INTERMEDIATE PROJECT

A series of projects for the not-so-experienced constructor. Although each article will describe in detail the operation, use, construction and, where relevant, the underlying theory of the project, constructors will, none the less, require an elementary knowledge of electronic engineering. Each project in the series will be based on inexpensive and commonly available parts.

9. IC MONITOR

J. Ruffell

Digital probes come in many shapes and versions. All of these, however, suffer from a single disadvantage: they can monitor the logic level at only one IC pin at a time. To overcome this limitation, we propose a 16-way IC monitor with a probe that can be clipped on to virtually any commonly used logic dual-in-line integrated circuit with up to 16 pins. Ideal for getting to grips with digital circuits, this IC monitor gives an instant indication of all input and output levels simultaneously. Interestingly, it automatically finds the power pins of the IC under test and works with most TTL and CMOS circuits.

The circuit of the IC monitor (Fig. 1) consists of 16 identical smaller circuits powered by one supply. The operation of the input circuits will be described with reference to the top one, which consists of D_{17}-D_{18}-R_{18}-N_6-R_2-D_{16}.

The IC monitor is powered by the circuit under test via the two supply pins of the IC it is connected to. This means that the power supply of the circuit under test must be capable of supplying an additional current of up to 500 mA to power the IC monitor. Make sure this is the case before connecting the monitor!

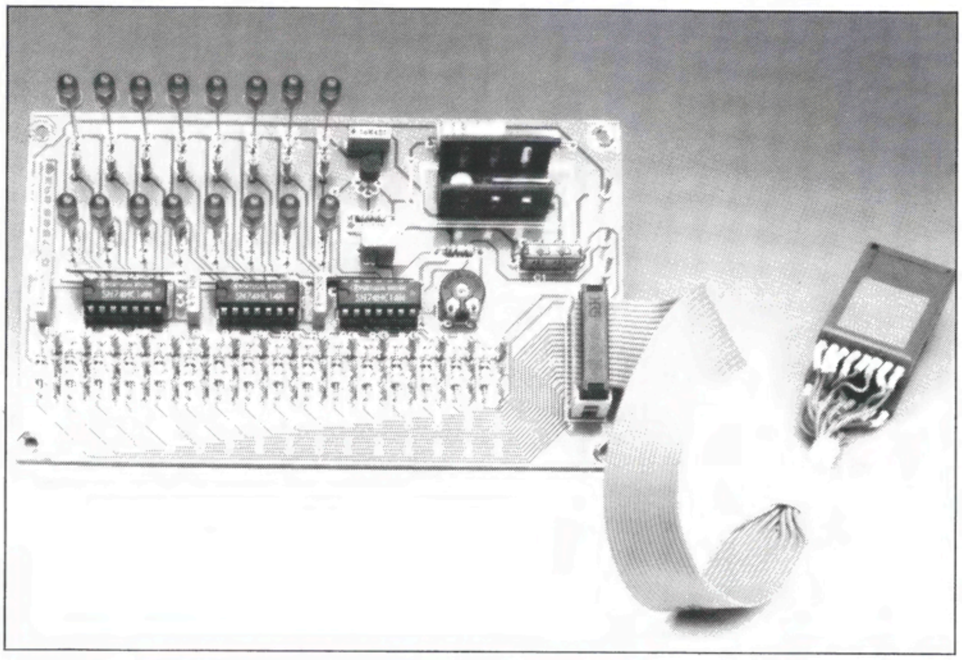
You are probably aware that pin 14 of 14-way DIL logic ICs is usually the positive supply terminal, and pin 7 the ground terminal. For 16-way ICs, the respective pins are usually 16 and 8. Unfortunately, there are also many ICs which deviate from this rule of thumb —their power connections are at pins other than 14 or 16, and 7 or 8. The IC monitor, however, finds the power pins automatically. How? Let's examine the input circuit a little closer.

If a valid logic level is measured at pin 2 of connector K_1, it will be either a 1 or a 0. Whichever, the absolute voltage is invariably a little lower (for a 1) than the positive supply voltage, or a little higher (for a 0) than 0 V. This is because the swing of logic IC outputs is nearly always smaller than their supply voltage owing to the forward drop across the output transistor(s). Invariably, only two of the diodes D_{17}–D_{48} will therefore conduct and pass the supply current because they are the ones connected to the highest potential —the supply voltage.

On the above assumption that pin 2 of K_1 carries a logic level and not the positive or negative supply voltage, diodes D_{18} and D_{17} block, but the monitor circuit is powered by two other diodes. The logic level is applied to the input of inverter N_6 via series resistor R_{18}. Depending on the measured logic level, the inverter supplies either a low output level (input = high), or a high output level (input = low). Hence, the LED at its output, D_{16}, lights only if the measured level is high (1).

TTL and CMOS

There are a large number of significant differences between ICs from the TTL



(transistor-transistor logic) and the CMOS (complementary metal-oxide silicon) family. The most important difference is the supply voltage range of about 4.5–5.25 V for TTL circuits against about 3–18 V for most CMOS ICs (note: there are many exceptions to this rule).

Since the IC monitor is to be suitable for use with TTL as well as CMOS ICs, it would appear logical to use CMOS inverters from the well-known CD4000 series, since these have the larger supply voltage range. Unfortunately, the outputs of these ICs can not sink enough current to drive a LED direct. The alternative, 16 discrete current amplifiers, must be rejected because it would require a quite complex circuit. There is, however, an IC family capable of working at relatively low supply voltages **and** sinking the current required to light a LED: the 74HC series.

The one disadvantage of the 74HC series, the maximum supply voltage of about 6 V, is fairly simple to overcome by using a series regulator which limits the supply voltage taken from the circuit under test to a value which is safe for the inverters in the IC monitor. This regulator is a discrete circuit, R_{51}-D_{50}-T_2. Before its limiting action starts, the output voltage of the series regulator follows the input voltage quite accurately, which is an important requirement for 5-V digital systems.

Circuit T_1-R_{50}-D_{49} forms a voltage source which limits the LED current(s) to an acceptable level at relatively high supply voltages. Let's assume that the circuit under test works at a supply voltage of 12 V, and that the voltages across D_{17} and D_{18} are about 2 V. Without T_1, the series resistor for the LED would have to drop about 10 V. Similarly, for a system operating at 5 V, the drop would work out at about 3 V, which evidently requires another resistor value. The solution to this problem has been found in the use of a series resistance, T_1, whose value increases automatically with the supply voltage. Since T_1 limits the LED voltage to about 2 V, a single resistor value (22 Ω) may be used for the full range of the supply voltage.

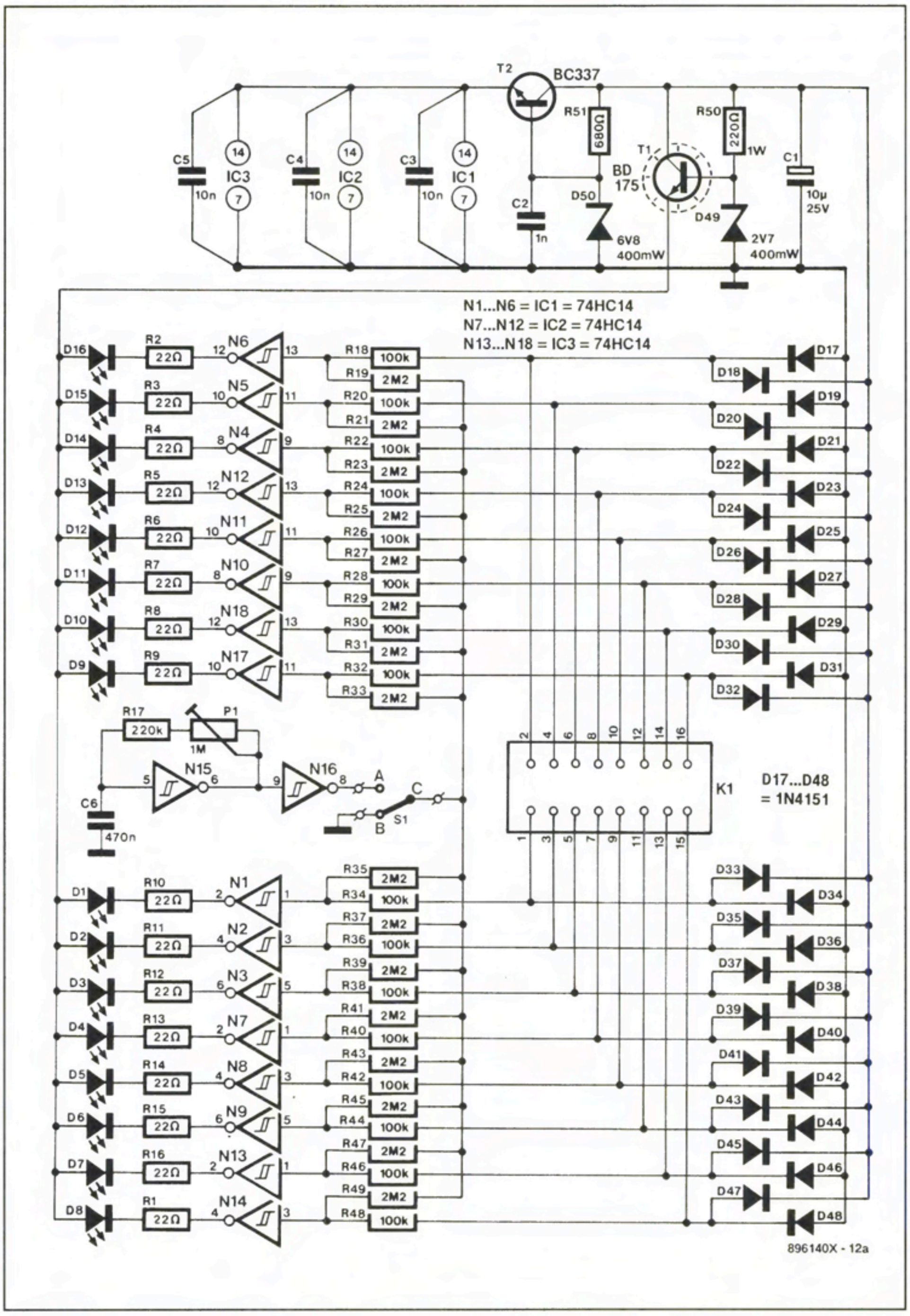


Fig. 1. Circuit diagram of the 16-input IC monitor for TTL and CMOS digital circuits.

Open input?

In general, inputs of CMOS ICs must never be left open. You may have found out already from experiments that an open (non-connected) CMOS input causes the IC to heat up and destroy itself rapidly. The actual destruction is normally caused by excessive current drawn by the output stages. Obviously, this effect must be avoided at all times and calls for an additional function of the IC monitor: detection of open CMOS inputs.

The circuit to do so is an oscillator, N_{15}-N_{16}-R_{17}-P_1-C_6. When switched on with S_1, it supplies alternating low and high levels to the inverter gates via 2.2 MΩ resistors. When the oscillator is switched off, these resistors ensure well-defined low levels at the inverter inputs that do not receive a logic signal from the circuit under test. The high resistor value of 2.2 MΩ ensures at the same time that measured signals do not see an additional load, so that the inverters can follow the high and low levels reliably.

Finally, note the type of diode in positions D_{17}–D_{48}: the 1N4151 is used rather than the perhaps more familiar 1N4148 because of its lower forward voltage drop, which is essential for correct operation of the circuit.

Construction

Since the circuit is quite complex by the standards used in this series of articles, it is best to build the IC monitor on the printed-circuit board shown in Fig. 2. This board is available ready-made through the Readers Services. For those with access to a photographic dark-room and the necessary etching and drilling equipment, the mirror image of the track side of the circuit board is shown to enable a transparent film to be made from a photocopy.

Since the pad density is fairly high in places, the PCB must be soldered with great care and precision. Work accurately and use a low-power iron and little solder to prevent short-circuits between adjacent tracks and pads.

Start the population with the wire links. Next, fit the passive parts (capacitors, resistors, IC sockets, the preset and the pin header). Lastly, mount the transistors and the diodes (but not the LEDs), taking good care to maintain the correct orientation.

The power transistor, T_2, is fitted with a small U-shaped heat-sink (TO-220 style) to assist in its cooling. The heat-sink is bolted on to the board together with the transistor. An insulating washer is not re-

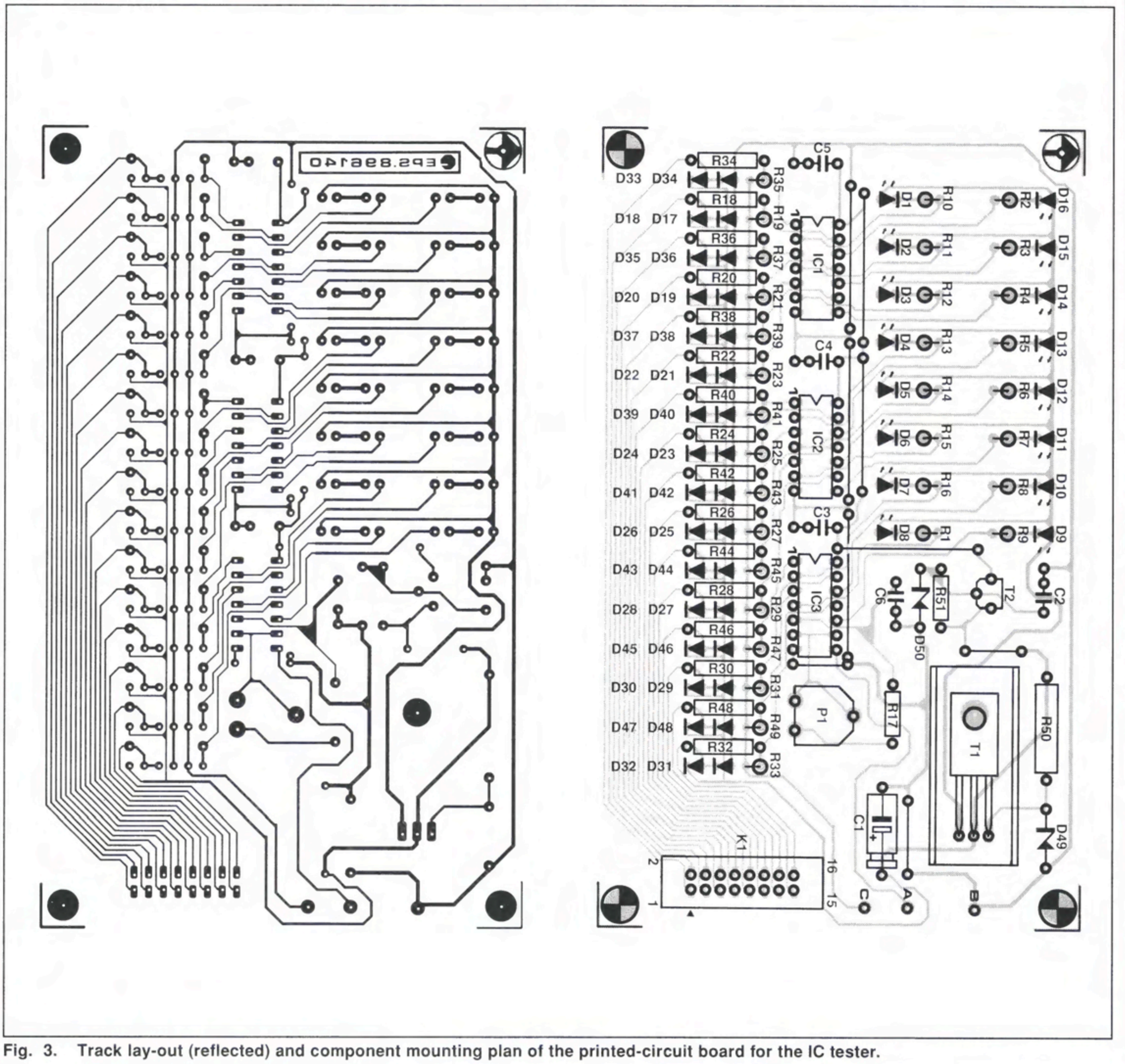


Fig. 3. Track lay-out (reflected) and component mounting plan of the printed-circuit board for the IC tester.

quired. Be sure to leave the terminals of the BD175 long enough so that they can be bent at right angles for inserting into the PCB holes without touching the heat-sink.

Next, mount each LED such that the lower side of its plastic body is about level with the top of the heat-sink. Do not fit the completed PCB into the enclosure as yet.

Initial test

Use a pair of light-duty flexible test leads with small crocodile clips to connect a DC power supply of 5–18 V to any two pins of connector K_1. Set P_1 to the centre of its travel. Set switch S_1 to position B (inverter inputs logic low). If the circuit works so far, the LED associated with the pin connected to the positive supply voltage will light. Set S_1 to position A (oscillator on) and check that 14 LEDs flash. Adjust P_1 for the required flash rate. Next, systematically connect the positive and negative

COMPONENTS LIST

Resistors:

R_1–R_{16} = 22Ω
R_{17} = 220k
R_{18};R_{20};R_{22};R_{24};R_{26};R_{28};R_{30};R_{32};R_{34};R_{36};R_{38};R_{40};R_{42};R_{44};R_{46};R_{48} = 100k
R_{19};R_{21};R_{23};R_{25};R_{27};R_{29};R_{31};R_{33};R_{35};R_{37};R_{39};R_{41};R_{43};R_{45};R_{47};R_{49} = 2M2
R_{50} = 220Ω 1 W
R_{51} = 680Ω
P_1 = 1M0 preset H

Capacitors:

C_1 = 10μ;25 V
C_2 = 1n0
C_3;C_4;C_5 = 10n
C_6 = 470n

Semiconductors:

D_1–D_{16} = LED; red; 5-mm dia.
D_{17}–D_{48} = 1N4151
D_{49} = 2V7; 400 mW zener diode
D_{50} = 6V8; 400 mW zener diode
IC_1;IC_2;IC_3 = 74HC14
T_1 = BD175
T_2 = BC337

Miscellaneous:

S_1 = miniature toggle switch.
K_1 = 16-way angled pin header for PCB mounting.
K_2 = 16-way IDC socket.
K_3 = 16-way IC test clip (e.g., ElectroMail stock number 423-627).
TO-220 or TO-126 style heat-sink.
Approx. 50 cm 16-way flatcable.
PCB Type 896140 (see Readers Services page).

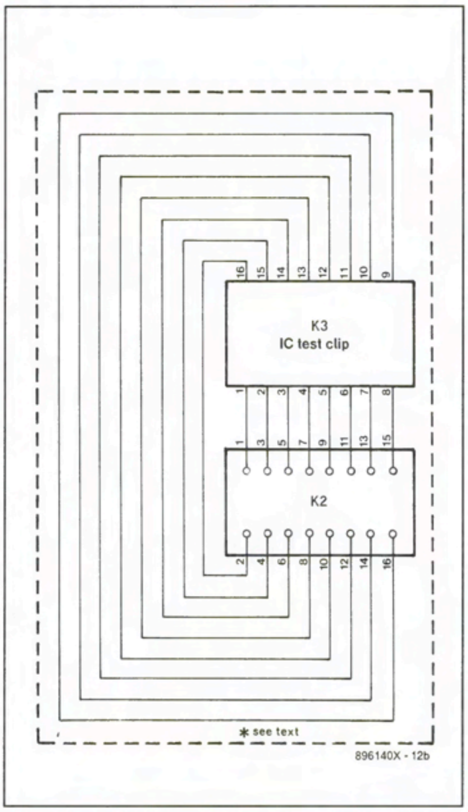


Fig. 3. Test clip wiring and connections.

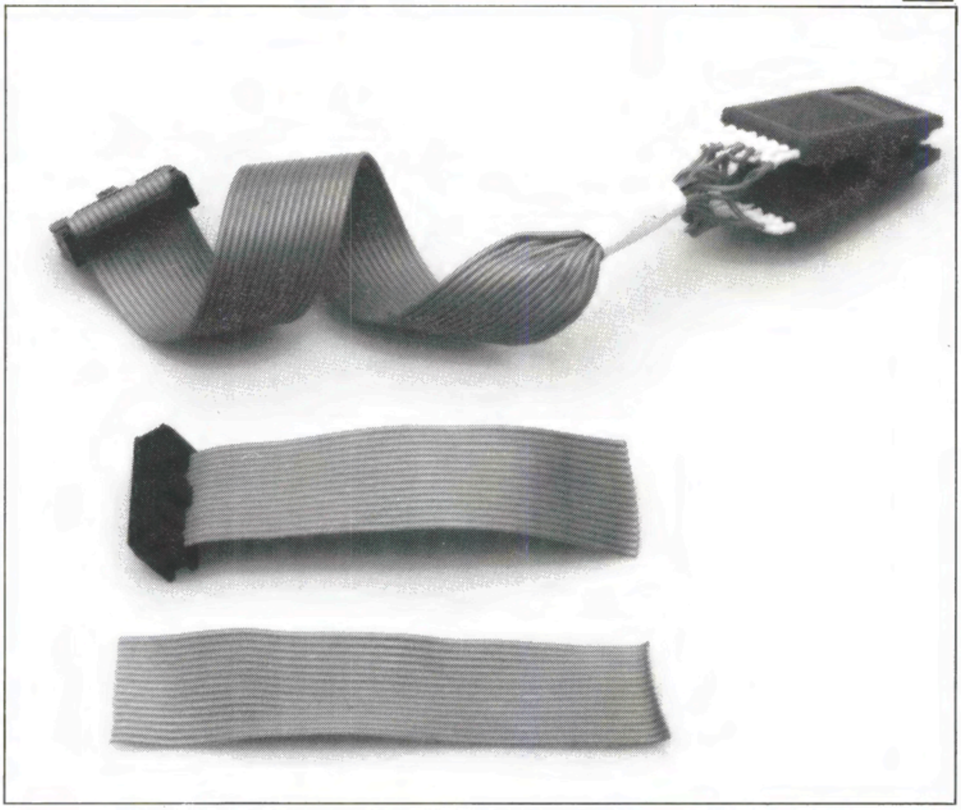


Fig. 4. The test cable is made from an IDC, a length of flatcable and a 16-way IC test clip.

supply wires to all other inputs to verify the operation of the associated diodes (e.g., pair D17-D18 for K1 pin 2).

Case and test cable

The completed, tested and adjusted printed-circuit board is fitted in a suitably sized ABS enclosure, for which a suggested front-panel lay-out is given in Fig. 5 (ready-made front panel adhesives are not available). Cut a rectangular slot in one of the short sides of the enclosure to enable an IDC (insulation displacement connector) to be connected to K1.

The construction of the 16-way flatcable between the IC monitor and the test clip is illustrated in Fig. 4. Contrary to what many electronics retailers and connector manufacturers would have you believe, an IDC is fairly simple to fit on to a flatcable of almost any width, without the use of special (very expensive) tools.

Cut the cable as straight as you can using a large pair of scissors. Insert it between the socket (or header) and the associated cap, taking care to align the individual wires in the cable with the V-shaped clamps which are to receive them. Note the position of pin 1 on the connector, which is usually marked. Make sure this pin is at the side of the single coloured wire in the flatcable.

Most IDCs have a U-shaped cap with snap-in fittings on the side guides, which readily lock with the main connector. Carefully place the cap on the socket, pressing it down with equal force at both extremes to prevent one guide locking before it is due. Use hand force to clamp the flatcable between the socket and the cap. Check whether the flatcable and the socket are at right angles. Next, use a small piece of wood and a light hammer, or a carefully operated vise, to press the cap further on to the socket until the parts click together. Apply a little more force to ensure a good connection. Some IDCs have an additional cap that functions as a strain relief. Fold the flatcable back and fit this second cap.

Connect the pins of the 16-way IC test clip to the corresponding wires at the other side of the flatcable. Be sure to connect the flatcable wires to the same pin numbers as K1 (K1 pin 1 goes to test clip pin 1, etc.). Finally, use an ohmmeter or a continuity tester to check whether all connections are in accordance with the circuit diagram.

Practical use

No doubt you will soon find the IC monitor an indispensable and easy-to-use test instrument for a wide variety of digital circuits. Open inputs are traced rapidly by switching S1 to the oscillator position. Any one LED which starts to flash in addition to already flashing ones indicates an open input (remember that slowly changing logic levels applied to the IC may cause LEDs to flash if the oscillator is switched off with S1). If the frequency of a measured logic level exceeds about 25 Hz, the relevant LED no longer flashes, but appears to light at reduced intensity. Finally, make a habit of switching off the circuit under test before placing the clip on an IC. ■

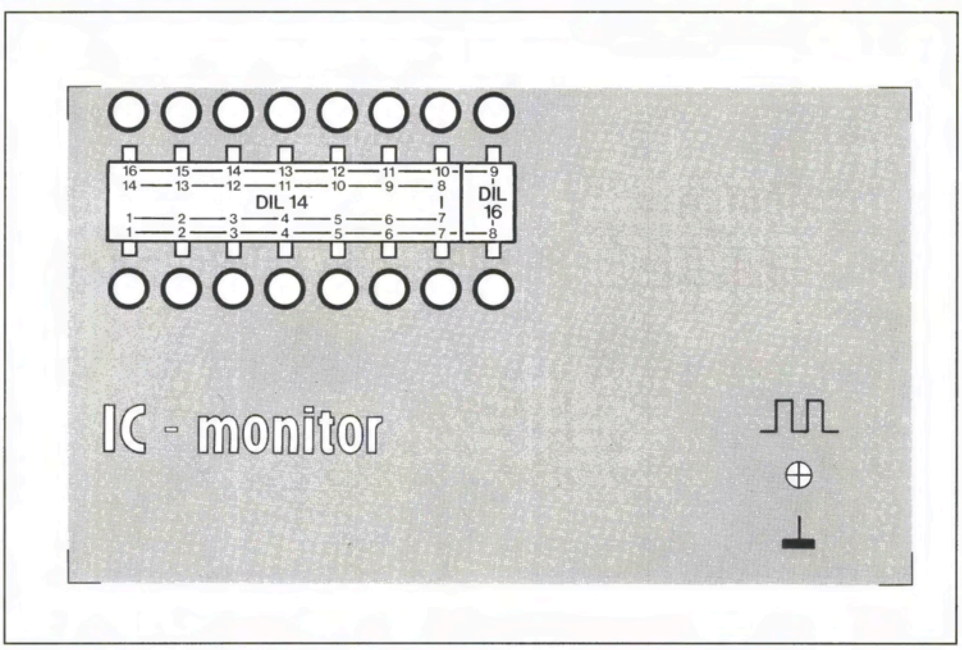


Fig. 5. Suggested front-panel lay-out.