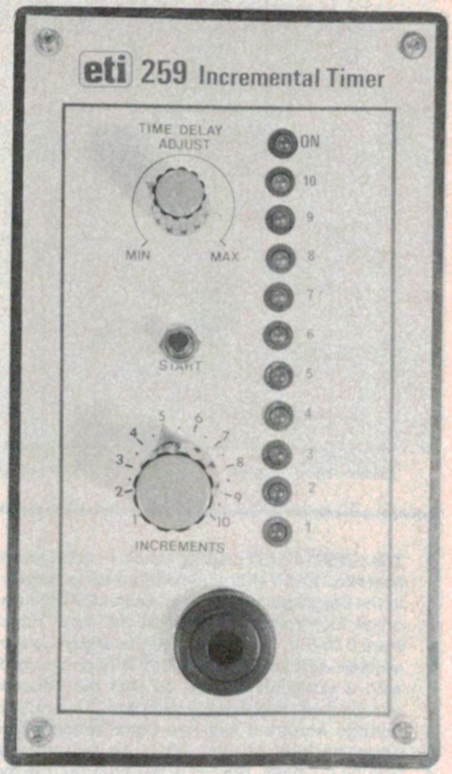
Versatile, low cost 'incremental' timer

This timer is based on the popular LM3914 LED display driver IC, rather than a 'timer' IC, and provides period timing in preset increments — you choose the number of increments, up to a maximum of 10. The period between increments may be preset by a front panel control and a 'bar' of LEDs indicates 'where you are'. A switched 240 Vac output is provided along with audio indication of the end of timing.



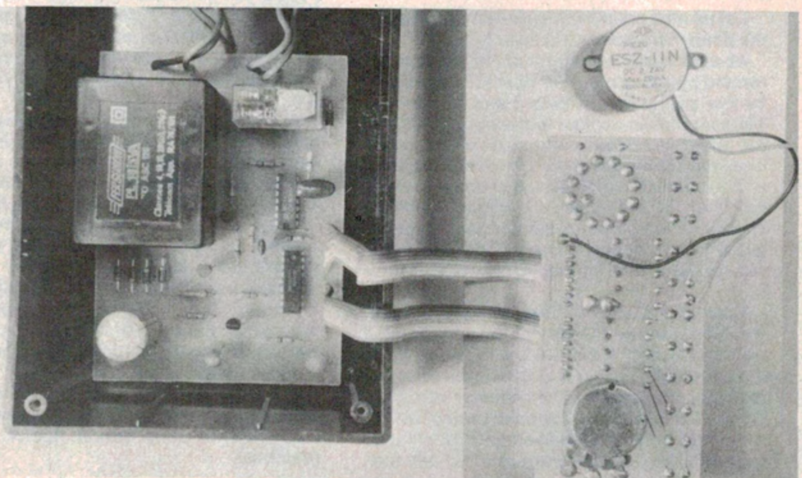
Graeme Teesdale

MANY ELECTRONIC timers published make use of a timing device, such as the ubiquitous 555 IC or UJTs like the 2N2646, to generate pulses at predetermined intervals which are used to operate a relay or alarm. Some employ digital counting techniques, using the mains frequency as a timing reference. This project employs an LM3914 LED display driver IC in an unusual way. The input is driven with a voltage that increases linearly with time. That is, the voltage increases equal amounts in equal periods of time.

The outputs of the LM3914 go 'active' in turn, lighting a LED, and further circuitry detects when a selected output goes active, setting off an audible alarm, tripping the relay circuit and resetting the timing.

At the one time, we obtain all the usual features included in many other timers, plus a 'bargraph' indication of how the timing period is progressing. This is very useful in the timing of many processes — particularly photographic processing, such as print development and resist development in the manufacture of pc boards. You can also coordinate a sequence of activities as the process continues, using the display to prompt you.

The total time, and thus the period between increments, may be varied by means of a potentiometer and the circuit has been arranged so that this provides about a 10:1 variation. The maximum period may be chosen by selecting the value of one capacitor. Accuracy is typically 1% over a wide temperature range.

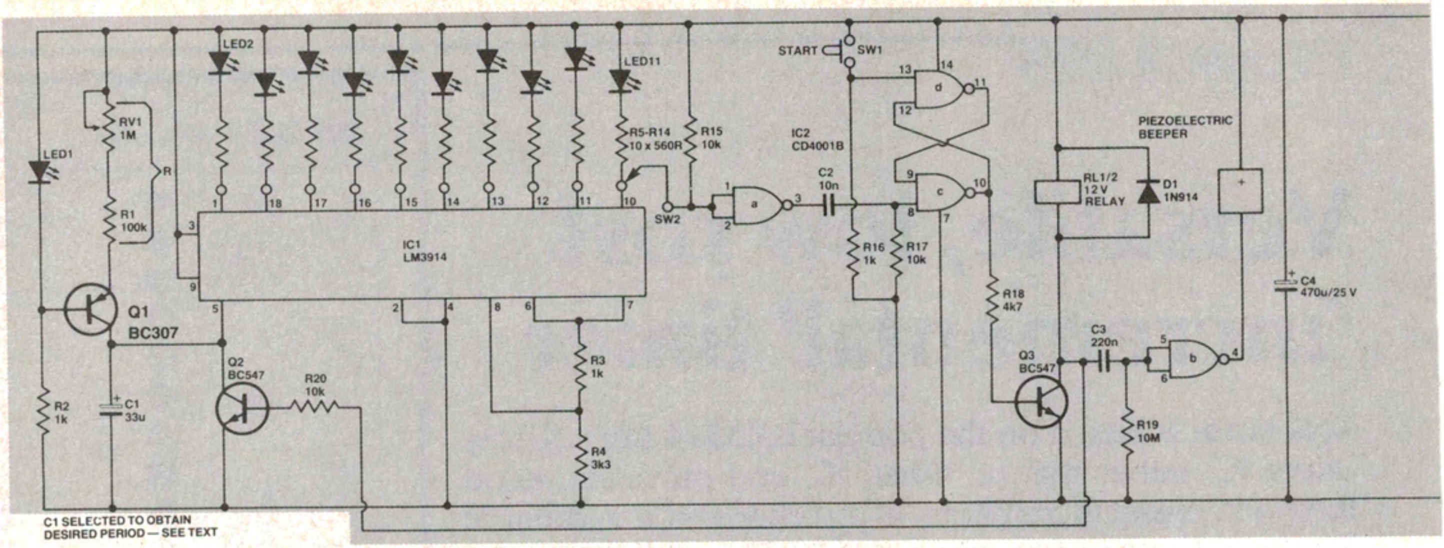

The inside story! As you can see, assembly is pretty straightforward.

Construction

Two pc boards are employed and the whole unit is housed in a standard 'jiffy' box measuring 196 x 113 x 60 mm. Although not absolutely essential, we recommend you use the pc boards designed for this project. The boards simplify construction and help ensure that there are few wiring errors. One board holds the power supply, relay and most of the electronics. This is the larger board, and is mounted in the bottom of the jiffy box. The other, smaller board holds all the display LEDs, the potentiometer, the increment selector switch, the START pushbutton and a few resistors. It is connected to the other board by two ribbon cables. This board is mounted to the front panel of the box via the securing nuts of the START button and the increment selector switch. The piezoelectric buzzer is separately mounted to the front panel.

Commence construction by drilling the box and front panel. The larger pc board (ETI-259a) should be used as a template to mark the hole positions for the four mounting bolts it requires. Also mark hole positions for the 240 Vac mains input cable. We strongly recommend you use a clamp-type grommet to secure the cable where it enters the box. Also mark out the hole positions for the 3-pin mains output socket. The terminal block may be bolted to the bottom of the case or glued ('liquid nails' will do).

The front panel artwork, obtainable from ETI, may be used as a template to mark out the hole centres ▶



HOW IT WORKS — ETI 259

The LM3914 LED display driver is connected as a zero-to-5 V (full scale) voltmeter to display in the bargraph mode. Thus, each LED will turn on at increments of 0.5 V as the input rises from 0 to 5 V. The input to IC1 is driven by the voltage across capacitor C1. This is charged with a constant current so that the voltage across it will rise linearly with time. That is, the voltage across it will rise equal amounts in equal periods of time. Thus, as the voltage across C1 rises, the LEDs will light up one by one until the voltage reaches 5 V or until C1 is discharged.

A relay and alarm circuit is built around IC2 plus Q3 and associated components. SW2 selects at which 'increment' the relay and alarm are operated by selecting one of the outputs of IC1. When that output goes 'active' (when the LED lights) the alarm sounds, the relay drops out and the timer is reset by discharging C1. For example, if the third increment is selected (pin 17, IC1) then LEDs 2, 3 and 4 only will light, the alarm sounding when LED4 lights. C1 is then discharged at that time, resetting the timer ready for its next use.

Now, let's get down to individual circuit details. First, the constant current source that charges C1. Transistor Q1 plus LED1, R2, RV1, and R1 form the constant current source. Figure 1 shows the collector characteristics of a typical silicon transistor. This shows that, if you hold the base current constant, the collector current will remain substantially constant for a widely varying range of collector voltage. Figure 2 shows the general circuit of a 'constant current generator' using an npn transistor, as in our circuit. The voltage between the base and the emitter return (the +ve supply rail) is held fixed by a zener diode. Thus, the voltage (Ve) across the emitter resistor, Re, is fixed at a value equal to the zener voltage (Vz) minus the base-emitter voltage drop of the transistor (about 0.6 V for a silicon transistor). With a fixed voltage across Re, the current through it will be constant. Thus the emitter current of the transistor, and therefore the collector current, will be constant. The resistor supplying current to the zener is generally chosen so that the zener current is five to ten times the base current of the transistor.

When you charge a capacitor with a fixed current, the voltage across the capacitor will rise linearly with time. As we want to drive IC1 with a voltage that increases linearly with time in order to obtain equal time increments, C1 is charged from the constant current generator formed by Q1, R2, RV1, R2 and LED1. Note that LED1 (a green LED — as an 'on' indicator) replaces the zener. The forward voltage drop of a LED behaves much like a zener, the LED used having a voltage drop of around 2.5 V. To vary the rate of charge (and thus the time it takes to charge C1 to a particular voltage) the current supplied by the constant current generator can be varied by varying the emitter resistance of Q1. RV1 performs this function.

The maximum period can be determined approximately from the following formula:

Total Time = 5 x C1

where C1 is in uF. Thus, a 33 uF capacitor (as specified) will charge to 5 V in around 165 seconds with RV1 set at maximum resistance. The tolerance on tantalum capacitors is quite broad, so the formula is only approximate.

The voltage across C1 'ramps' upward as it charges. As the input to IC1 is quite a high impedance, it has little effect on the charging rate of C1.

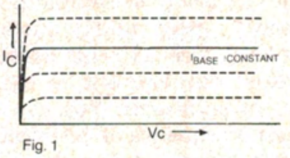


Fig. 1

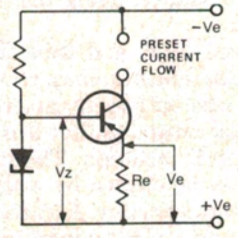


Fig. 2

Let us now consider the overall operation of the timer, commencing at switch-on.

At switch-on, the output of the RS flip-flop formed by gates 'c' and 'd' from IC2 (pin 10) will be low as the inputs, pins 8 and 13, are low. Thus no bias is applied to the base of Q3 and the relay will not be operated. Its collector voltage will be the same as the +ve supply rail and thus the base of Q2 will draw current via R20 and Q2 will be on. C1 will be unable to charge as the collector-emitter junction of Q2 will shunt the collector current of Q1 to the 0 V rail. As there is no input to IC1, no LEDs will be lit.

When the START button is pressed (SW1), the output of the RS flip-flop (pin 10), formed by gates 'c' and 'd' from IC2, will go high, turning on Q3. The collector of Q3 will conduct and the relay will operate. The collector voltage of Q3 will fall to nearly 0 V and the base of Q2 will no longer be forward-biased and Q2 will thus turn off. The collector current of Q1 will then commence to flow into C1 and the voltage across it will rise. As the voltage at the input of IC1 rises, LEDs 2 to 11 will turn on at 0.5 V increments.

If we now assume that SW2 was set to select the fourth increment (pin 16 of IC1, driving LED 5), then the input of gate 'a' from IC2, connected as an inverter, would go low when LED 5 turns on. Initially, the input to gate 'a' from IC2 is held high by R15, its output will be low and C2 will be discharged. When its input goes low (at the selected increment) its output goes high and C2 charges rapidly via R17. Thus a voltage pulse is applied to pin 8 of IC2 — one input of the RS flip-flop. This causes pin 10 of IC2 (output of the RS flip-flop) to go low again, removing gate bias from Q3, which turns off, de-activating the relay. When this happens, the collector voltage of Q3 goes high and C3 charges via R19. Now, gate 'b' from IC2 is connected as an inverter, its input being connected to R19/C3. When pins 5/6 of IC2 go high, pin 4 goes low and the piezoelectric beeper sounds. C3 takes a second or two to charge, the voltage across R19 decreasing as it does so. When it falls below the 'low' threshold of pins 5/6 of IC2, pin 4 goes high once more and the beeper ceases to sound.

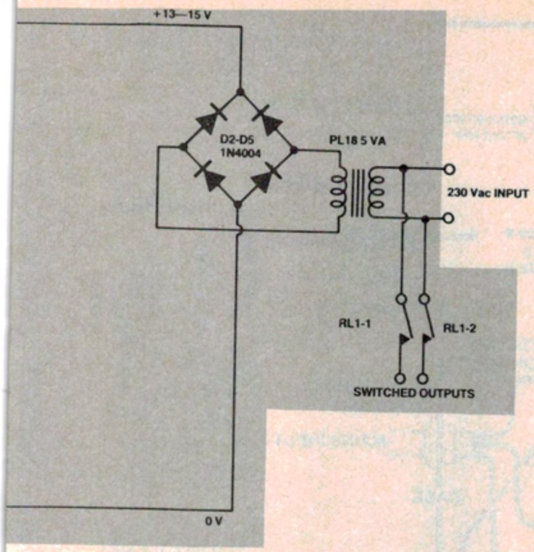
When the collector of C3 goes high when LED 5 lights (remember?), Q2 receives base bias once more, via R20. It turns on again, shunting the collector current of Q1 to 0 V and discharging C1. Thus the timer is reset at the end of the selected period.

By varying RV1, the time it takes C1 to charge to a particular voltage is varied, and thus the period of each increment and the total period can be varied. The time interval of the first increment is slightly shorter than the subsequent increments as Q2 is not capable of discharging C1 completely due to its collector-emitter saturation voltage (about 200 mV or so).

A conventional diode bridge rectifier is employed and C4 provides smoothing. A Ferguson pc-mount transformer is employed to drop the 240 Vac mains to a suitable voltage. Only one secondary winding from this transformer is used, providing 9 Vrms to the rectifier, which thus gives a dc supply of around 13-15 volts.

Resistors are used from each output of IC1 to each LED cathode to ensure that the outputs of IC1 drop below the 'low' threshold of the inputs to gate 'a' of IC2 when the IC1 outputs are 'active'.

The relay contacts are rated at 5 A and will switch a load of up to 1200 watts, providing the load has a unity power factor (i.e: it's resistive).



PARTS LIST — ETI 259

Resistors	**all ½W, 5%**
R1	100k
R2,3,16	1k
R4	3k3
R5-14	560R
R15,17,20	10k
R18	4k7
R19	10M
RV1	1M lin. pot.
Capacitors	
C1	33u/16 V tant.
C2	10n greencap
C3	220n
C4	470u/25 V electro.
Semiconductors	
D1	1N914,1N4148 etc.
D2-D5	1N4002,1N4004 etc.
IC1	LM3914
IC2	4001
Q1	BC307,BC177 etc.
Q2,Q3	BC547,BC107 etc.
LED1	TIL220G green LED
LED2-11	TIL220R red LEDs

Miscellaneous

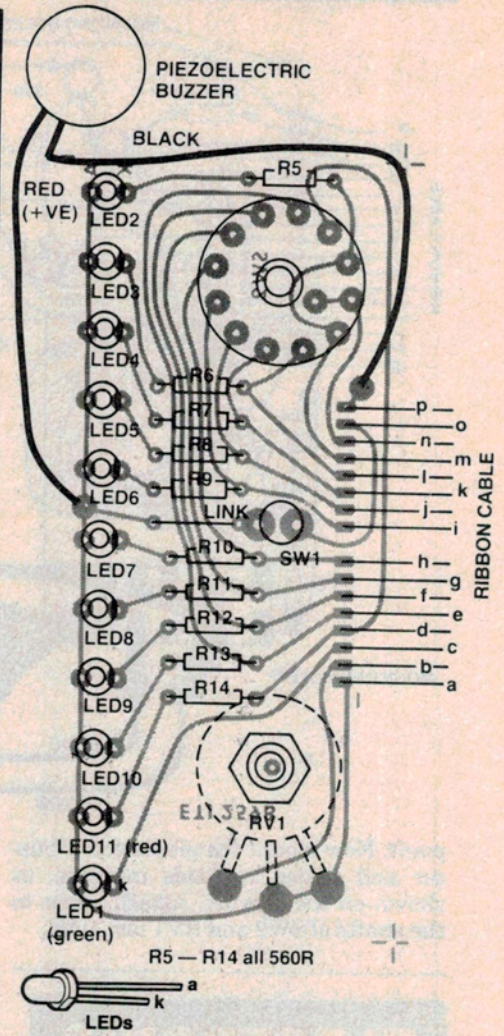
ETI-259a and ETI-259b pc boards; T1 — PL18/5VA transformer or similar; SW1 — miniature pushbutton; SW2 — 1-pole, 10-position rotary switch; RL1 — 12 V relay with 240 Vac/5 A contacts e.g: Fujitsu FRL-621DO12 or Takamisawa VB 12STAN or Pye 265/12/G2V; piezoelectric alarm or buzzer, e.g: Piezo-II type ESZ-11N; jiffy box 196 x 113 x 60 mm or similar; four-way or six-way terminal block; mains cord, cable clamp and plug; 3-pin mains socket; LED mounts; Scotchcal panel; ribbon cable; wire; nylon nuts and bolts, etc.

Price estimate

We estimate the cost of purchasing all the components for this project will be in the range:

$32 — $45

Note that this is an **estimate** only and **not** a recommended price.



for drilling the front panel. Centre punch them before drilling. Leave the panel at this stage, as it will be completed later.

The 3-pin mains outlet socket may be mounted to the box at this stage. Attach mains wire to each pin connection, using the appropriate colour coding (brown — active, blue — neutral, green/yellow — earth). Each wire needs to be about 70-80 mm long. Now secure the mains input cable. Strip the end first and cut the blue and brown wires so that they are 120-150 mm shorter than the green/yellow wire. This ensures that, should the cable ever be pulled out of the case, the earth wire will be the last to break.

The two pc boards may now be assembled. Tackle the smaller board first. Install the link first — it's in the middle of the board. The resistors should come next; these are all the same value — 560 ohms. Mount the LEDs next, inserting them in the board one by one and making sure you have each the right way round, as indicated on the overlay — cathode lead faces into the board. Each LED is positioned so that the distance between the board and the base of the LED is 12 mm. When distanced correctly, solder the leads in place.

The increment selector switch, SW2, may be mounted next. The holes in the pc board for its pins should be the correct size; check this. The switch can only go in one way. Carefully line up the pins and insert the switch in the board, pushing it all the way home. Solder the pins. Now the START pushbutton may be mounted. Make sure the holes for its pins have been drilled oversize too. You will need to trim the lugs on the pushbutton so that they fit in the pc board holes. Mount the pushbutton, making sure that the distance between the board and its mounting shoulder (with washer) is the same as that for SW2. You could temporarily mount the board to the front panel, using SW2 to secure it, and then solder the pushbutton's pins when the board is parallel to the panel.

The potentiometer is mounted last. Position it so that its lugs are over the appropriate pads on the pc board and then secure it to the board with its nut. Use a spring washer or a star washer under the nut. Then bend the lugs down to the pc board pads and solder them in place.

Last of all, attach two pieces of 8-way ribbon cable. These should each be about 130-150 mm long.

The front panel assembly may now be completed. If you're using a Scotchcal stick-on panel, this should be carefully attached to the ready-drilled aluminium jiffy box panel. Smooth it on, rubbing from the centre outwards to remove any bubbles. Cut the holes in the Scotchcal with a scalpel or other sharp-bladed knife. Insert the LED mounts in their holes next. Now you can mount the pc board, making sure that the LEDs all seat correctly in the mounts. Carefully tighten the nuts on the shafts of the START pushbutton and SW2 so as not to damage the Scotchcal on the panel. A large solder lug was secured between the washer for the pushbutton and the front panel to provide a mains earth▶

CHANGING THE PERIOD

The total time period may be altered by changing the value of C1. The approximate maximum period may be found from this formula:

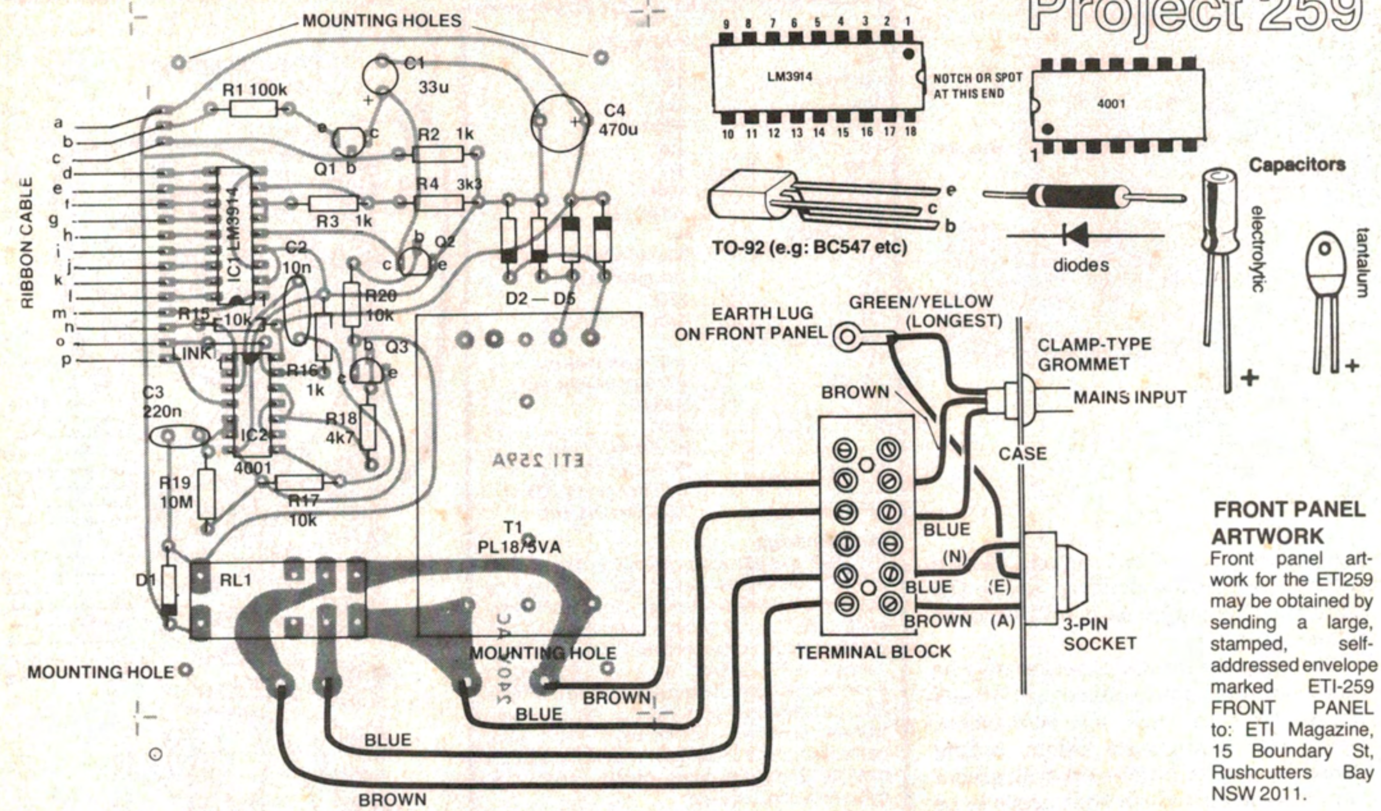
Period (approx.) = 5 x C1

where the value of C1 is in uF. It's only approximate as the tolerance on tantalum capacitors is quite broad. Thus with a 33u capacitor for C1, as specified, the maximum period is around 165 seconds or so. Given a desired period, calculate the capacitor value from:

C1 = period/5

and the value will be in uF. Choose the next highest preferred value, for safety's sake. You can then set the maximum period, and thus the period of the increments, using RV1, calibrating the unit with your watch. It's advisable not to use a capacitor any greater than about 120 uF — but this will give you a maximum period of 10 minutes!

Note that an RBLL-type electrolytic may be used for C1, but accuracy may suffer a little compared to tantalum types. The voltage never gets above 5 V, so a capacitor rated at 6 V, 10 V or 16 V is perfectly adequate.



FRONT PANEL ARTWORK
Front panel artwork for the ETI259 may be obtained by sending a large, stamped, self-addressed envelope marked ETI-259 FRONT PANEL to: ETI Magazine, 15 Boundary St, Rushcutters Bay NSW 2011.

point. Now mount the piezoelectric buzzer and solder its leads in place, as shown on the overlay. Attach knobs to the shafts of SW2 and RV1 last of all.

The next stage of construction to tackle is the large pc board. All the resistors and capacitors should be mounted first, taking care that you get C1 and C4 the right way round. Next, mount the diodes and the three transistors, again taking care with orientation. Mount IC1 (the LM3914) next — get it the right way round, followed by IC2. The latter is a CMOS IC and should only be handled by the ends of the package. When soldering it in place, solder pins 7 and 14 first, followed by the other pins. Use a hot iron with a clean tip when soldering the IC pins, solder each one quickly and pause every few joints to let the IC package cool down a little.

Mount the relay next. We used a type which can be readily soldered in place — a Fujitsu type FRL 621D012, although the board has been laid out to take several other common types. Make sure the board has been drilled out to accept the relay used before commencing construction.

The pc mount transformer can now be mounted to the board and its pins soldered in place. Note that it can only go on one way. Last of all the ribbon cable from the smaller pc board can be attached and then two pairs of mains wires, each about 40-50 mm long. These are the mains input and switched mains output leads. Use colour-coded wires, cut from mains cord, to avoid wiring errors.

The main pc board may now be mounted to the case. Use nylon nuts and bolts. Raise the board off the bottom of the box a few millimetres using fibre spacers. Use nylon nuts and bolts for the terminal block if it is bolted to the box too. Now complete the mains wiring, as indicated in the overlay/wiring diagram. The earth lead from the mains input cord goes to the solder lug attached to the front panel (under the pushbutton). A lead from this lug goes to the earth pin on the 3-pin mains output socket.

After a careful final check, you're ready to test the unit.

Testing

Set the 'Time Delay Adjust' control to minimum and the 'Increments' switch to 10. Plug the timer into the mains and turn it on. Wait five seconds or so for the power supply to reach full voltage and press the START pushbutton when the sweep second hand of your watch, or the seconds display on your digital watch, is at a convenient point. The LEDs 1 to 10 will light up, the piezoelectric buzzer sounding when LED 10 signals the end of the timing period. If you have used a 33u capacitor for C1, as per the parts list, then this should take close to 15 seconds. The relay should pull in when you press the START button, dropping out when LED 10 lights. You can calibrate the Time Delay Adjust pot. to suit the applications for which you use the project so that you obtain the required period.

A little experimentation and practice will show you how to use the unit to best advantage. ●