, the timing modes are as has been described above. However, in the other position of the switch, S11 provides fully reversed switching times.

Independent of reversing the modes, S11 can be useful simply for switching the load on and off when the timer is 'at rest'. For example, if at night you wanted to set the unit to leave a light burning for some hours in the house while it is unoccupied, you would literally be in the dark while the timer was being set if the light could not be independently controlled via S11.

All of this is reason enough to explain why

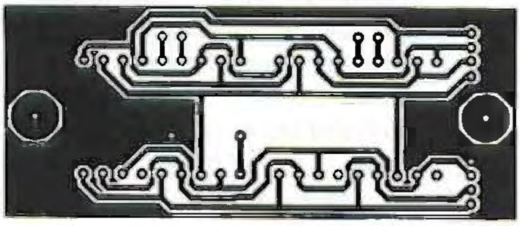


Figure 7. PCB track layout

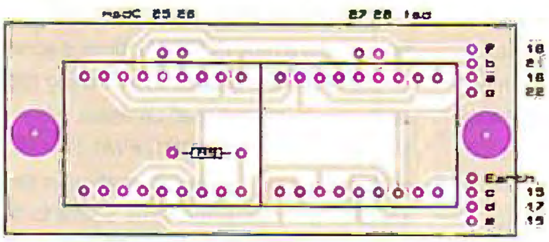
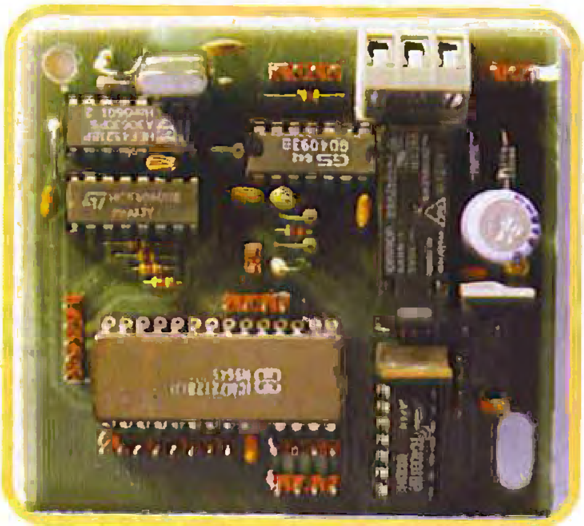


Figure 8. Component layout

a neon indicator needs to be wired across the switched mains output. Without an indicator there would be potential danger when something is plugged into the timer since it is not always easy to work out if the switched socket is already live or not.

The large capacitor C10 is also important, in fact essential if you will be using the timer to switch inductive loads. Without this capacitor it is possible at an inductive turn-off for the unit to experience a mains spike large enough to make the electronics re-trigger, taking the timer repeatedly through its timing cycle. On my prototype, I wanted not only a switched 240 volt socket but also one for120 volt mains. Without C10, the timer continually re-cycled due to the back emf created when switching off the internal auto-transformer used to produce this lower voltage.



Finally, R10. This is a safety resistor used here to discharge C10 when power to the unit is switched off. Without R10, and even after the timer has been un-plugged for, say, 15 minutes or even much longer, C10 could still be carrying a lethal charge. If some load is always connected (as in my case where the auto-transformer is a permanent load) then R10 may not be necessary. But a resistor is only a few pence and for safety should always be fitted here.

That completes the description of how the circuit works and outlines various timing sequences which can be employed. There is one other mode not so far mentioned which may be useful. Using S6 to select INTERVAL but without closing S5 to load any period into the 7217's second register, the unit can be used as a standard, switchless countdown timer. All that happens is that the total time period is loaded into the first register by closing S4, the timer counts down to 00.00 and the buzzer sounds. With the control switches set as described here, any load already connected to the timer can be left plugged in as no power is ever switched to the mains socket.

Making the timer

All the components are standard and should be easily obtained.

Two circuit boards are required for the easiest construction of this timer: one for the majority of the timing components and another for the display. They need only be single-sided boards but require a fill power-plane to ensure that all the earth connections are made. Transparency positives have been printed with this article should you wish to make your own PCBs. In addition, enlarged outlines of the boards are included to help ensure that all components, but particularly asymmetric ones, are correctly positioned before being fitted and soldered. (Figures 5, 6, 7 and 8).

It should be noted that an unusually large number of components such as switches and displays are off the main board and hence many inter-connections are required - 41 in fact. Connecting the mains Live to the board requires an appropriate screw block capable of handling the current being switched by the relay. (The recommended relay will switch up to 8 A). All the other connections can be made using standard, 0.1 inch PCB plugs and sockets whose outlines are shown on the main board graphic. I do strongly recommend that some sort of rainbow ribbon wire is used to avoid connection errors or at least to ensure that any made can be quickly corrected.

All DIL ICs should be fitted into appropriate sockets rather than soldered directly into the board. Please note that all these DIL ICs and the field-effect transistor, TR1, are static-sensitive and should receive minimum handling.

Two resistors and one capacitor are not fitted to the main PCB. R9 (39 ohms) lights the appropriate 'decimal' point in the display and so is connected directly to the display PCB. C10 (470n) is a somewhat special capacitor and only a Class X2 type designed to be connected directly across 240 volt AC mains should be used. R10 (1 Meg) is used to discharge this capacitor and can be soldered directly across C10's wire leads. This C/R combination should be fitted directly into the Live and Neutral terminals on the back of the mains socket.

The anodes of the 16 diodes, D8-23, are best wired directly to the 8,4,2 and 1 contacts at the rear of each thumb switch. The cathode ends of the diodes can then be commoned in four sections by soldering each of the 8, 4, 2 and 1 groups to the same tracks on a piece of copper strip board (see photograph).

Figure 9 shows a possible Front Panel layout with 7 of the control switches set in

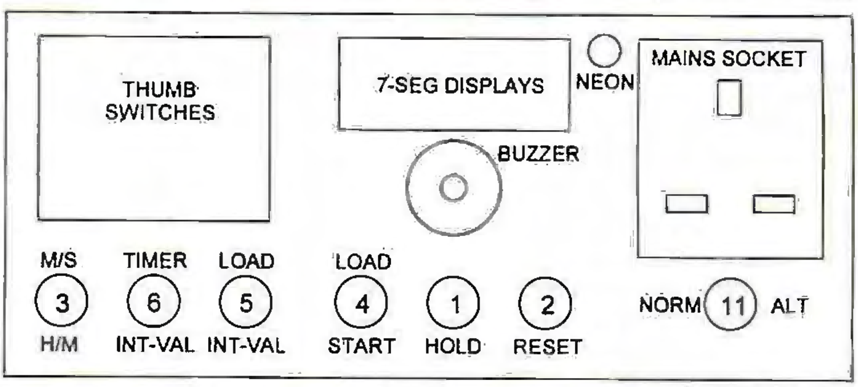
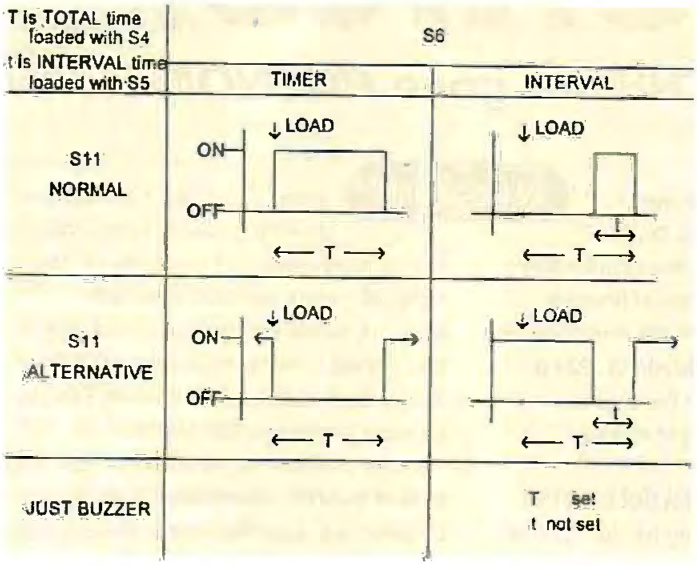


Figure 9. Possible front panel layout

two groups of three and one of one. Switches 1 to 6 are all small with the lever types operating up and down. Switch 11 is large and its lever operates from side to side.

With so many control switches on the front face I suggest that the input mains switch, S12, and the fuse holder be fitted on the rear panel, through which the mains lead also passes.



Using the timer

Set Switch 11 first and then consider each of the other switches in turn, reading in order from left to right on the suggested Front Panel layout.

Switch 11 is in its NORMAL position.

1. Do you wish to time in Minutes and Seconds or Hours and Minutes? Set Switch 3.
2. Do you want to use (a) the standard TIMER? or (b) the INTERVAL timer? Set Switch 6.

Then for:

(a) TIMER. (i) Set the Thumb Switches to the total time needed.
(ii) Ignore Switch 5 and press Switch 4.

The thumb switch setting will appear on the display. The socket will be switched on and the countdown will proceed to 00.00, when the socket will switch off.

Or for:

(b) INTERVAL (i) Set the Thumb Switches to pq.rs, the period when the socket is to be on.
(ii) Press Switch 5 to store this in the INTERVAL register.
(iii) Reset the Thumb Switches to the total period the timer is to run.
(iv) Press Switch 4.

The current thumb switch setting will appear on the display. The socket remains off but the countdown proceeds. When the display reads pq.rs the socket will switch on and remain on until 00.00 is displayed when the buzzer will sound.

3. Do you want to use the timer without ever switching mains to the socket?

(i) Switch the timer off and then on again to clear all registers.
(ii) Set Switch 3 for Minutes/Seconds or Hours/Minutes.
(iii) Set Thumb Switches to the total time period needed.
(iv) Set Switch 6 to INTERVAL.
(v) Ignore Switch 5 and Press Switch 4. The thumb switch setting will appear on the display. The countdown will start and eventually the unit will time-out when the buzzer will sound. At no time will mains be switched to the socket.

4. The HOLD switch and RESET press button can be operated with the timer 'at rest' or at any time during the countdown, irrespective of whether the socket is switched on or off.

5. Switch 11 can also be operated at any time. This switch will reverse whatever the current state of the socket happens to be. Figure 10 shows graphically under what circumstances the socket is on or off when the various modes are being used. For example, with S11 switched to ALT(ERNATIVE) and using the unit as a TIMER, the mains socket is initially on, goes off as the set time is loaded, and switches on indefinitely after time T, when the unit times out. In the INTERVAL setting, with t loaded with press-button 5, the socket is on initially, remains on when the total running time T is loaded and the count down begins, and remains on until the interim moment is reached when it switches off for time t. At the end of the total timing cycle, the socket is switched live indefinitely.

6. Setting the first and third thumb switches to a figure greater than 5 and then loading this setting will cause the 7217 BIFI to mis-count.

Parts List

Resistors	
R1	4M7
R2	2K2
R3,4,5	10K
R6	1K
R7	3K3
R8,10	1M
R9	39
Capacitors	
C1,4,5,6,7,9,12	0.1
C2	22p
C3	82p
C8,13	1uf
C10	470n, 240vAC, Class X2
C11	470uf, 16 volt
Diodes	
D1-23	1N4148
D24,25	1N4001
Semiconductor	
TR1 N type, MOSFET	MTP3055A, or pin equivalent
Integrated Circuits	
IC1	4521 CMOS
IC2	4040 CMOS
IC3	4093 CMOS
IC4	7217 BIFI
IC5	4001 CMOS
IC6	7805 volt reg.
IC DIL Sockets	
Two at 14 pin, two at 16 pin and one at 28 pin	
Switches	
S1	Miniature Lever, On/Off
S2,4,5	Press to make
S3,6	Miniature Lever, SPDT
S7-10	Thumb Switches, 10 position, BCD
S11	Lever, SPDT, 240 volts, 10A
S12	Lever, DPDT, 240 volts, 10A
Relay	5 volt, 8A C/O contacts*

*This relay is in the Omron G6RN series and available from Farnell, order code 959-078.

Miscellaneous	
Buzzer	Piezo Sounder
7-seg displays 1 and 2	Double, Common Anode
Fuse	8 amp, and holder
Transformer	6-0-6 volt secondary, ? Amp
Neon	240 volt AC
Mains socket	Standard surface type
PCB plugs and sockets, Case, etc	