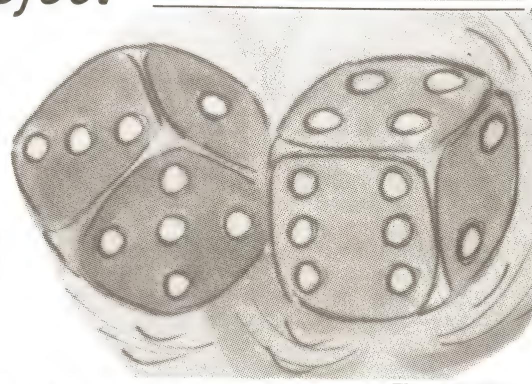
Teach-In '96 – Constructional Project



VARI-SPEED DICE

MAX HORSEY PCB DESIGN BY ALEX SIMM

When the chips are down, let them shake, rattle and roll out your fate. Illustrates how Teach-In Part Four might be applied.

THIS project is based on the information provided in *Teach-In* Part 4 and shows how modules may be selected and combined to produce a working project.

The Vari-Speed Dice includes a simple l.e.d. display, formed around two rows of six l.e.d.s which "chase" before stopping at "random". A novel feature of the circuit is that instead of the display stopping abruptly it gently slows to a halt, rather like a roulette wheel, thereby adding to the excitement if a particular number is required.

Making electronic circuits "random" is very difficult since any monostable or timer module will use a fixed time sequence. The project therefore relies upon a simple timer, plus the time for which the Start button is held down. The human factor adds the required degree of randomness!

BLOCK DIAGRAM

A block diagram of the modules required to make up the circuit is shown in Fig. 1. When the start button is pressed and held down, the timer causes the astable to start at full speed. The square wave from the astable drives the first counter/l.e.d. driver module, which causes six l.e.d.s to flash in sequence.

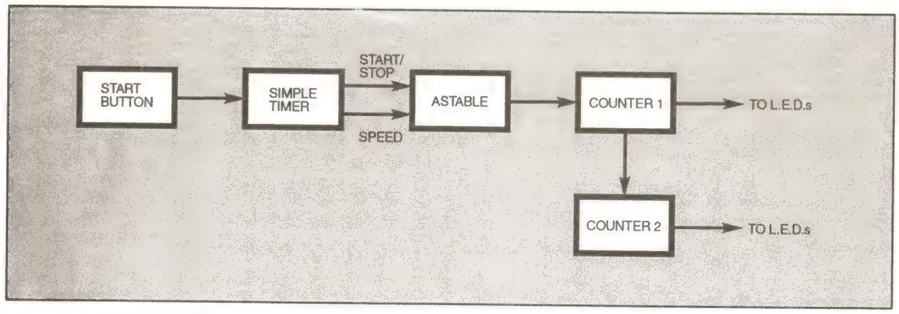
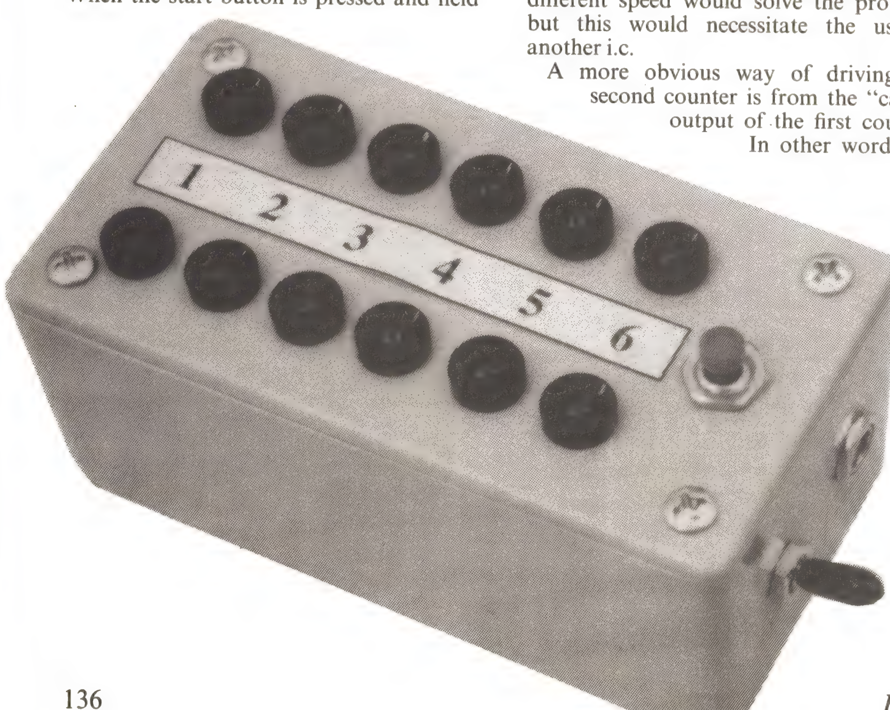


Fig. 1. Block diagram for the Vari-Speed Dice.



The same output from the astable could be used to drive the second counter, but this would make the l.e.d.s always stop at the same pairs. A second astable, set at a different speed would solve the problem, but this would necessitate the use of another i.c.

A more obvious way of driving the second counter is from the "carry" output of the first counter. In other words the second counter moves one step for every six steps of the first. The result is just as random as using two astable modules.

CHOOSING THE MODULES

The complete circuit diagram for the Vari-Speed Dice is shown in Fig. 2.

The Timer is based on the Simple Capacitive Delay module described in *Teach-In* Part 2 (Fig. 2.3). When the Start switch S1 is pressed, capacitor C1 is discharged. When S1 is released, C1 charges up slowly via resistor R1. The values of R1 and C1 determine the speed with which the voltage across C1 rises – higher values equals longer time.

A slowly changing voltage is often a nuisance in logic circuits, many of which require a sudden change from logic 0 to logic 1. However, in this design the slowly rising voltage is put to good use in controlling the speed of the astable.

VOLTAGE CONTROLLED ASTABLE

A number of astable modules are outlined in *Teach-In* Part 4. The one chosen for use here is the Voltage Controlled Frequency module of Fig. 4.7, which has its frequency (speed) varied by changing the voltage on the two input resistors, R2 and R3 in Fig. 2. This circuit does not provided a "glitch- free" output, but this is of no consequence since any glitches which cause the counter to move one step more than expected will add to the randomness.

In Fig. 2, the astable is formed around two NOR gates, IC1c and IC1d. Its basic frequency is determined by the values of resistors R2 and R3, and capacitors C2 and C3 (larger values = lower frequency). Their values have been chosen to set the oscillator speed to make it impossible to predict the outcome of the count. (If the value of C2 were to be increased to 100nF the speed would be just slow enough to allow a sharp contestant to fix the result by releasing the button at a particular moment.)

A method of switching an astable on and off by controlling the voltage at one of the pins was also discussed in Part 4 (Fig. 4.3). The technique is used here in the circuit of Fig. 2, IC1c pin 9 being the on/off input, which is controlled by the output from IC1b pin 4. When IC1c pin 9 is held high (made positive) the astable stops oscillating.

Referring to IC1a and IC1b, when the voltage at the junction of R1 and C1 is low, pins 1 and 2 will be low, consequently pins 3, 5 and 6 will be high and pin 4 low. In other words, output pin 4 merely copies the logic on input pins 1 and 2. Using a pair of gates in this way provides a cleaner voltage change at IC1c pin 9 than would be the case if the pin was connected directly to C1.

When switch S1 is pressed, the voltage at the positive side of capacitor C1 falls to zero and, as a result, IC1c pin 9 also goes low. Since the lower ends of resistors R2 and R3 are also connected to C1, and thus also at 0V, the astable oscillates at its maximum speed (as discussed in Part 4).

As C1 charges, the voltage at its junction with R2 and R3 rises, causing the astable to slow down. When the voltage across C1 reaches half the supply voltage, the astable is at its minimum speed. Then, as this voltage crosses the half way level, the logic at IC1b pin 4 changes from low to high, causing the astable to stop oscillating.

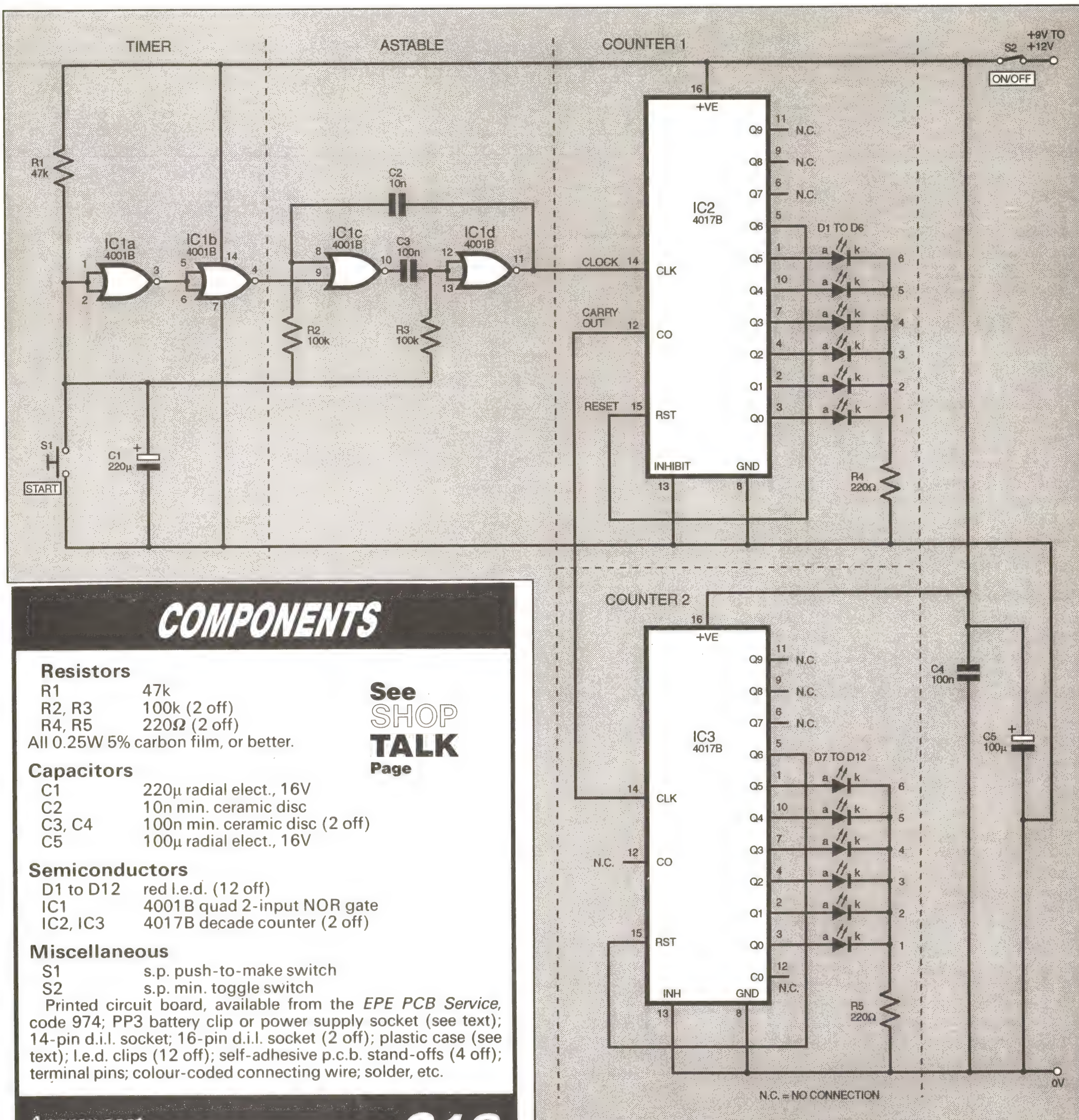
COUNTER/ CHASER

The l.e.d. counter/chaser circuits are based on those discussed in Part 4, Fig. 4.12 and Fig. 4.13, using a CMOS 4017B decade counter. Essentially, both counters are identical and are formed around IC2 and IC3. Each is connected so that it counts from one to six, then resets to one again at the next clock pulse.

Counter IC2 is "Clocked" on its input pin 14 by the output pulses from IC1d pin 11 of the astable. Pulses from the "Carry Out" pin 12 of IC2 provide the clock pulses for counter IC3.

On both IC2 and IC3, Reset pin 15 is connected to output pin 5, which is the seventh output (Q6). Consequently, each i.c. counts from the first output (Q0), through outputs Q1 to Q5, then resetting back to Q0 immediately the count reaches output Q6.

Each output is connected to an l.e.d. Since only one l.e.d. can be on at any one time, a single series resistor, R4 for IC2 and R5 for IC3, is used to control the current. The current available from each output



COMPONENTS

Resistors
R1 47k
R2, R3 100k (2 off)
R4, R5 220Ω (2 off)
All 0.25W 5% carbon film, or better.

See SHOP TALK Page

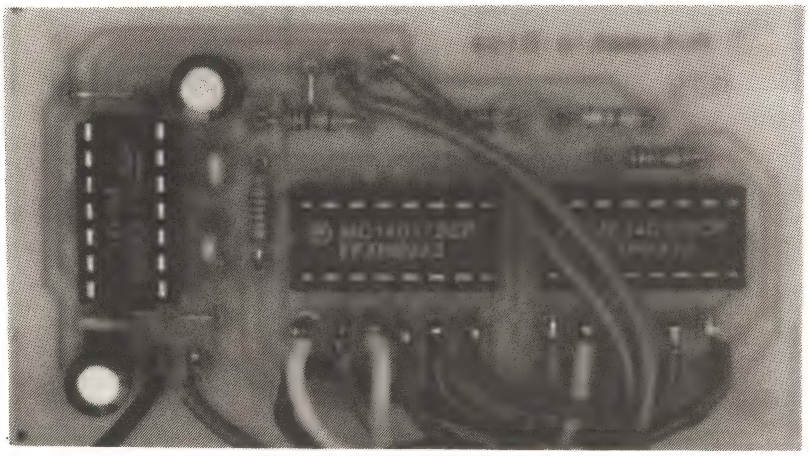
Capacitors
C1 220µ radial elect., 16V
C2 10n min. ceramic disc
C3, C4 100n min. ceramic disc (2 off)
C5 100µ radial elect., 16V

Semiconductors
D1 to D12 red l.e.d. (12 off)
IC1 4001B quad 2-input NOR gate
IC2, IC3 4017B decade counter (2 off)

Miscellaneous
S1 s.p. push-to-make switch
S2 s.p. min. toggle switch
Printed circuit board, available from the *EPE PCB Service*, code 974; PP3 battery clip or power supply socket (see text); 14-pin d.i.l. socket; 16-pin d.i.l. socket (2 off); plastic case (see text); l.e.d. clips (12 off); self-adhesive p.c.b. stand-offs (4 off); terminal pins; colour-coded connecting wire; solder, etc.

Approx cost guidance only **£18**

Fig. 2. Full circuit diagram for the Vari-Speed Dice.



Completed printed circuit board.

is rather small, and the i.c. is not really designed for driving l.e.d.s directly. However, with a supply of 9V or 12V (from, say, a mains adaptor) the l.e.d.s are more than adequately lit.

If extra brightness is required, special low-current l.e.d.s are available. Alternatively the CMOS 4017B could be replaced by the 74HC4017 which has a much higher output current, but *MUST NOT* be used on a supply of *MORE* than 6V. The subject of CMOS output currents and l.e.d. series resistors is referred to in Part 4.

Capacitors C4 and C5 provide the required power line decoupling, as discussed in Part 1. Switch S2 is a power supply On/Off switch, particularly important if a battery is used to power the circuit.

CONSTRUCTION

Details of the printed circuit board (p.c.b.) and its connections for the Vari-Speed Dice are shown in Fig. 3. This board is available from the *EPE PCB Service*, code 974.

Fit the two short wire links (not the connecting wires), followed by the i.c. sockets and resistors. Now fit the small ceramic disc capacitors. The labelling of these can sometimes be confusing. Note that if the legend "103" is printed on the capacitor body it means the capacitance value is 10nF (0·01μF) and that "104" means 100nF (0·1μF).

To some readers, this may seem quite illogical. However, "103" actually translates like a resistor colour code, namely, "one", "zero" plus "three" more zeros, i.e. 10,000, measured in picofarads (pF). Clarifying further:

$$1F = 10^6\mu F = 10^9 nF = 10^{12} pF$$

Capacitors C1 and C5 are electrolytic and must be fitted the correct way round. The negative end is normally printed on the body; the positive end is indicated by a longer lead.

Solder terminal pins into the p.c.b. for all the external connections.

The p.c.b. allows the l.e.d.s to be mounted directly to it, if preferred. However, in the prototype, the l.e.d.s were mounted on the case lid and linked to the p.c.b. with wires. It is *much* easier to mount the l.e.d.s in the case *before* connecting them to the circuit.

If this is the chosen method, note from Fig. 3 that the l.e.d. anodes (a) have separate wires connecting back to the board. The l.e.d. cathodes (k), however, are soldered to each other in two groups, each group is then connected to the board via a single wire.

HOUSING THE DICE

The prototype was used with a 12V battery eliminator (mains adaptor) and was housed in a plastic case measuring 104mm × 53mm × 44mm. Although the circuit can be powered by a 9V battery, note that a PP3 battery will not easily fit into this size of box.

As seen in the photographs, l.e.d.s were mounted in two straight lines. Alternatively, two circular arrangements could be used. When marking out the positions of the l.e.d.s, allow room for their mounting clips. Although the l.e.d.s could be inserted directly into the case, the use of clips makes the mounting task easier and provides a much neater finish.

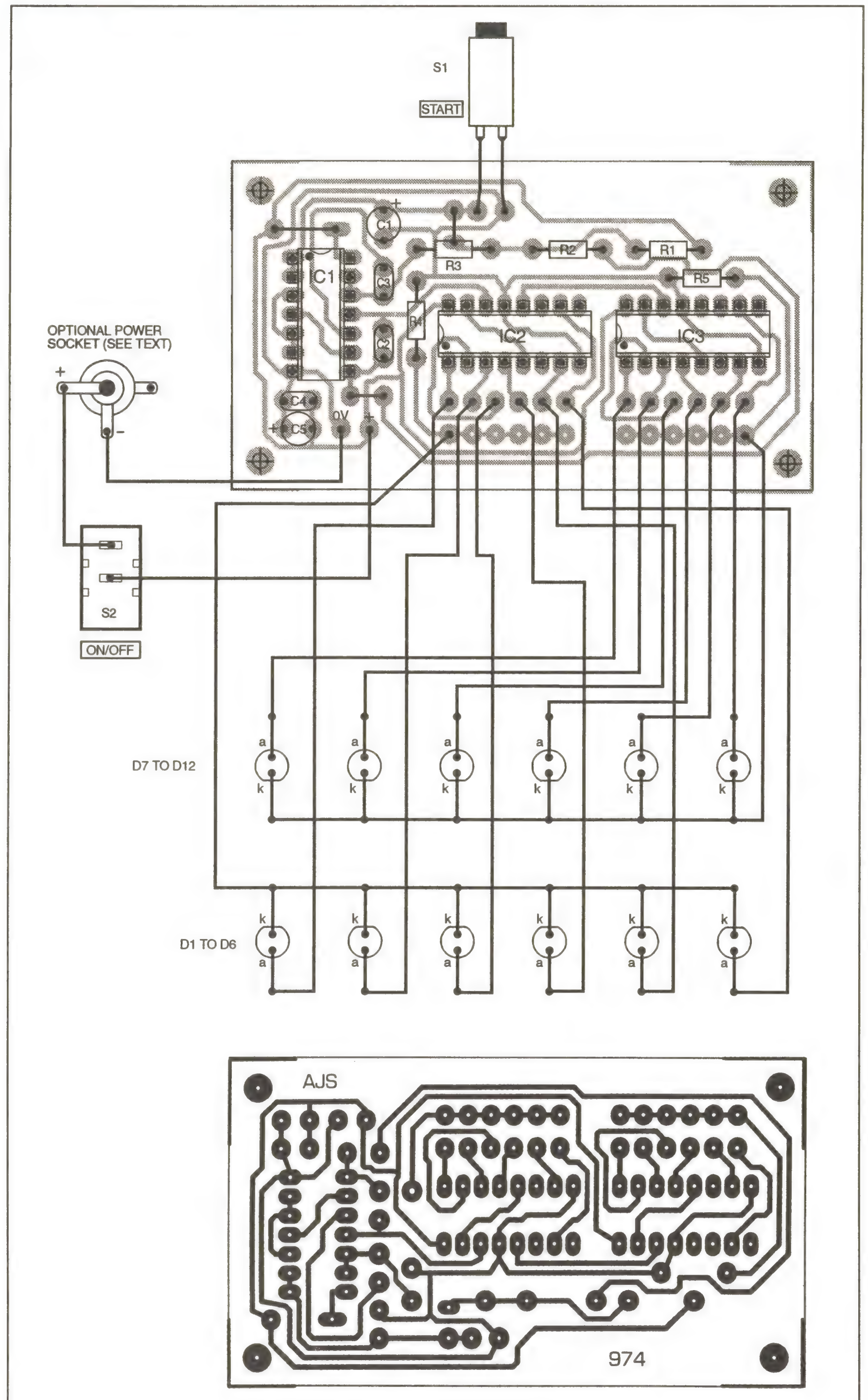


Fig. 3. Printed circuit board component layout, interwiring and full size underside copper foil master pattern. The spare copper pads, below IC2/IC3, can be used for direct *board mounting of the l.e.d.s.*

Mark the positions of the Start pushbutton switch, On/Off switch and Power Input socket, if required. Drill the holes, taking particular care to get the l.e.d. holes in line – even if just one l.e.d. is not exactly in line the appearance is spoilt. It helps if a very small drill is used first.

Position the l.e.d.s into their clips ensuring that the cathode (k) leads are all facing the same way as shown in Fig. 3. This makes the common cathode (k) connections much simpler to arrange. The cathode side of an l.e.d. is usually the shorter lead. If the leads have been cut, note that the cathode of a round l.e.d. is likely to be denoted by a tiny flat mark at the base of the body.

Now connect and solder the l.e.d. cathodes using a length of *bare* wire. This common junction is connected to the p.c.b. using a length of *insulated* wire.

Use colour coded insulated wire to link the l.e.d.s to the terminal pins. In other words, use a black lead for the common cathode connection, a brown lead for l.e.d. D1, red for D2, orange for D3, etc. Using coloured leads in resistor colour code order greatly eases assembly, particularly if fault finding is necessary.

The l.e.d. leads should be shortened before soldering and bent neatly against the plastic body of the case after soldering.

Complete the external wiring. Discharge static electricity from your body before handling the i.c.s, by touching a grounded item first. Then insert the i.c.s into their sockets ensuring that their orientation notches line up as shown.

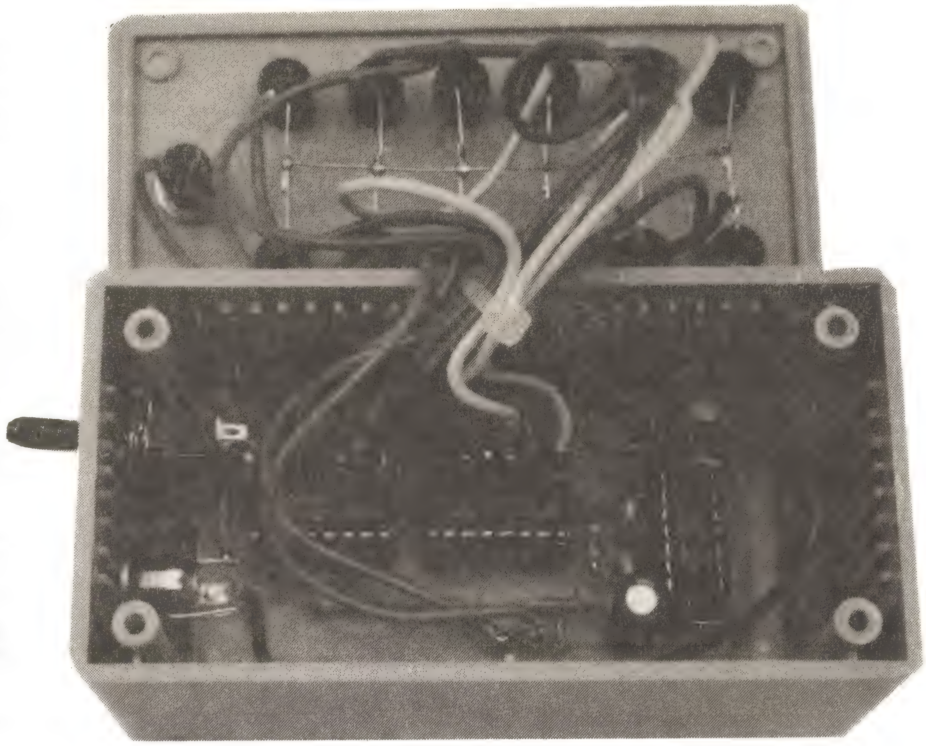
Now thoroughly check the board with a magnifying glass, ensuring that components are correctly positioned and that all solder joints are correctly made.

TESTING

A regulated 9V or 12V supply which can be limited to a maximum output current of 100mA is ideal for testing, and will be unlikely to harm the circuit even if major mistakes have been made.

Connect the supply, switch on S2, and check that one l.e.d. of each set lights up. If this does not happen, switch off and recheck for mistakes.

If all is well, press switch S1. The l.e.d.s should chase, with one set chasing six times faster than the other. Release S1. After a brief pause, the chase should slow down and finally stop. The pause length may be shortened by reducing the value of either resistor R1 or capacitor C1.



The p.c.b. is positioned on the base of the box with self-adhesive stand-offs. Take care that the lid mounted components do not short on the p.c.b.

FAULT FINDING

If the circuit does not behave as expected, decide first if the fault affects the whole circuit, or just one module and if so, which one. For example, measure the voltage across pins 7 and 14 of IC1, and across pins 8 and 16 of IC2 and IC3. If a voltage reading equal to that of the power supply is present, and with the correct polarity, check each module as described below. If not, check that the power socket has been connected correctly and that there is a voltage across it.

Read the fault finding guide in Part 1 of the series for general help, and using a voltmeter with its negative side connected to 0V in the circuit try the following tests:

When S1 is pressed, the voltage at IC1 pins 1 and 2 should be 0V. When S1 is released this voltage should rise to the maximum power supply level. The voltage at IC1 pins 3, 5 and 6 should be equal to the positive supply when S1 is pressed, switching to about 0V a few seconds after S1 is released. IC1 pin 4 should do the opposite of pin 3. Check that the voltage on IC1 pin 9 copies that on IC1 pin 4.

Correct operation of the astable can only be checked with the aid of an oscilloscope: a square wave should be seen at IC1 pin 11 and IC2 pin 14.

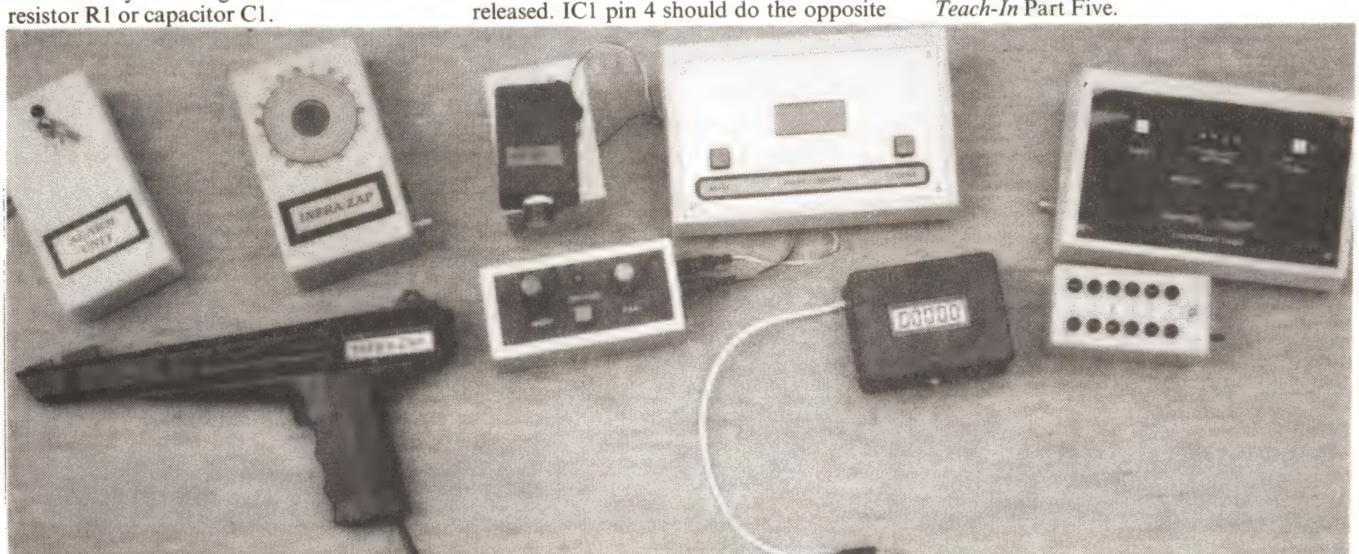
Failure of all the l.e.d.s is likely to imply that they are connected the wrong way round or the common connection between their cathodes and the p.c.b. has been forgotten.

INSTALLATION

The p.c.b. may be fastened to the base of the case using self-adhesive p.c.b. supports. Check that when the lid is positioned, a short circuit cannot occur between exposed parts on the p.c.b. and the bare l.e.d. wires. Screw the lid into position, and give the project a final test. □

PART FIVE

Next month an Infra-Red Zapper construction project will be the subject of *Teach-In* Part Five.



Collection of "demonstration" modules used to back up the Teach-In Series.