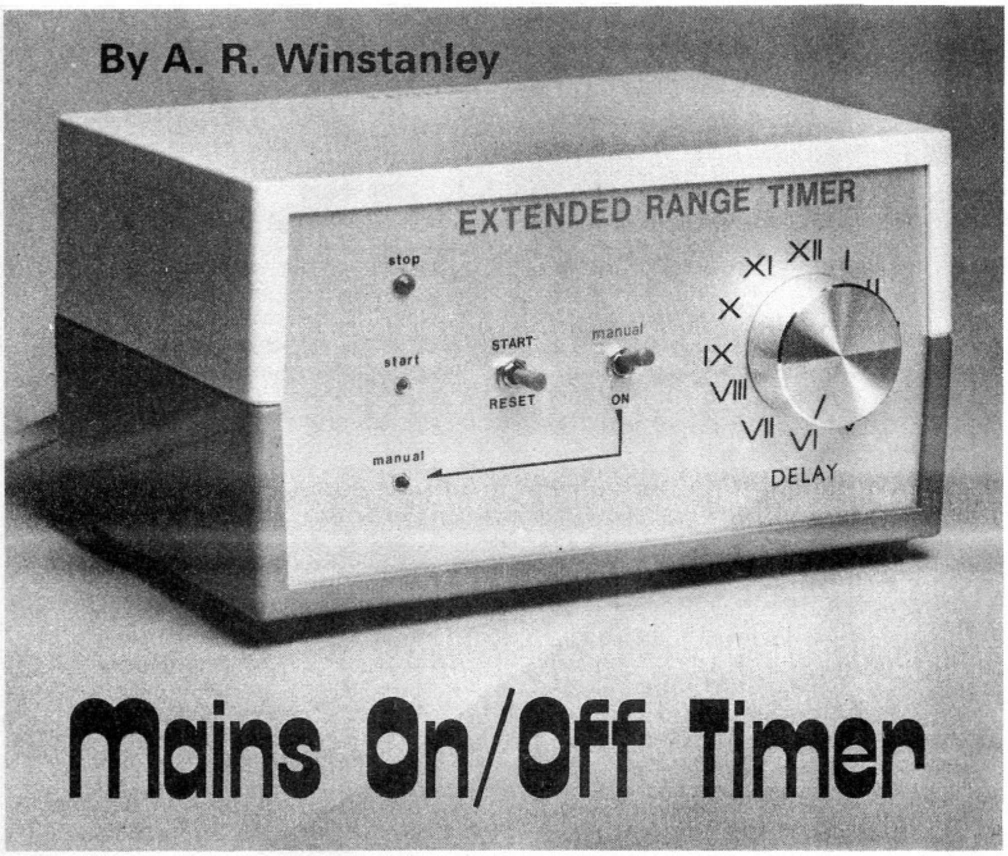
By A. R. Winstanley

Mains On/Off Timer



PERHAPS one of the less pleasant ways of starting a day is to be awoken to the nerve-shattering jangling of one very large and very loud alarm clock! There must be better ways of being roused from sleep, and this project would seem to make life a little easier in this respect.

TIMED DELAYS

The Mains On/Off Timer is a versatile unit which will generate timed delays of up to twelve hours in one-hour increments. Once this period is up the Timer will switch on or switch off any mains load connected to its output sockets, and this load can have a power rating of up to 1800 watts; therefore the unit is suitable for driving many appliances.

Thus by connecting a mains radio to the Timer and setting the appropriate delay, one can be awoken to the more acceptable strains of Terry Wogan.

The Timer utilises the Ferranti ZN1034 precision timer i.c. to produce very accurate timing periods using low value timing components when compared with typical component values used with, for example, the NE555 timer.

Also, the ZN1034 is equally at home producing delays of one second or one week—compare this with the maximum one hour delay generated by the 555. Indeed, by using two ZN1034 timers a delay of up to one year is attainable.

THE TIMER I.C.

The internal circuitry of the ZN1034E (the 'E' denotes a 14-pin d.i.l. package) is very simply illustrated in Fig. 1. The i.c. features an on-chip oscillator and twelve-stage divider. The frequency of oscillation is determined by an external *RC* circuit. When the oscillator has cycled 4095 times the control logic switches over the complementary outputs at pins 2 and 3.

The external *RC* circuit therefore determines the delay period which the i.c. will generate. The use of an oscillator and counter in this manner enables an *RC* circuit with a relatively low time constant to be utilised to deliver relatively long delays.

The timing period is given by the formula

$$t = k \times B \times C$$

where t is the delay (seconds)
R is the external timing resistor (ohms)
C is the external timing capacitor (Farads)
and k is a multiplying constant.

The constant, k, is determined by the value of a "calibration resistor." With pins 11 and 12 of the i.c. linked, an internal 100 kilohm resistor is selected, and $k = 2736$.

If pins 11 and 12 are linked by a 50 kilohm resistor then the calibration resistor is increased to 150 kilohms and $k = 4095$. If instead a 300 kilohm resistor is connected between pin 12 and ground then k becomes 7500, and in this mode the i.c. is able to produce its longest delay periods. If the internal resistor is used, this will give the best coefficient of temperature, but whatever method is chosen, the calibration resistor should not exceed 300 kilohms.

When choosing values of R and C, the following limits apply:

$$5k\Omega \leqslant R \leqslant 5M\Omega$$
$$C \geqslant 3300pF$$

The timing period commences when the device is triggered by grounding pin 1. Two complementary outputs are available at pins 2 and 3; pin 2 ($\bar{Q}$) is normally high and goes low during timing; the opposite is true of pin 3 (Q).

COMPONENTS approximate cost £25

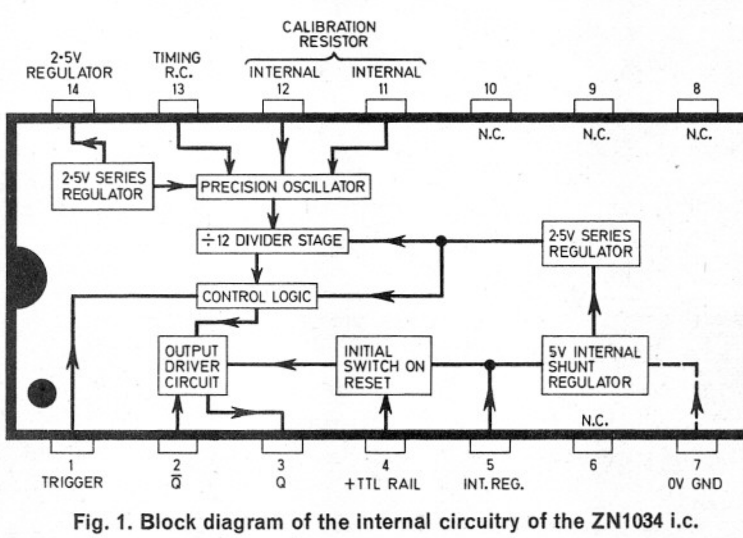


Fig. 1. Block diagram of the internal circuitry of the ZN1034 i.c.

A typical "high" value would be about 3·5V and a "low" would be in the order of 0·3V. When either output is high, it can supply current of up to 25mA to the load connected to it; but when the output is low, if the load is biased correctly then current may sink into the output, and again this current must be limited to 25mA.

POWER REQUIREMENTS

Concerning the power supply rails, the i.c. will operate directly from 5V to 450V d.c. When used with a 5V rail (as with TTL circuits) then pin 4 can be connected straight to +5V. Alternatively when used with a rail exceeding 5V, a series resistor must be connected between pins 4 and 5 and the positive rail. A 5V shunt regulator on pin 5 takes care of the rest.

The value of this series resistance is given by

$$R_s = \frac{(V_s - 5)}{I}$$

where R is the resistor value (ohms)
V_s is the supply rail voltage
and I is the current flowing through the resistor. (amps)

The current is 5mA plus any current drawn at the outputs.

A switch-on reset is incorporated into the chip which resets the time delay if the supply is interrupted.

OSCILLATOR FREQUENCY

The actual precision oscillator can be observed in operation by placing a high-impedance frequency meter or cathode-ray oscilloscope on pin 13. The impedance must be at least ten times that of the timing resistor or the test instrument impedance may alter the *RC* constant.

The actual delay period will be 4095 × period of waveform measured on the 'scope. Measuring the oscillator frequency in this way is often more desirable than having to wait a few hours to check the accuracy of the timer. A provision has been built into the Timer to allow measurement of the oscillator period with an oscilloscope.

CIRCUIT DESCRIPTION

The complete circuit diagram of the Timer is shown in Fig. 2. Mains voltage is stepped down by T1 to 12V a.c. This is rectified by D1-D4, an encapsulated bridge rectifier and smoothed by C1 to produce an unregulated supply of some 17V d.c.; R1 is a series dropping resistor which permits the operation of IC1 from the 17V supply. Capacitors C2, C3 and C4 are used to decouple the supply rails and serve to reduce any spurious noise.

The internal 100 kilohm calibration resistor is brought into circuit by the link between pins 11 and 12. Capacitor C5 is the timing capacitor and switch S3 is a 12-way rotary switch which selects the timing resistor. With S3 at position 1, a 390 kilohm resistor is selected as the timing resistor. The delay t is thus

$$t = k \times R \times C$$
$$= 2736 \times 390\text{k}\Omega \times 3{\cdot}3\mu\text{F}$$
$$= 3521 \text{ seconds or about one hour (58 minutes)}$$

(Internal 100 kilohm calibration resistor selected, so $k = 2736$.)

With S2 in position 2, two 390 kilohm resistors are in circuit and the delay is about two hours, and so on. No preset has been included in the timing resistor chain which might allow exact trimming of the oscillator period to produce spot-on delays (e.g. exactly one hour). Such a preset would obviously be nearly impossible to set up unless an oscilloscope or frequency meter was available to help. In fact reasonable accuracy is obtained when a tantalum capacitor is used for C5.

Socket SK3 is optional and permits the measurement of the basic oscillator period with test equipment. With a 10 megohm c.r.o. and probe, this socket should be usable with the timer set for a delay of up to three hours. After this the scope impedance might cause false readings to be taken.

The i.c. is triggered by grounding pin 1 via S2. The switch-on reset can be utilised to cut short the time delay if required: this can be done by temporarily interrupting the 17V

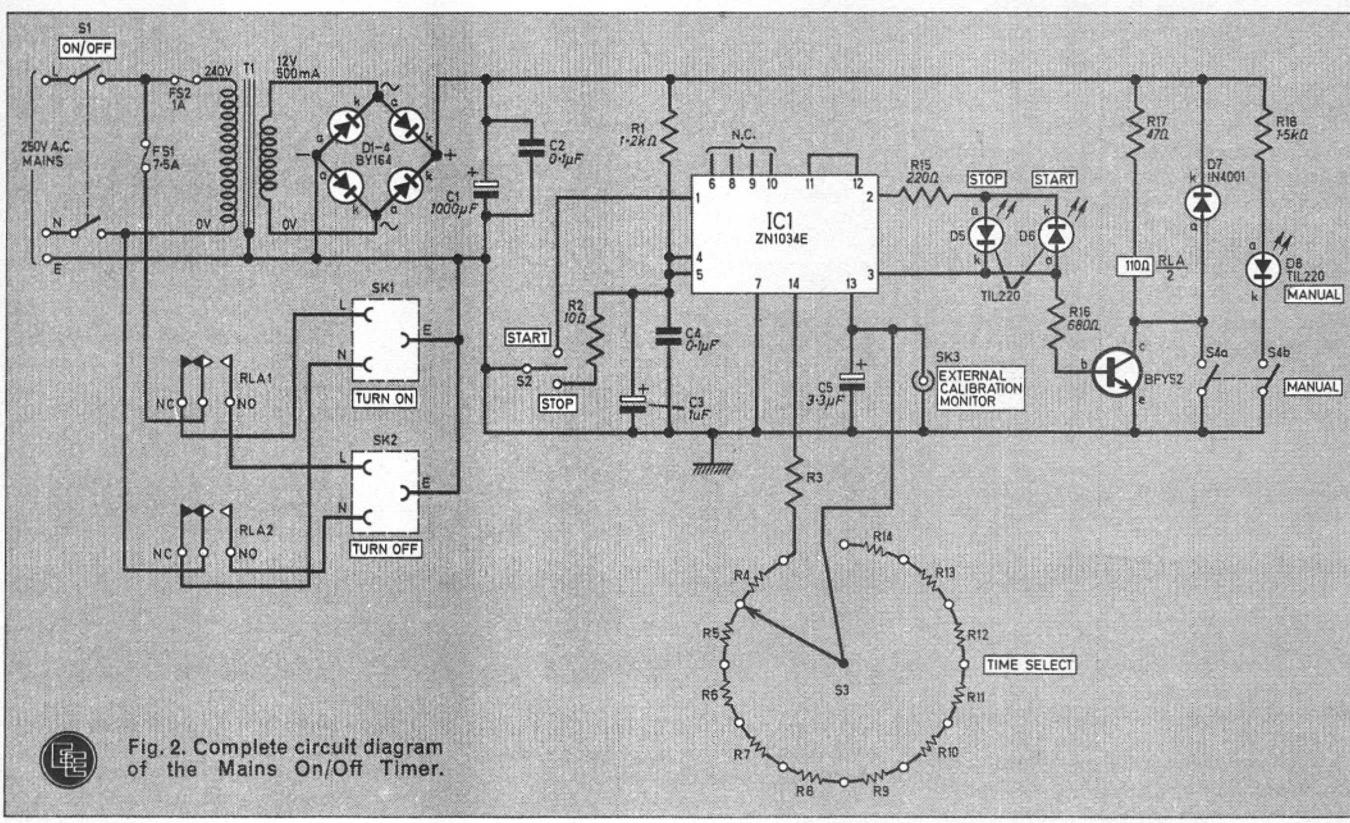
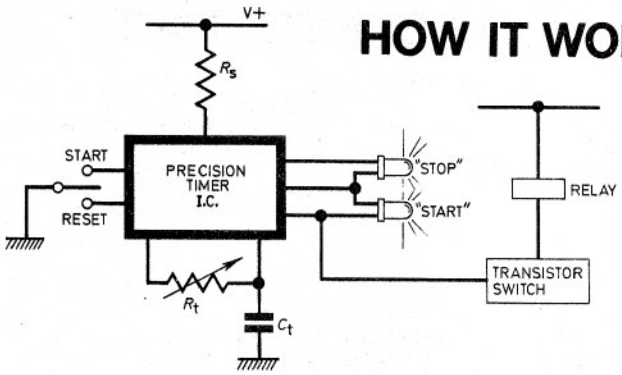


Fig. 2. Complete circuit diagram of the Mains On/Off Timer.

HOW IT WORKS



A precision timer i.c. forms the basis of this design. An external *RC* network (R_t and C_t) alters the frequency of an internal oscillator. When the oscillator has cycled 4095 times, the internal i.c. logic detects this and causes a transistor to switch off, thereby removing power from the relay coil and turning off the mains load.

Two complementary outputs are available on the i.c., and both are utilised to provide a visual indication by means of two l.e.d.s to signal whether the timer has "started" or "stopped."

The i.c. is both triggered and reset with one switch. Timing resistor R_t is varied in steps by means of a rotary switch to allow different delays to be obtained. The Timer generates delays of between 1 and 12 hours, but in theory the i.c. can deliver delays of between about 15 microseconds and about 3 weeks.

The relay contacts switch the mains load off after the delay is up, but in this design by utilising both sets of changeover contacts, the load can be switched on or off after the delay.

supply to the i.c. with a normally-closed switch. Instead, however, a reset function was derived by grounding pins 4 and 5 with S2—this grounds the i.c. and resets it. Resistor R1 ensures that there is no danger of shorting out the supply, and R2 limits the peak current caused by C3 and C4 discharging to 0V.

By resetting the i.c. in this manner it was possible to incorporate the trigger (START) *and* RESET functions into one switch.

I.C. OUTPUIT

Both of the i.c. outputs are used. When the i.c. is not timing, then pin 2 is high and pin 3 low. Therefore output current flows out of pin 2 and sinks into pin 3, illuminating D5 to indicate the timer has stopped. Light emitting diode D6 cannot illuminate because it is reverse-biased by about two volts. Resistor R15 limits the current flowing in the l.e.d. to less than 10mA—generally enough to cause an easily visible glow.

Upon commencement of the timing period (IC1 being triggered by S2), pin 3 goes high and pin 2 low—D5 must therefore extinguish and D6 illuminates to indicate that the timer has started timing. Also, TR1 switches on with pin 3 going high. This completes the circuit to RLA which now operates. Resistor R17 is a series dropping resistor and is necessary to enable the 12V 110 ohm relay to be used with a 17V supply. A transistor is required because the i.c. cannot possibly supply the 110mA or so required by the relay.

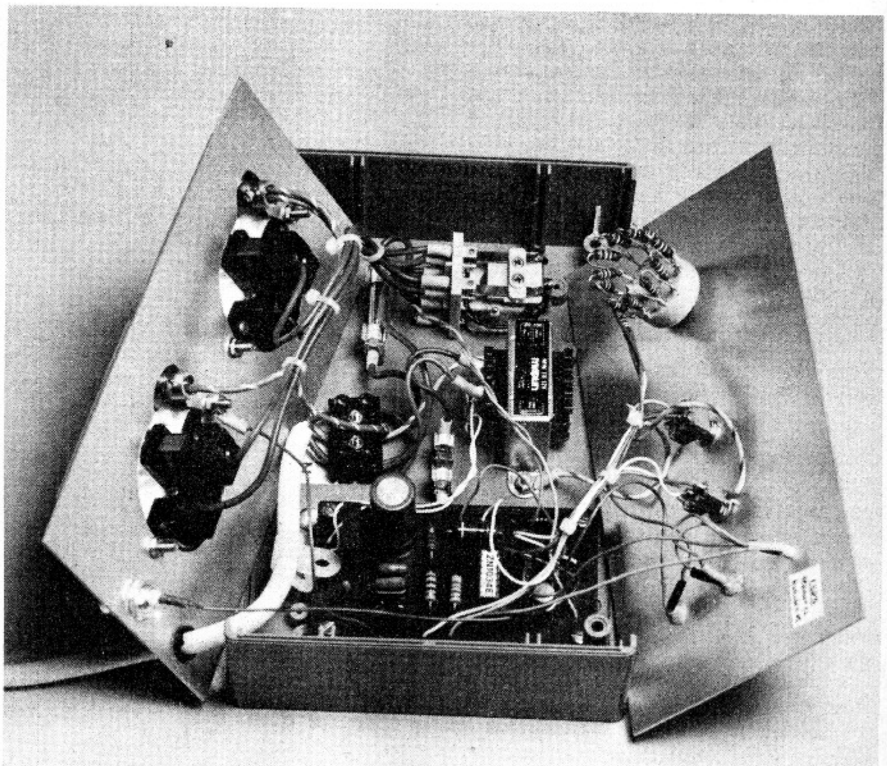
Switch S4 has been incorporated to allow a MANUAL operation of the relay independently of the Timer which switches on the relay itself and illuminates D8 to indicate the manual function.

RELAY

The relay used in the prototype was an R.S. Open Type 348-835 which is equipped with a pair of 10A 250V a.c. changeover contacts. Socket SK1 is connected to the mains through the normally-closed contacts. When the relay operates, these contacts open and switch off the load connected to SK1 which switches on again when the Timer is reset or times out.

The opposite is true of SK2. When the unit is timing, SK2 switches on and switches off when the unit times out. The use of these "complementary" sockets means that any load can be turned on or turned off when the Timer has completed its cycle.

In the final design, the relay contacts have been derated to 7·5A by means of FS1 so that neither the relay contacts or the mains interwiring can be operated at their absolute maximum ratings. Fuse FS2 protects the transformer in case a fault should develop.



Completed Timer with front and rear panels displaced showing interior layout and wiring.

CONSTRUCTION starts here

CIRCUIT BOARD

The circuit is built on a glass fibre printed circuit board for high reliability and strength. The foil layout and component overlay is shown actual size in Fig. 3. The prototype was made using etch-resistant transfers for the tracks and resist ink for the larger areas of copper foil.

There are several points which must be observed when soldering the components to the p.c.b. Firstly make absolutely certain of the polarity of C1. Also ensure the correct orientation of D7. Finally, whilst an i.c. socket was not used on the prototype, it is recommended that one is used to prevent thermal damage to the rather expensive i.c. during soldering. Complete the p.c.b. in accordance with Fig. 3 and then move on to the casework.

CASE DETAILS

The prototype was housed neatly in a plastic Verobox type 75-1412K which has aluminium front and rear panels. The front panel should be drilled to take the three switches and three light-emitting diodes. Take care to ensure that the front panel is not scratched during this operation as this would greatly detract from its final appearance.

Letter the front panel as necessary and give it several light coats of lacquer for protection. A solid machine-turned aluminium knob and two different-coloured end caps for the miniature toggle switches completes the front panel and gives a very professional finish.

REAR PANEL

The rear panel must be punched or cut to take the two main sockets, mains cable inlet, and also SK3 if used. There will not be much room left on the rear fascia after the two mains sockets are in place, and so this stage of the construction needs to be planned with care.

If flush-fitting sockets are used, then two large cut-outs will be required; on the prototype this was very easily accomplished with a tank cutter and hand brace. Other methods include drilling a ring of holes, punching out the centre and then filing till smooth.

COMPONENTS

Resistors

R1	1·2kΩ
R2	10Ω
R3-R14	390kΩ (12 off)
R15	220Ω
R16	680Ω
R17	47Ω 1W
R18	1·5kΩ

All ¼W carbon ± 5% carbon except R17 (1W)

Capacitors

C1	1000μF 25V p.c.b. elect.
C2	0·1μF polyester
C3	1μF 35V tantalum
C4	0·1μF polyester
C5	3·3μF 35V tantalum

Semiconductors

D1-D4	BY164 60V 1·4A bridge rectifier
D5, 6, 8	TIL220 or similar l.e.d. with mounting clip (3 off)
D7	1N4001 or similar silicon diode
TR1	BFY52 silicon *npn*
IC1	ZN1034E precision timer i.c. 14 pin d.i.l.

Miscellaneous

T1	Mains primary/12V 500mA secondary transformer
RLA	12V 110 ohm coil with two sets of changeover contacts rated at 250V 10A
S1	d.p.d.t. 10A mains toggle
S2	s.p.d.t. miniature toggle, centre biased
S3	1-pole 12-way rotary switch
S4	d.p.d.t. miniature toggle
SK1, SK2	13A 250V flat pin flush mains socket (2 off)
SK3	See text
FS1	1A 20mm
FS2	7·5A 1¼ inch

Chassis fuse holders for FS1 and FS2; case, Verobox 75-1412-K; glass fibre p.c.b.; 14 pin d.i.l. socket; control knob; 13A cable and plug; p.v.c. insulated interconnecting wire; 10A mains interconnecting wire; 10A connecting block; coloured caps for S2 and S4 (one red and one green); p.c.b. mounting pillars.

See Shop Talk page 19

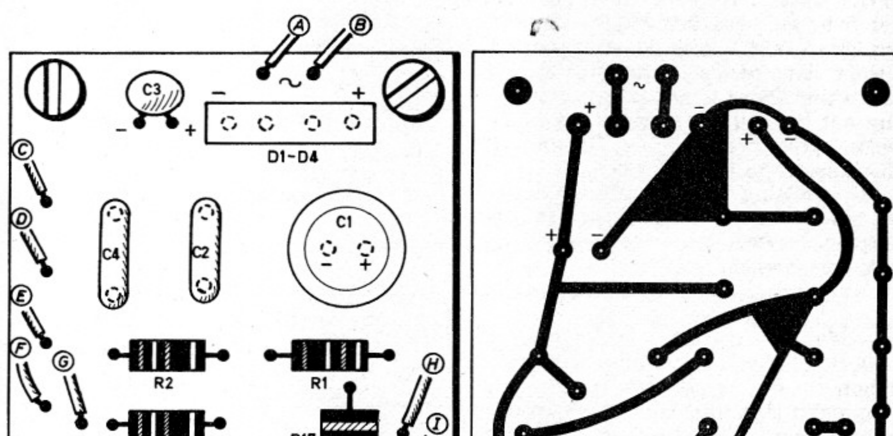
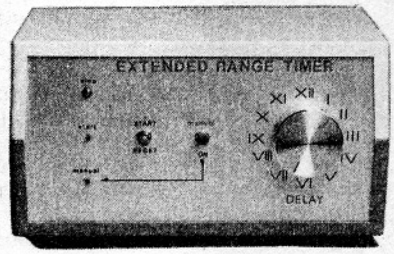
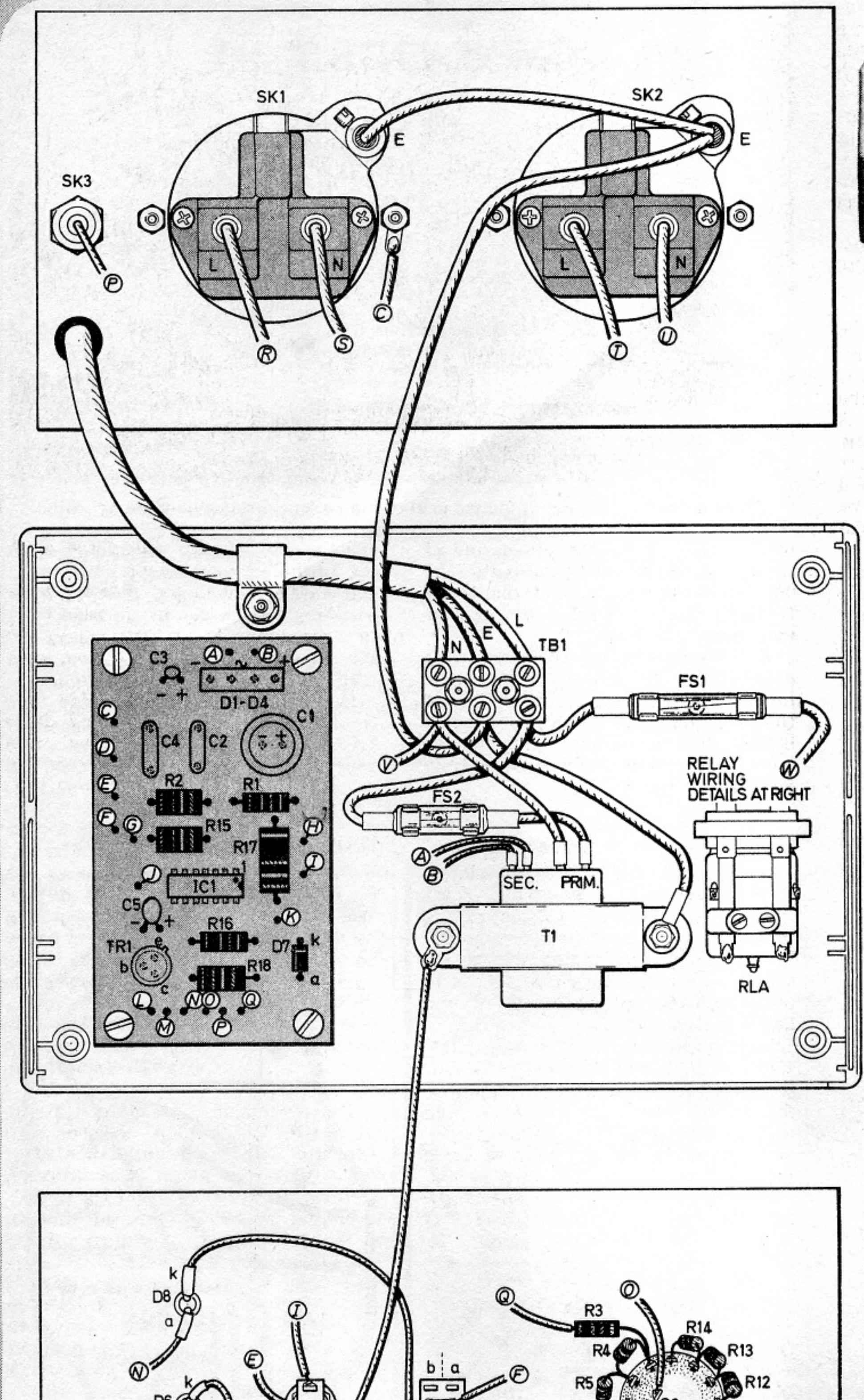


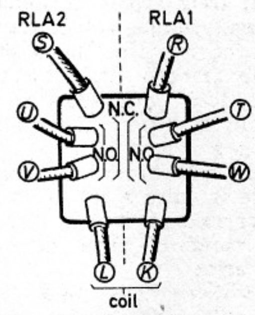
Fig. 3. Printed circuit board component layout and underside foil pattern (actual size).



Mains On/Off Timer

Fig. 4. The case opened out to show the position of the internal components and the internal wiring. All cables carrying a.c. mains must be rated at 240V 13A. This includes the wiring to SK1, SK2, RLA, FS1 and T1 primary. The relay connections are shown below. These may differ if the specified relay is not used. Connections to locations on the p.c.b. are made using veropins.





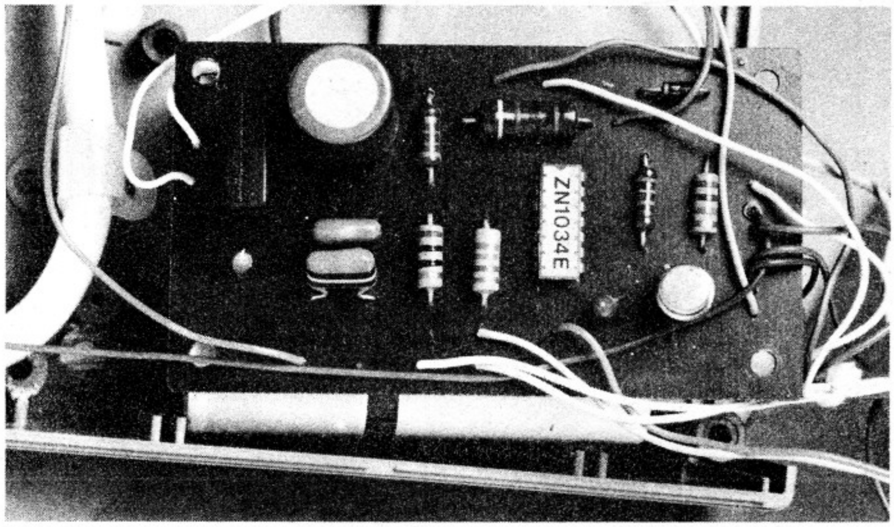
RELAY WIRING
RLA

The resulting large holes were then slightly modified with an Abrafile to take the shape of the earth terminals of the mains sockets.

It will be seen that as the mains inlet hole must be very near the right hand edge of the panel, then an adjacent hollow pillar moulded into the base needs to be trimmed right down to allow the mains cable to pass through unhindered. This pillar must be cut with a hacksaw, making quite sure that you don't cut into the edge of the case itself.

A hole (or two holes, depending on the type of socket used) will be required for SK3, if used. If a BNC socket is used, as in the case of the prototype, then one hole only is needed, the 0V connection being made through the earth. If, for example, two 4mm sockets are used then provision has been made on the p.c.b. for a 0V connection to be extended to one of the sockets.

Fit the sockets to the rear panel and fit a grommet to the mains cable inlet hole. Letter SK1 and SK2 "turn on" and "turn off" respectively.



Close up view of the top of the p.c.b. showing component positioning and wiring.

INTERNAL WIRING

The dark grey chassis is drilled to take the p.c.b. mountings, two fuseholders, transformer, terminal block, relay and mains cable clamp. The positioning of these holes should be carefully marked out so that the holes do not foul with the pre-moulded pillars in the base. The mains cable clamp is a nylon "P" clip which prevents the cable from being pulled out.

There is quite a lot of interwiring to be carried out but if Fig. 4 is followed carefully then no problems should arise.

All mains-voltage joints must be neatly soldered and insulated with p.v.c. sleeving, and all of this wiring is carried out with 10A (or greater) mains cable coloured blue, brown or green/yellow to coincide with the standard mains colour code. The transformer and FS2 can, however, be wired with normal 6A mains cable. The mains inlet must be rated at 13A. All other wiring can be carried out with lightweight hook-up wire, preferably stranded.

The relay connections shown in the diagram are for the specified relay only, and may differ if other makes of open relay are used.

EARTHING

Concerning the earthing arrangements, the front panel must be earthed using a very large earthing tag placed under one of the miniature toggle switches. An alternative here would be to solder the earth wire directly to the metal body of one of the switches. The rear panel is earthed with a 4BA solder tag under one of the mains socket mounting bolts. The 0V line of the p.c.b., and the transformer mounting bracket, are earthed in a similar fashion.

The wiring can be tidied up using nylon ties. The wires are arranged into looms, the tie is threaded around the loom and pulled tight. The excess is then snipped off. When forming the looms, keep mains cables away from low voltage wiring.

CHECKING AND SETTING UP

With all of the wiring completed, check carefully all aspects of your work. Check the p.c.b. for errors like reversed components or dry joints, etc. Recheck the mains wiring for quality and make sure that this is in order. Check the polarities of the l.e.d.s are correct.

If a multimeter is available, select a low ohms range and test for a low resistance between the earth pin of the mains plug and the front and rear panels. Test for infinite resistances between the earth pin and live and neutral pins of the plug.

If you are satisfied, fix down the top cover of the case, plug in and switch on. The STOP l.e.d. should be alight. Move S1 to START and allow it to return to centre off. The STOP indicator should extinguish and the START l.e.d. glow. The relay should also be heard switching in. Reset the timer at S1 and the relay should click out and the l.e.d.s switch over again.

Check now that the manual switch operates the relay and MANUAL l.e.d. when moved down. Set the knob for a one hour delay and start the timer; check that roughly a one hour delay is achieved. This last test will give a good indication of the accuracy to be expected with other delay settings. The prototype gave exactly 58 minutes delay on a one hour setting—this is exactly the period calculated with the formula given earlier.

If a c.r.o. is available, then the basic oscillator period can be measured (up to a maximum three hour delay) and the expected time delay computed with the formula given previously.

If everything seems in order then try the timer on a very long delay setting to confirm its accuracy. Here again the prototype was less than ten minutes out on an eleven-hour setting.

USING THE TIMER

Someone will possibly want to use a cassette recorder with the device. This is in order provided that the cassette recorder is not allowed somehow to remain for long periods in the "play" position **with the power removed.** Otherwise the rubber pinchwheel may possibly become physically distorted if it is kept "pinching" the tape against the capstan spindle for too long.

The timer can quite successfully be used with "auto stop" recorders to turn the power off altogether after the tape mechanism has stopped automatically at the end of a tape.

Finally it was discovered that in spite of the decoupling incorporated in the circuit, spurious noise generated by other appliances sharing the same socket being switched on and off sometimes reset the Timer. The Timer will not however *start* timing when a transient appears on the line.

The only way round this it seems is to use the timer and nothing else off one mains outlet, or plug into a suitable mains "suppression unit". It can be noted that the timer is not susceptible to transients generated by appliances in other parts of the building, and it is in order to share a mains wall socket with loads that are always on all of the time, like digital clocks, for example. ⌑