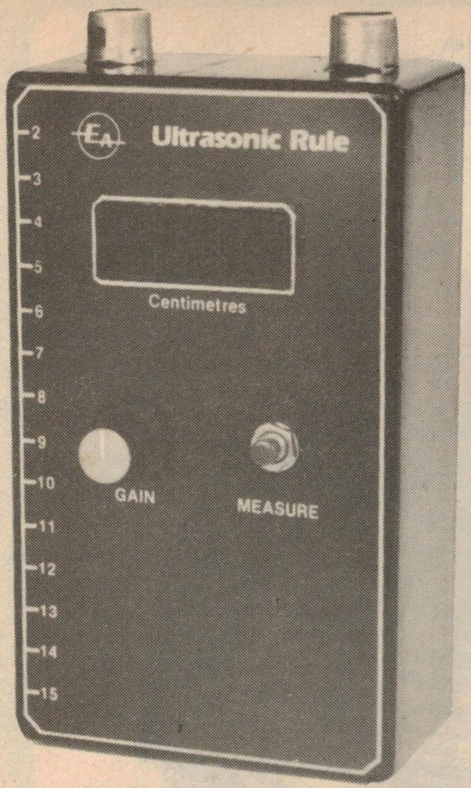
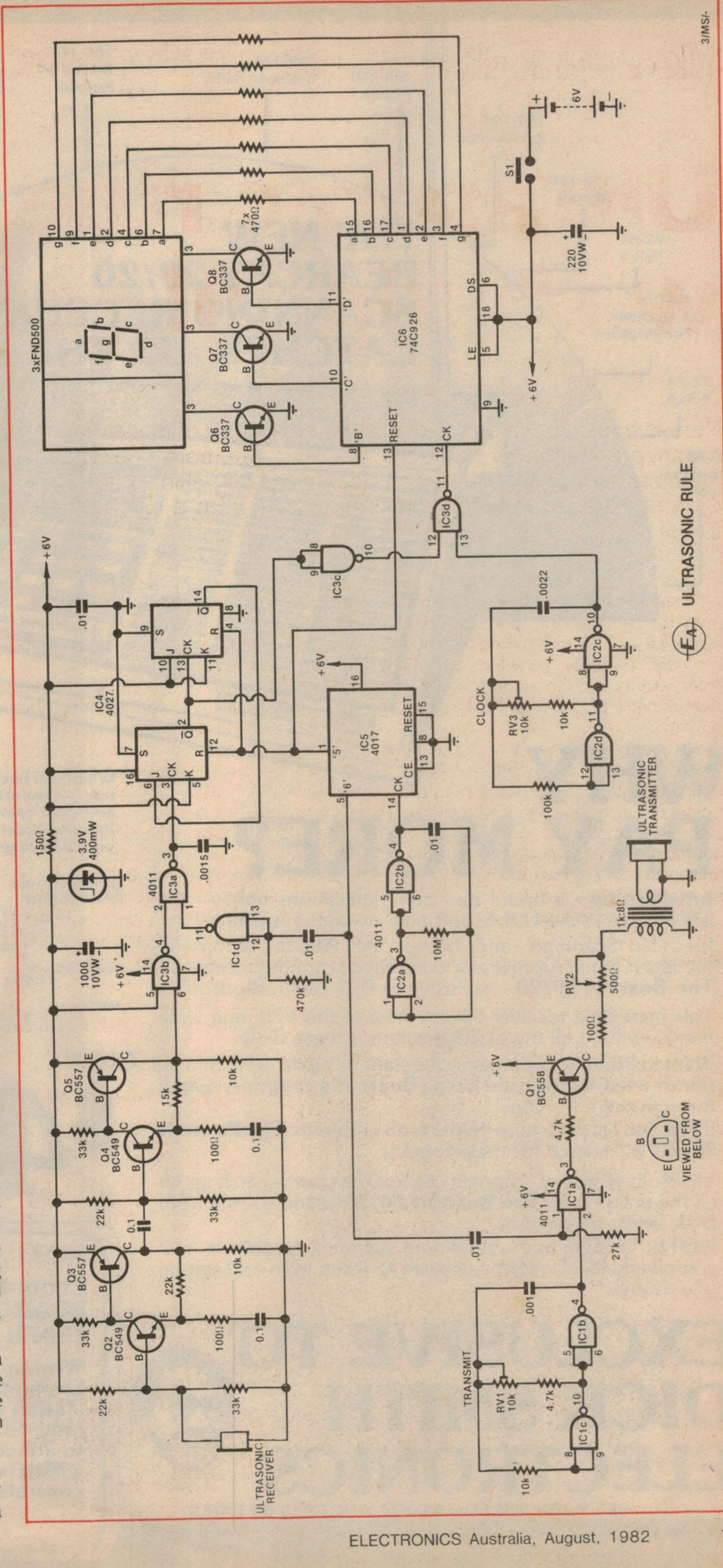


The prototype can measure distances ranging from 50cm to about 7 metres.



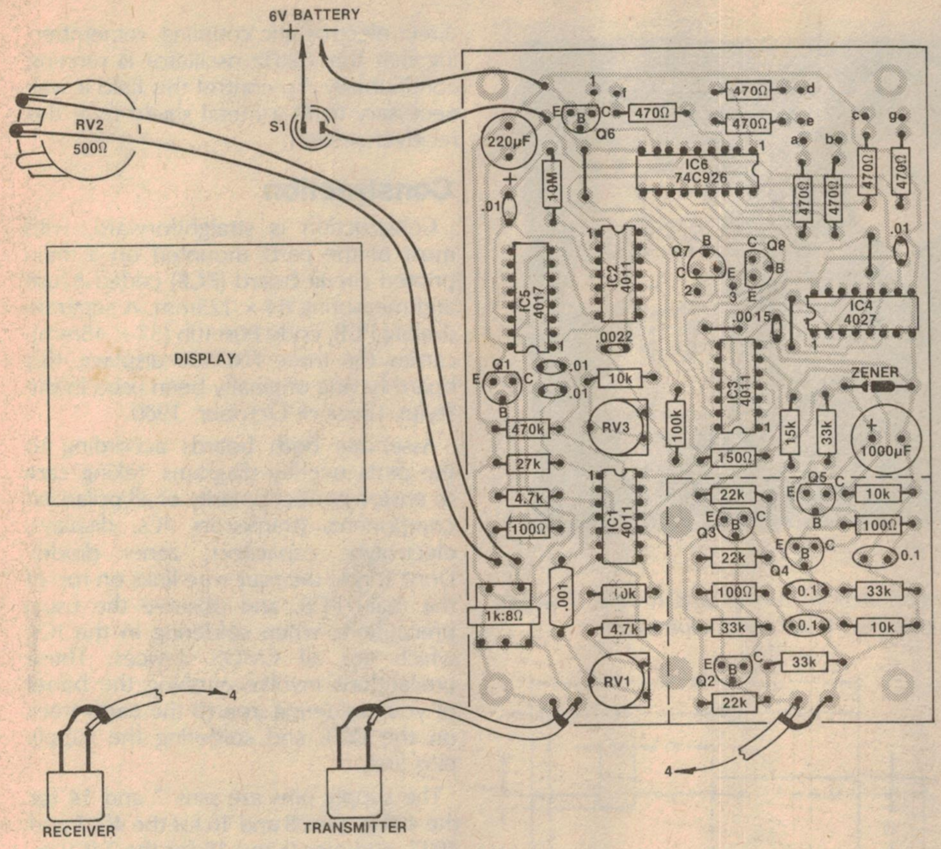
pulses of 100ms duration at pins 1 and 5. The pulses from pin 5 are coupled to pin 1 of IC1a via a .01μF capacitor. This capacitor, in conjunction with the associated 27kΩ resistor, reduces the pulse length to approximately 0.15ms, and the transmitter is gated on for this period.

At the same time, the 100ms pulses from IC5 are fed to IC1d via a .01μF capacitor which, in association with a 470kΩ resistor, gives a time constant of about 3ms, 20 times that of the transmitter "on" period. This pulse is inverted by IC1d and the output taken to pin 1 of IC3a, which gates off the receiver output during this period.

The purpose is to inhibit the receiver output during the transmit time, and for a significant time afterwards. The extended time is necessary to allow for any ringing in the transmitter transducer which, because of its high Q, can be quite lengthy. While ever this is strong enough to pass through the receiver and affect the counting circuit, it can cause a false reading.

As a result of this inhibit time, there is a minimum distance below which the device will not function. Based on the above figures this is about 50cm, which is an acceptable compromise.

At the end of the 3ms inhibit period, IC3 is gated on and any pulse sensed by the receiver is passed to pin 3 of IC4, a



Wiring diagram and parts layout of the main PCB. The area inside the dotted line should be covered by a metal shield fashioned from tinplate (see diagram).

PARTS LIST

1 1kΩ:8Ω miniature audio transformer
1 40kHz ultrasonic transmitter
1 40kHz ultrasonic receiver
1 printed circuit board, code 82ur8, 84 × 125mm
1 printed circuit board, code 80st10b, 57 × 48mm
1 SPST momentary contact switch
1 knob to suit
1 Scotchcal front panel, 88 × 151mm
1 4-cell "AA" battery holder (square)

SEMICONDUCTORS
3 4011 quad NAND gates
1 4027 dual J-K flipflop
1 4017 decade counter
1 74C926 4-digit counter
1 BC558 PNP transistor
2 BC557 PNP transistors
2 BC549 NPN transistors
3 BC337 NPN transistors
1 3.9V 400mW zener diode
3 FND500 7-segment displays

CAPACITORS
1 1000µF 10VW electrolytic
1 220µF 10VW electrolytic
3 0.1µF metallised polyester (greencap)
4 .01µF greencap
1 .0022µF greencap
1 .0015µF greencap
1 .001µF polystyrene or greencap

RESISTORS (¼W, 5%)
1 × 10MΩ, 1 × 470kΩ, 1 × 100kΩ, 4 × 33kΩ, 1 × 27kΩ, 3 × 22kΩ, 1 × 15kΩ, 4 × 10kΩ, 2 × 4.7kΩ, 7 × 470Ω, 1 × 150Ω, 3 × 100Ω, 2 × 10kΩ 5mm horizontal trimpots, 1 × 500Ω linear potentiometer

MISCELLANEOUS
Shielded cable, hook-up wire, rainbow cable, machine screws and nuts, epoxy adhesive, scrap aluminium for battery clamp, tinplate (93 × 91mm) for shield, 4 "AA" 1.5V batteries.

4027 dual J-K flipflop. But before such a pulse is received a lot of other things happen and, to understand these, we must put aside the receiver function for the moment.

Let us look now at IC2 and IC2d. This is a clock oscillator running at 166kHz, being set to this frequency by trimpot VR3. It is these pulses which are counted between the time a pulse is transmitted and the time a return pulse is sensed by the receiver. They go via IC3d, functioning as a gate, to the clock input (pin 12) of IC6, a 74C926 counter.

The figure of 166kHz has been selected on the basis that, at the speed of sound in air, each pulse counted represents 1cm. (For inches this would need to be reduced by a factor of 2.54 – to 65.4kHz approximately – by changing the .0022µF capacitor to a larger value.)

The manner in which IC3d is gated on and off, at the start and finish of the counting period, is quite a tricky arrangement. We have already learned that 1Hz pulses, derived from the 10Hz oscillator IC2a,b and by 10/1 division in IC5, are delivered at pins 1 and 5 of the 4017. More precisely, pin 1 of IC5 delivers the first pulse, and pin 5 delivers a second pulse 100ms later.

The pulse from pin 1 performs two functions: it resets the 74C926 counter to "000" via the counter's reset pin (13), and it resets both flipflops in the 4027. This latter action sets $\overline{Q}2$ (pin 2) high and, via the inverting action of IC3c, pulls pin 12 of IC3d low and gates off the 166kHz signal from IC2d to the clock input of IC6.

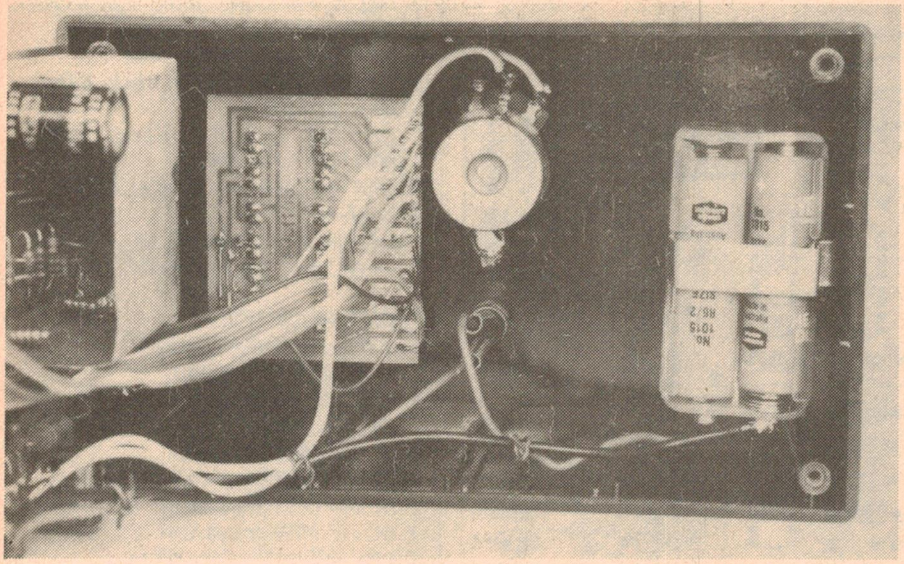
This sets the stage for the measurement sequence. The second pulse now appears at pin 5 of the 4017, gates on the transmitter and inhibits the receiver in the manner already described. But the receiver inhibit function goes one stage further; in gating off the receiver signals by means of IC3a it also sends the output (pin 3) of IC3a high which, in turn, takes CK2 of the 4027 high and pulls $\overline{Q}2$ low.

With $\overline{Q}2$ low, the pin 10 output of IC3c goes high, gates on IC3d, and allows the 166kHz clock pulses to reach the counter, which commences counting. This counting commences at the instant that the transmitter pulse commences. The output of IC3a subsequently goes low at the end of the receiver inhibit period, but the 4027 ignores low pulses at its clock terminals.

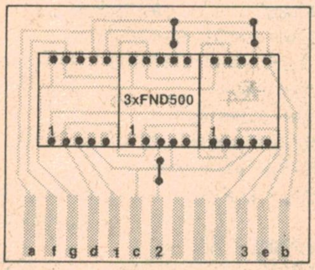
Counting continues until a return pulse is sensed by the receiver. Then the output of IC3a goes high again, the flipflop toggles, Q2 goes high, and counting ceases.

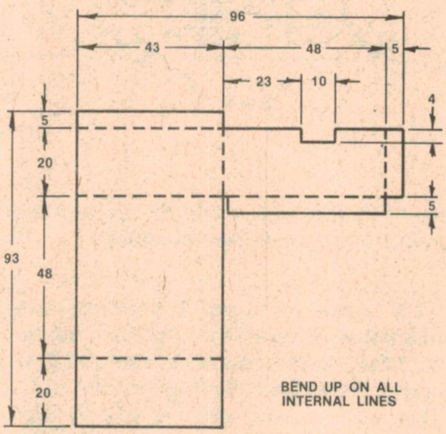
At this point the counting sequence proper is complete, but there is one more function. This is a protective function against any spurious return pulses, from more distant objects, which could upset the original count.

To understand this we must go back to the original reset action initiated by the pulse from pin 1 of the 4017. This sets both $\overline{Q}2$ and $\overline{Q}1$ high, $\overline{Q}2$ being subsequently pulled low by the inhibit pulse fed to IC3a. Although this pulse also appears on CK1 (pin 13), it is ignored because it is a low pulse to which these clock inputs do not respond.



Use rainbow cable to make the necessary connections to the display PCB. The batteries are held in position using a clamp fashioned from scrap aluminium.





Above: make sure that you mount the FND500s with the ribbed edge towards the top. At right is the metalwork diagram for metal shield.

As a result, $\overline{Q}$1 remains high until $\overline{Q}$2 goes high at the end of the count. This takes CK1 high, which sends $\overline{Q}$1 low, and J2 low with it. With J2 low, any further signals into CK2 will be ignored, this condition prevailing until the next reset sequence from the 4017.

The 74C926 is a four digit counter which drives a multiplexed seven-segment display. Only three digits – B, C and D – are used. As configured in this circuit, the 74C926 has its latch enable tied high so that it simultaneously counts and displays the number of clock pulses received. This counting operation is not really visible because of the speed of the count, and the very brief period involved. Only when the counting stops is the presentation readable.

As has probably been deduced from all the foregoing, the system transmits a pulse and makes a count once every second, and this is the rate of display update. There is nothing critical about this rate and the 10Hz oscillator from which it is derived uses fixed value components with no adjustment facility.

A point already mentioned briefly concerns energy from the transmitter reaching the receiver system by paths other than the wanted reflection.

One such path is the acoustic one already discussed in some detail, and this includes the mechanical path for acoustic energy provided by the case on which both transducers are mounted.

While the receiver inhibit period has been included to minimise this, transmitter transducer ringing can still be a problem. This is the reason for the variable resistor (VR2) in the transmitter output circuit; to reduce the strength of the transmitted pulse to no more than necessary in any particular situation. The need to control output is particularly important when new batteries have been fitted.

Another 40kHz leakage path is by direct electrostatic coupling, remembering that the 40kHz oscillator is running continuously. To control this field it was necessary to fit a metal shield over the receiver section.

Construction

Construction is straightforward, with most of the parts mounted on a main printed circuit board (PCB) coded 82ur8 and measuring 84 × 125mm. A separate display PCB, code 80st10b (57 × 48mm), carries the three FND500 displays, this board having originally been used in the Stylus Timer of October, 1980.

Assemble both boards according to the parts overlay diagrams, taking care to ensure correct polarity of all polarised components (transistors, ICs, displays, electrolytic capacitors, zener diode). Don't forget the four wire links on top of the main PCB, and observe the usual precautions when soldering in the ICs, which are all CMOS devices. These precautions involve earthing the barrel of your soldering iron to the earth track on the PCB, and soldering the supply pins first.

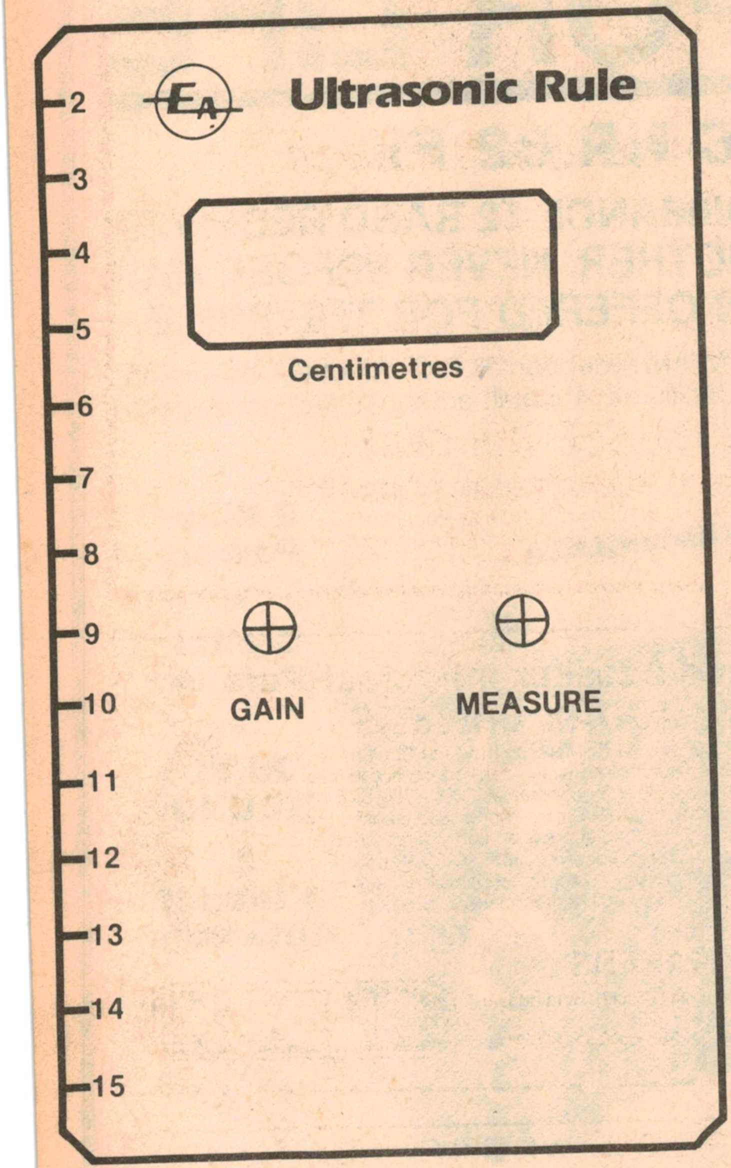
The supply pins are pins 7 and 14 for the 4011s, pins 8 and 16 for the 4027 and 4017, and pins 9 and 18 for the 74C926.

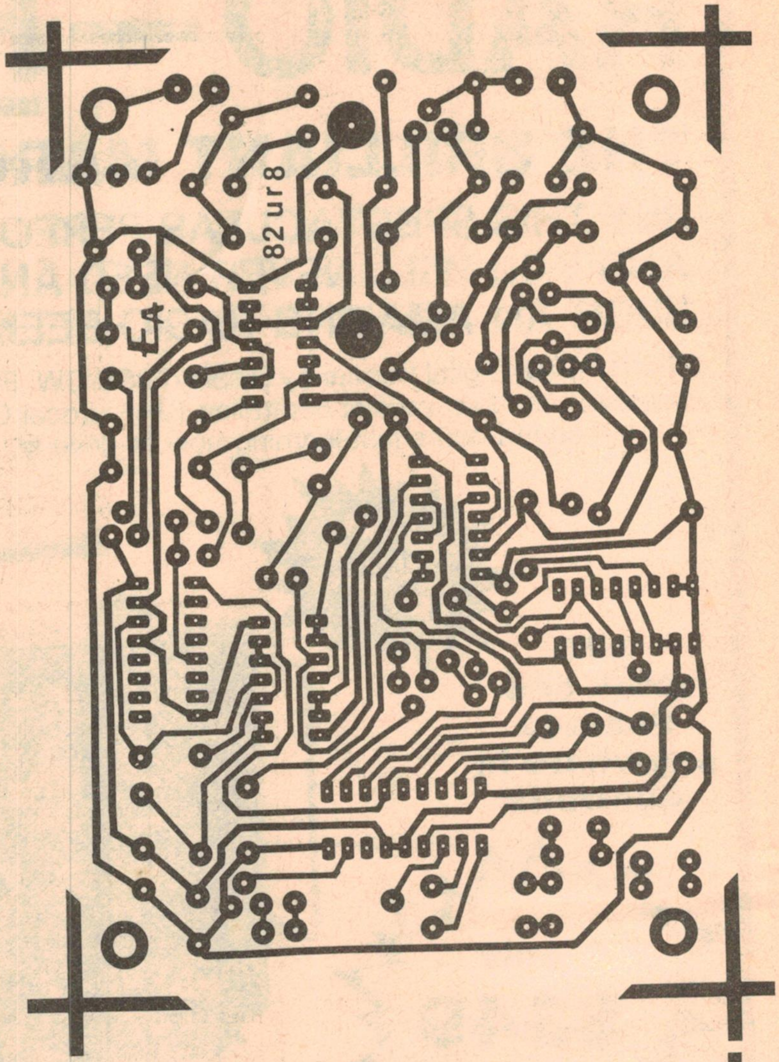
Details of the metal shield to be fitted over the receiver circuitry are given in the accompanying diagram. The shield is fabricated from tinplate and secured to the PCB by two self-tapping screws inserted from the copper side of the board. Check that the shield is connected to earth track of the PCB when the screws have been tightened down. You should also make sure that the screw heads are of lesser diameter than the locating pads on the board, to avoid any risk of shorts to adjacent tracks.

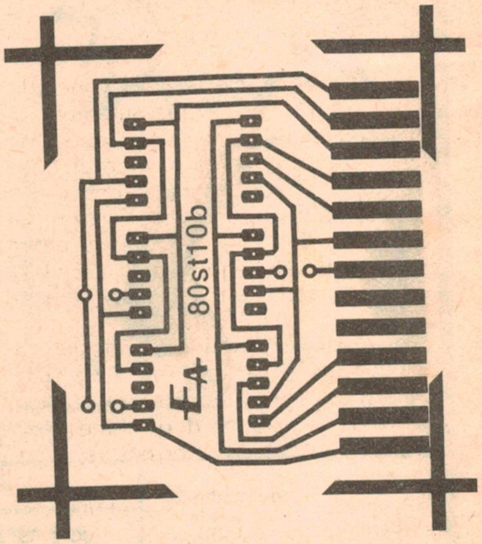
The complete unit is housed in a plastic zippy box measuring 50 × 94 × 158mm, with the main board mounted on the aluminium base. Carefully affix the Scotchcal adhesive label to the top of the box, then make the rectangular cutout for the LED displays by drilling and filing to shape. Finished Scotchcal labels will be available from kit suppliers.

Note that the Ultrasonic Rule measures the distance from the transducer elements to the reflecting surface. For this reason, the front panel artwork includes a handy scale down one side. When making wall-to-wall measurements, simply add the length of the box to the reading on the display.

The two transducers are mounted on one end of the box. Each requires two small holes for the terminal pins and is mounted flush against the case and held in place with a small ring of epoxy







All artworks are shown actual size.

adhesive. The transmit and receive devices are not identical, so make sure they are properly identified.

The unit is powered by a 6V battery pack consisting of four "AA" size batteries in a plastic holder. Current drain is in the order of 30-35mA and is quite reasonable for cells of this size, particularly in view of the short duty cycle. We used a bracket fashioned from a piece of scrap aluminium to secure the batteries in position.

Adjustments

Once the unit is working, there are two adjustments to make. One is to trim the 40kHz oscillator (IC1b, IC1c) by means of VR1 until it agrees with the natural resonance of the transmitter transducer. The other is to calibrate the unit by adjusting the clock oscillator (IC2c, IC2d) by means of VR3.

To peak the 40kHz oscillator we first need a means to measure the strength of signals reaching the receiver. A suitable method involves connected an AC millivoltmeter (range 1V or higher) to the collector of Q3 via a suitable isolating capacitor, say .01μF-0.1μF.

Next we must turn on the transmitter continuously by connecting a clip lead from pin 1 of IC1a to the 6V supply rail and by bridging the pushbutton switch.

Point the transducers toward a convenient flat surface about 30cm or so away and look for a meter reading. There may not be one but adjust VR1 until one is obtained, then peak it. The peak is quite sharp but easily set.

Calibration involves adjusting the clock oscillator (IC2c, IC2d) until the unit indicates correctly over a measured distance. The exact distance is not important, but between two and three metres is probably the most convenient. Choose a flat wall, with clear surroundings, and measure from about halfway along the transducer body.

Performance

How well does the unit work in typical, practical situations? What is its range? How accurate is it? And how reliable is its performance?

Its range, under the most favourable conditions, would appear to be about seven metres. When the range is exceeded the readout shows "888". Fairly obviously, the range will be affected by the nature of the reflecting surface, and our seven metre measurement was made from a a large painted brick wall, in a clear area, at right angles to the line of propagation.

Softer surfaces, or those at an angle, will generally reduce this range, and something between three and four metres would be a more reasonable range to expect consistently. Also, as we hinted above, the reflecting surface needs to be fairly large (say one square metre or more) and the surrounding area reasonably clear of other large objects.

Given an acceptable set-up, the accuracy is quite high; of the order of one or two centimetres, even at five or six metres. As is usual with digital readout systems, the last digit may dither to some extent, presenting an ambiguity of about one centimetre, plus or minus.

As to the reliability of the readings, a great deal depends on the surroundings. While there is little doubt that the measurement it shows is an accurate one for the reflection it is receiving, this reflection may not always be the wanted one. The beam from the transducer is quite broad so that the reflected signal may come from objects well to one side of the intended line of measurement.

We estimate that the current cost of components for this project is approximately

$48

This includes sales tax.

We conducted some experiments with small cardboard horns on one or both transducers, in an effort to reduce the beam width, but results were inconclusive. Some other material, more suited to these frequencies, may do a better job, and the reader may care to experiment.

One situation which it does not like is a long narrow hallway, particularly with doors in the side walls. Reflections from the walls, or from the door frames, will almost certainly confuse the measurement.

Similarly, a room full of furniture can cause all kinds of confusing reflections and produce obviously silly readings. In some cases this can be avoided by choosing an obviously clear path, or by working from one end of the room in preference to the other. Similarly, holding the unit as high as possible may help get the signal over the top of the furniture.