Get ready for the next deluge

Build this electronic rain gauge

Have you always wanted a rain gauge but could never be bothered going out to empty it? Our electronic rain gauge automatically empties itself, has a remote display which can be indoors, and measures up to 999mm rainfall with 1mm resolution. Best of all, it uses cheap and readily available parts.

by JOHN CLARKE

Are you often frustrated when the rainfall reports come over the radio? You know that the rain in your area was a veritable deluge but the overnight report says only 15mm.

"What rot!" you say but you don't have the evidence to satisfy yourself that the report is wrong or that the rainfall in your area was much heavier than the official report. Well now you can have the evidence of an electronic rain gauge.

Of course, you don't need an *electronic* rain gauge to know what the rainfall is. You can rely on the good old-fashioned rain gauge consisting of a transparent funnel shaped collector with graduations down the side but consider the disadvantages. You have to go outside to read and empty the thing. That means, horror of horrors, you might get wet.

Our Electronic Rain Gauge has all the features of a standard rain gauge with the following advantages:

- It can be read without ambiguities from the digital display which has 1mm resolution.
- Maximum reading of 999mm.
- The remote display can be located in a convenient position within your home. Battery operation means no need for mains power.
- It automatically empties the collected water.
- Resetting the display is done with the press of a button.

The rain collector for our electronic gauge is a rectangular box which incorporates a funnel shaped collector. This feeds the rain water into a measuring gauge which generates a pulse for each 1mm of rainfall.

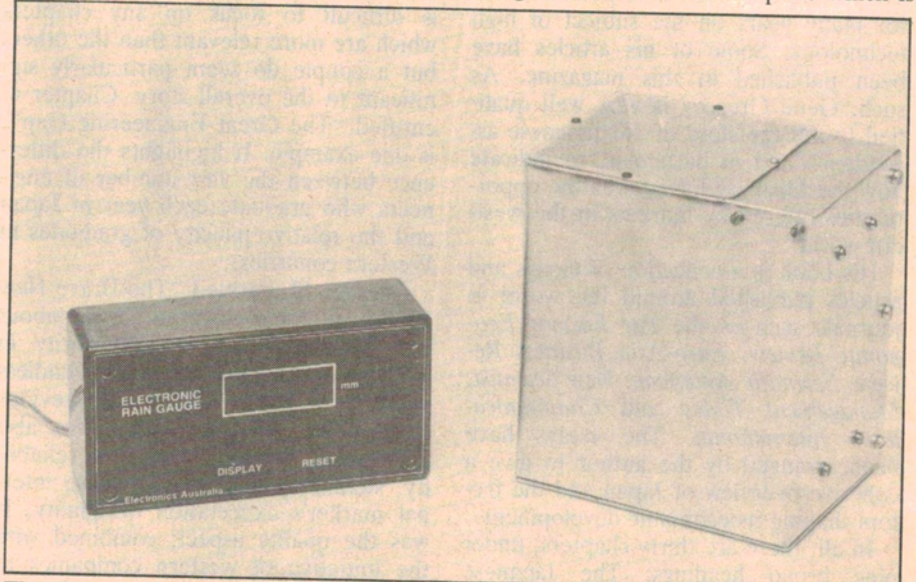
The digital display is housed in a small plastic case. It contains three 7-segment LED displays plus two push-button switches. One switch activates the display while the second switch resets the counter.

For each pulse from the measuring gauge, the digital display increments by one and it can count up to 999mm of rainfall.

Rain gauge operation

As mentioned above, the rain gauge includes a funnel which feeds water into the measurement mechanism. Fig.1 shows an exploded diagram of the mechanism which comprises a measuring spoon pivoted on a spindle and counter-balanced with small magnets. The contacts of an adjacent reed switch close whenever the magnets swing past.

As the spoon fills with water, its mass eventually overcomes the counter-balance mass and the attraction of the magnets to the attraction plate which is



The remote digital display counts pulses from the rain collector at right. The latter employs a self-emptying spoon mechanism that generates a pulse for each 1mm of rainfall.

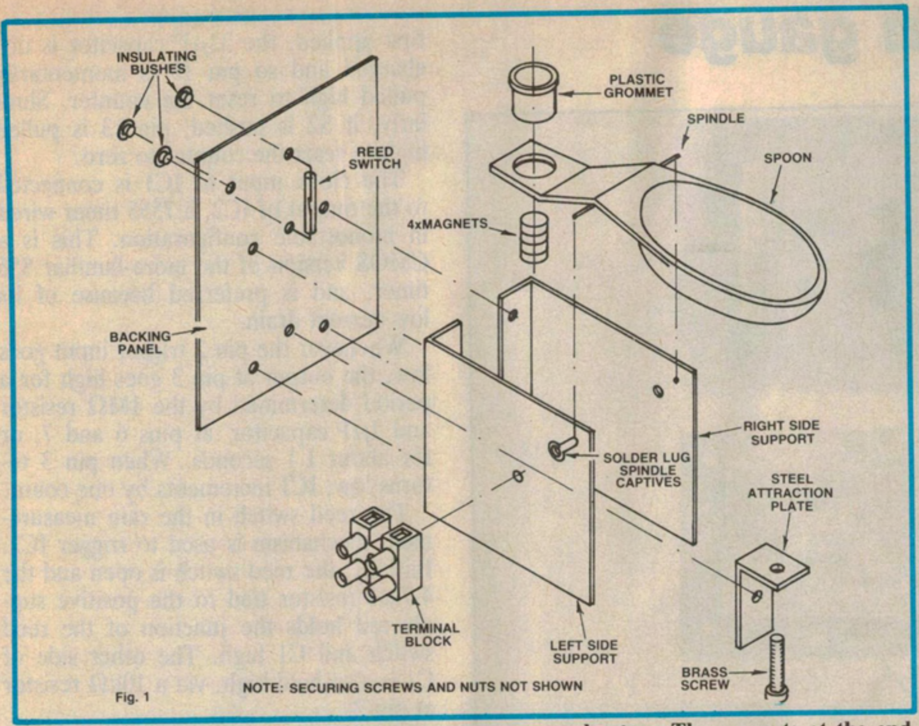


Fig.1: exploded diagram of the self-emptying spoon mechanism. The magnets at the end of the handle trigger a reed switch each time the spoon tips.

just below the reed switch. The spoon then tips forward to release the water in the spoon. The magnets then return the spoon to its normal resting position as set by the brass screw.

Note that the steel attraction plate and brass screw are vital to the correct operation of the mechanism. When the spoon is in its natural rest position, the spoon handle is supported on the brass screw.

The spoon normally stays in this rest position for two reasons: (1) because of the weight of the magnets; and (2) due to the magnetic force between the magnets and the attraction plate. The brass screw sets the distance between the attraction plate and magnets to adjust the amount of magnetic attraction.

Note that a brass or aluminium adjustment screw must be used here so that the magnets are not attracted to it.

As the spoon fills with water, the total mass eventually becomes sufficient to overcome the gravitational pull and magnetic attraction.

The spoon begins to tip and this moves the magnets away from the attraction plate. Since the magnetic force varies inversely to the square of the distance from the plate, the spoon does not need to tip far before the magnetic attraction becomes very small. Thus the spoon tips suddenly and empties its contents before reverting to the normal position, ready to be filled again.

Since the force between the magnets and the attraction plate is set by the distance between them, the amount of water required to tip the spoon is set by adjusting this distance. The further the magnets are from the attraction plate the less the amount of water required to tip the spoon.

The reed switch is located in such a position that when the spoon is in its rest position, the reed contacts are open. When the spoon tips, the magnet passes to close the reed contacts. Thus there are two closures of the reed switch, once when the spoon tips forward and again when it returns to the rest position.

Counter circuitry

The rain gauge circuit comprises a 4-digit counter, three 7-segment displays and a timer. Fig.2 shows the circuit details.

IC1 is a 74C926 4-digit counter made by National Semiconductor. It is a complicated device which contains a 4-digit decade counter, four 4-bit latches and multiplexed display drivers. In our circuit, only three of the internal decade counters are used and thus only three 7-segment displays are required.

Current limiting resistors between IC1 and the commoned display segments set the brightness of the displays. Separate transistors, Q1, Q2 and Q3, drive each display independently from the B, C and D outputs of IC1.

Note that the emitter connections of the display driver transistors are connected to ground via Display switch S1. This turns on the display whenever the switch is pressed. The display is normally left off to keep the battry drain low, typically around 140 microamps or so.

The reset and clock inputs control the operation of IC1. The reset (pin 13) is normally held low by the 2.2kΩ resistor connected to ground. When power is

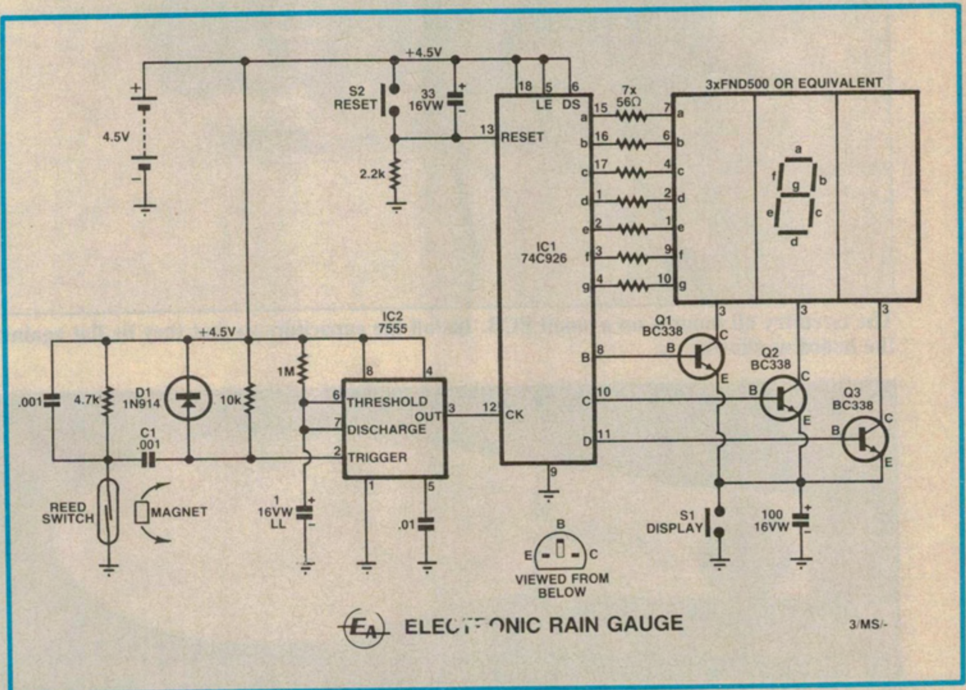


Fig.2: the circuit is based on a 4-digit counter (IC1), a 7555 timer (IC2) and three 7-segment displays. Power comes from a 4.5V battery.

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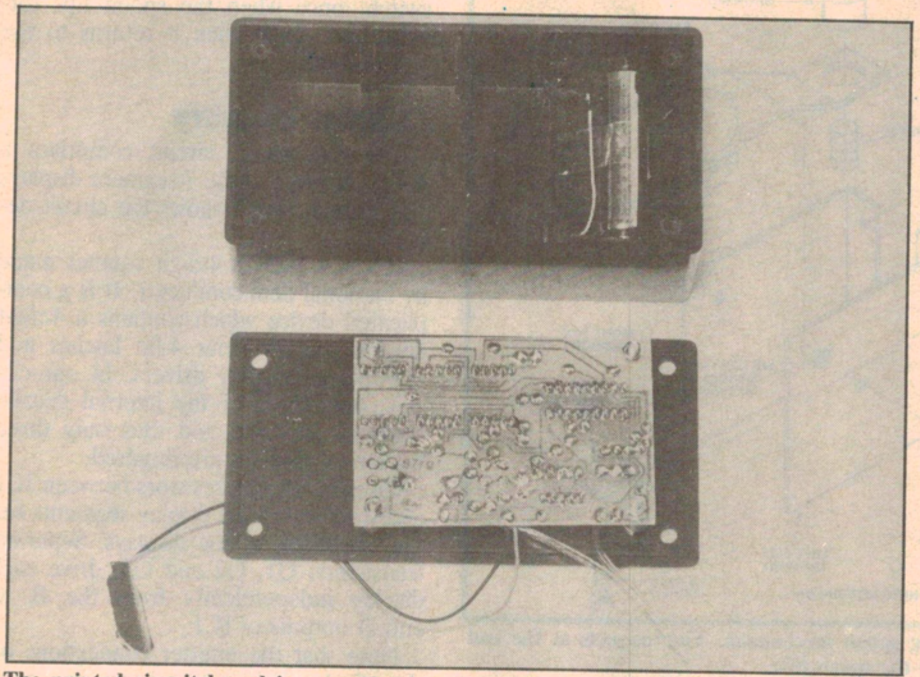
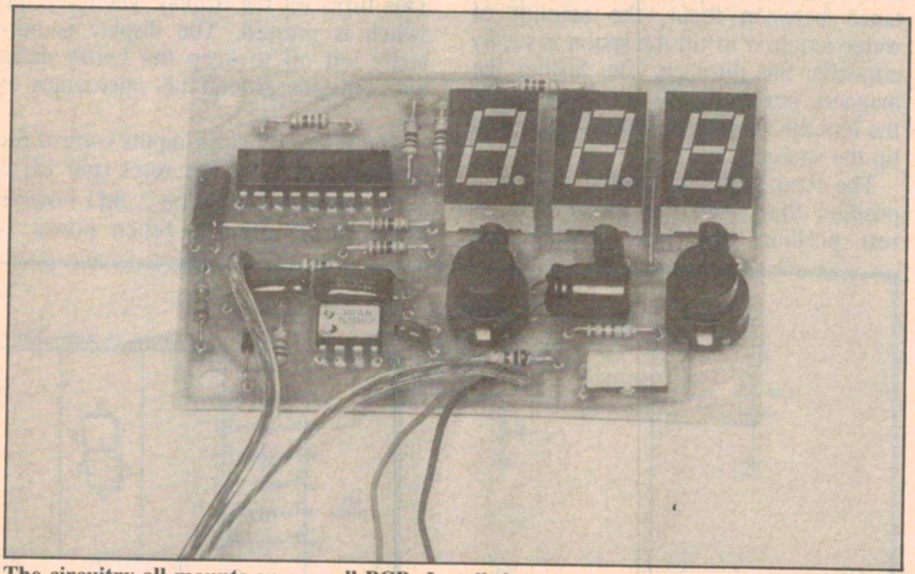
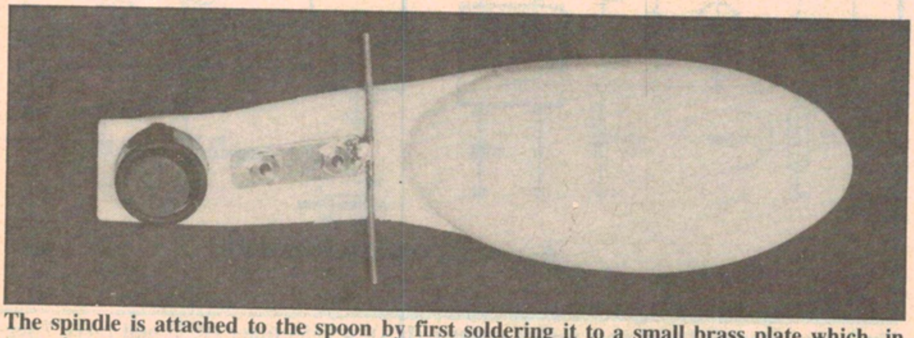


The printed circuit board is secured to the case lid using standoffs and machine screws and nuts. Note shorting link across one of the battery compartments.



The circuitry all mounts on a small PCB. Install the capacitors so that they lie flat against the board as shown.



The spindle is attached to the spoon by first soldering it to a small brass plate which, in turn, is attached to the handle using screws and nuts.

first applied, the 33μF capacitor is discharged and so pin 13 is momentarily pulled high to reset the counter. Similarly, if S2 is pushed, pin 13 is pulled high to reset the counter to zero.

The clock input to IC1 is connected to the output of IC2, a 7555 timer wired in monostable configuration. This is a CMOS version of the more-familiar 555 timer, and is preferred because of its low current drain.

Whenever the pin 2 trigger input goes low, the output at pin 3 goes high for a period determined by the 1MΩ resistor and 1μF capacitor at pins 6 and 7, or for about 1.1 seconds. When pin 3 returns low, IC1 increments by one count.

The reed switch in the rain measurement mechanism is used to trigger IC2. Initially, the reed switch is open and the 4.7kΩ resistor tied to the positive supply rail holds the junction of the reed switch and C1 high. The other side of C1 is also held high, via a 10kΩ resistor at pin 2.

When the reed switch subsequently closes, the left hand side of C1 (as viewed on the circuit diagram) is pulled to ground. This pulls pin 2 low until C1 charges up to the positive supply rail via the 10kΩ resistor at pin 2.

When the reed switch opens again, the left hand side of C1 is pulled to the postive supply rail via the 4.7kΩ resistor. At the same time, the resulting voltage on the right hand side of C1 is clamped to 0.6V above the positive rail by D1.

Since the output pulse from IC2 lasts for 1.1 seconds, each emptying of the spoon generates only one pulse, even though the reed switch closes twice for each event. It is interesting to note that we could have made this time-constant much longer, without prejudicing the rain gauge operation. Even in a tropical downpour which could be at the rate of 250mm per hour, IC2 would generate only one pulse every 14.4 seconds.

Note that a 0.001μF capacitor is connected between the reed switch and positive supply rail. This is used to remove any radio frequency noise which may be picked up by the long line between the reed switch and the counter circuitry.

Power for the circuit is derived from three AA-size cells which provide a nominal 4.5V supply. The current drain with the display off is typically about 140μA. With the display on, the current drain rises to around 100mA or so, depending on the number actually being displayed. With normal intermittent use of the display, the battery life for alka-

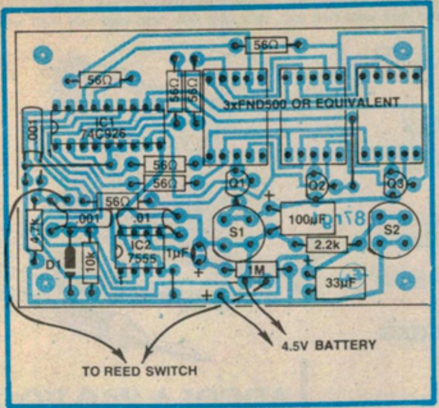
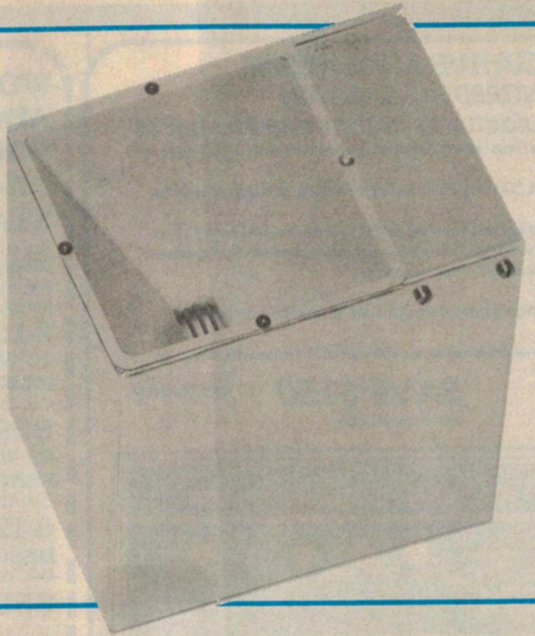


Fig.3: parts layout for the PCB. Don't forget the three wire links and take care when installing the polarised components.



Our prototype rain collector used a square section funnel, but you can use a round funnel if you wish (see text). The grille consists of short lengths of tinned copper wire.

line cells should be about a year or so.

We did consider the possibility of a 240VAC mains supply with a regulated 5V DC output but since the circuit has such a low current drain with the display off, we deemed it not worthwhile.

Construction

The electronic display unit of the rain gauge is housed in a plastic case measuring 130 x 67 x 43mm. A Scotchcal label measuring 127 x 64mm is used for the front panel. All electronic components, with the exception of the reed switch, are mounted on a printed circuit board coded 87rg1 and measuring 82 x 55mm.

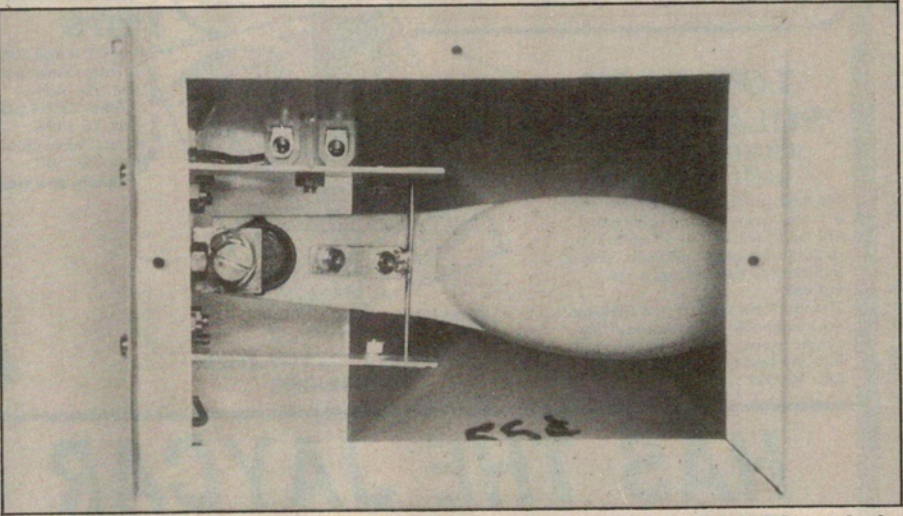
Start construction by installing the parts on the PCB as shown in Fig.3. It is a good idea to install the three wire links first, followed by the resistors, diode and ICs. This done, the three LED displays and the pushbutton switches can be installed.

Make sure you orient the displays correctly — ie, with the decimal point towards the bottom of the PCB. Similarly, take care with the orientation of the ICs and the diode. The pushbutton switches must be installed with the flat side of each switch facing left as shown in Fig.3.

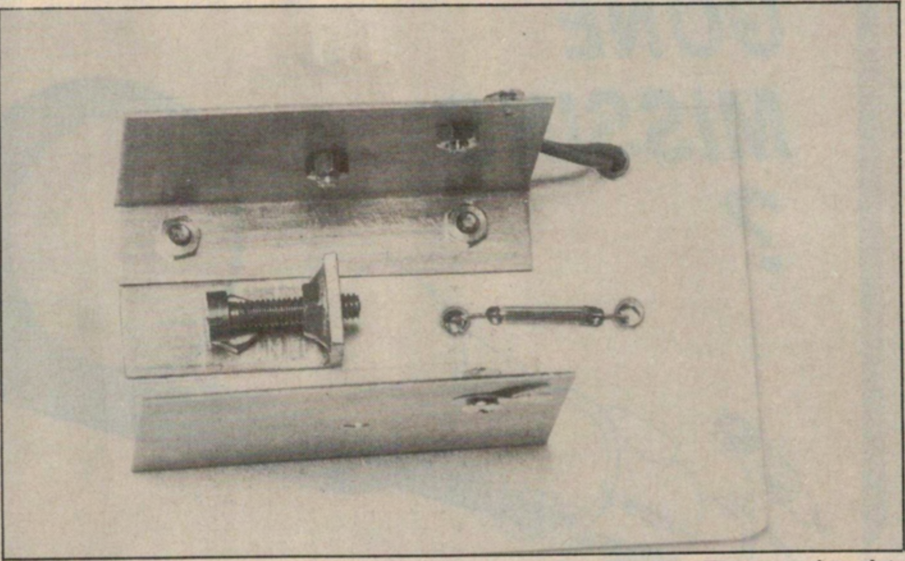
The three transistors can be installed next. Orient them as shown in the diagram and push them down onto the PCB so that they sit below the displays.

Assembly of the PCB can now be completed by installing the capacitors. These must all be mounted flat against the PCB as shown, otherwise they will later foul the front panel. Be careful with the electrolytic capacitors — they are polarised and must be oriented correctly.

The 4-cell battery holder must be modified so that one of the battery compartments is shorted with a length



Above: view inside the rain collector showing how the spoon is positioned beneath the funnel. The magnets rest on the brass screw at left.



View showing the support bracket section of the spoon mechanism. The attraction plate (see Fig.1) must be made of steel while the adjustment screw must be made of brass.

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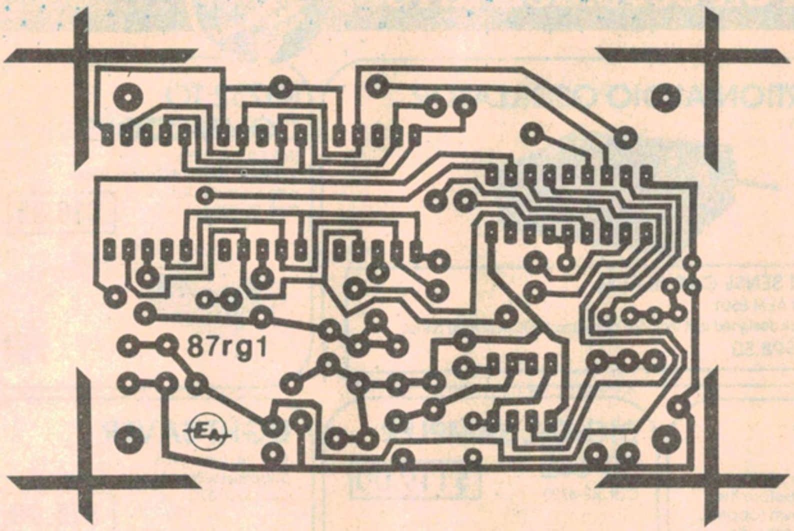

Fig.5: actual size PCB artwork. The board is coded 87rg1 and measures 82 x 55mm.

of wire. This will provide for three cells. Also the plastic support surrounds for the cell of the spare compartment will need to be cut away with side cutters. This will allow the PCB to fit within the case with the battery holder located in the right hand corner across the width of the case.

Finally, solder the battery clip leads to the PCB and install the leads to the reed switch.

Testing

You are now ready to test the electronics for correct operation. To do this, clip the battery into place and press the Display switch. The display should light and read 000. Now momentarily short the reed switch leads together. This should cause the counter to read 001 after about one second. From there on, shorting the leads at intervals of a little more than a second should continue to increment the counter.

Pressing the Reset switch should reset the counter to 000 again.

If the unit fails to function correctly check for shorts between PCB tracks, breaks in PCB tracks, incorrect parts placement or open-circuit connections. Do not immediately suspect the ICs since these are rugged devices and, unless installed back-to-front, are not likely to be faulty.

Once the counter is operating correctly, work can begin on the plastic case. Use the Scotchcal label as a guide when marking out the hole positions in the lid. Note that the PCB is mounted on the lid using countersunk screws. These are later hidden when the Scotchcal label is fitted.

For the display, we cut out a rectangular hole by drilling a series of small holes around the inside perimeter of the cutout and then filing to shape. A red plastic filter was then cut to snuggly fit into the cutout. This improves readability of the displays and the appearance.

Finally, a hole must be drilled in the rear of the case to allow entry for the reed switch leads. Once all the holes are drilled and the screws and nuts for the PCB are in place, the Scotchcal label can be fitted to the front panel.

Mechanical assembly

Construction of the rain gauge is dependent upon the type of funnel, measuring spoon and magnets used. The dimensions shown Fig.4 are of our prototype and may have to be varied to suit your particular unit.

We used a square rather than round section funnel, since it is easier to build a housing to accommodate this shape and the spoon mechanism. Note particularly that the collection volume of the funnel for 1mm of rain must be less than the spoon capacity, otherwise the spoon will overflow before 1mm of rain falls.

In fact, it is necessary to give the spoon a much larger capacity than the minimum to prevent water from splashing over the spoon lip.

For example, our funnel has a collection area of 75mm square or 56.25 sq. cm. The collected volume for 1mm (0.1cm) of rain is therefore 7.5 x 7.5 x 0.1 = 5.625ml (1ml = 1cc or 1 cubic cm). Therefore the measuring spoon

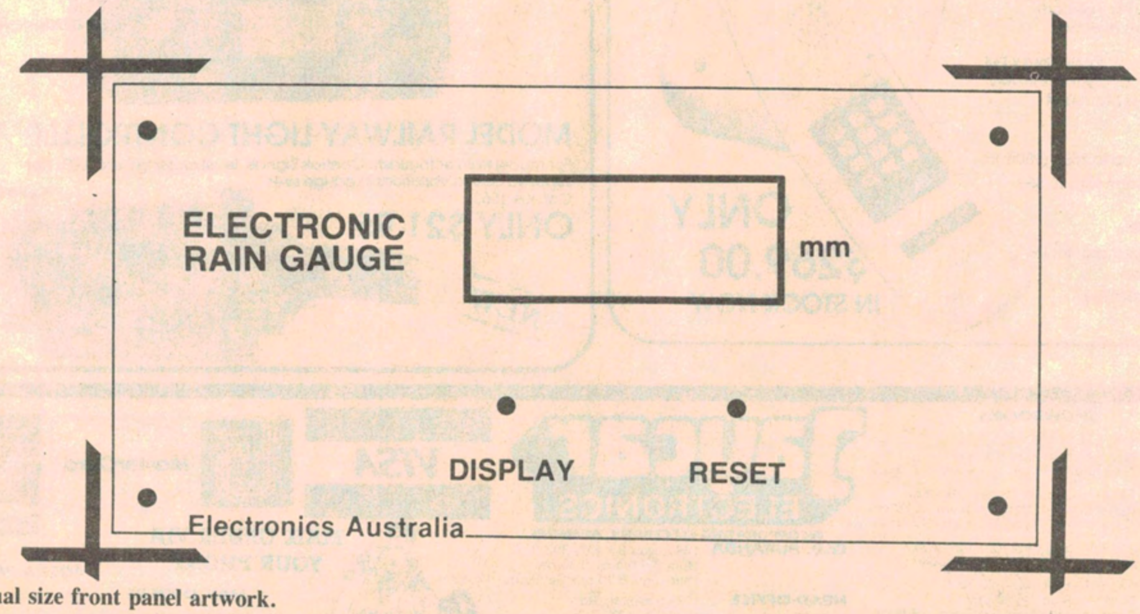

Fig.6: actual size front panel artwork.

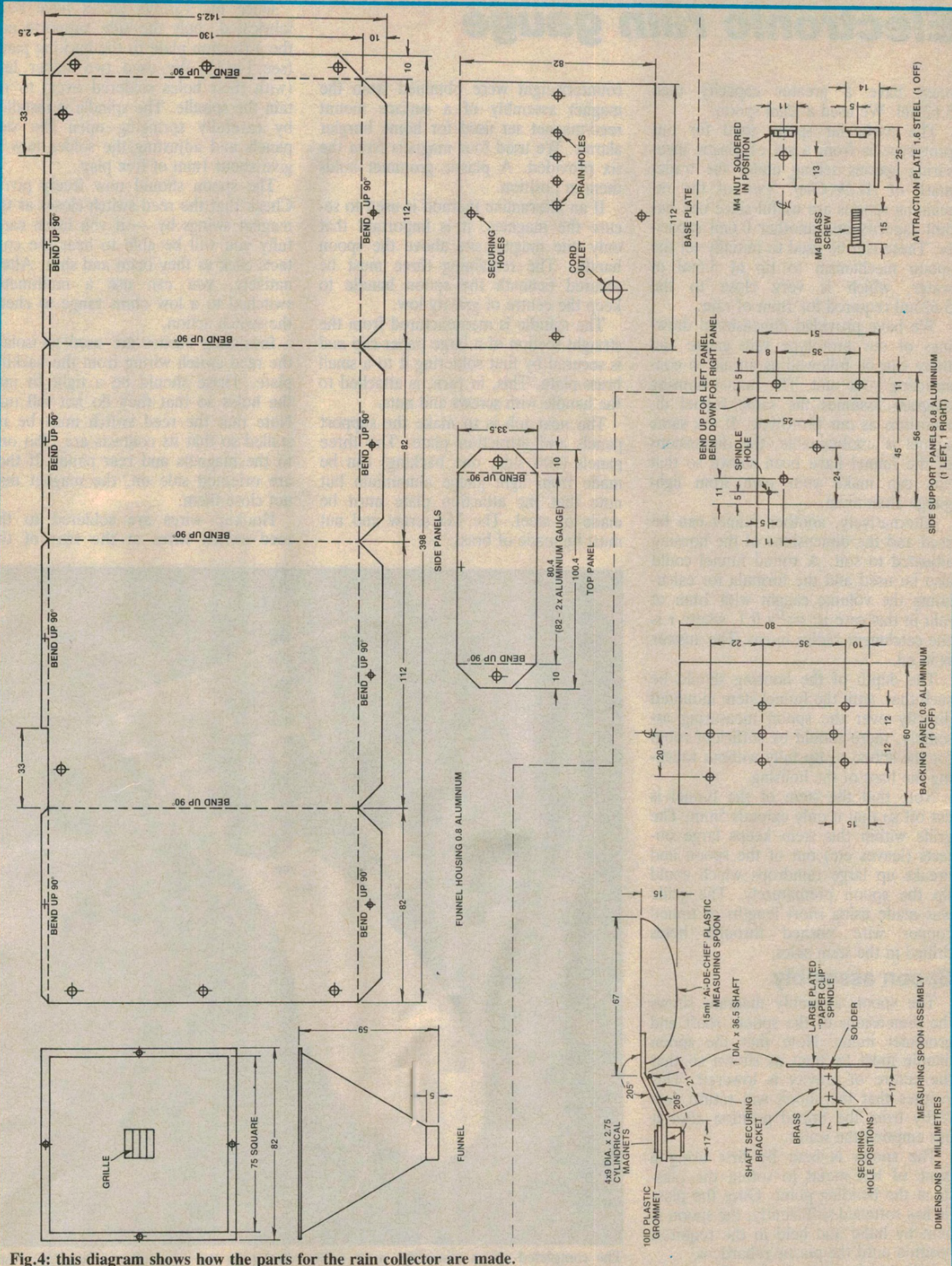

Fig.4: this diagram shows how the parts for the rain collector are made.

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must have a greater capacity than 5.625ml. We used a 15ml spoon.

The particular spoon used for our prototype is from a set of plastic measuring spoons selling under the trademark of *Ai.De.Chef.* Two of the remaining spoons are useful since one has 5ml capacity and another 0.6ml capacity. These can be used to initially set the spoon mechanism to tip at 5.6ml of water, which is very close to the 5.625ml required for 1mm of rain.

We have provided dimensional drawings of our prototype rain gauge and these can be followed as an aid in constructing your unit. The funnel housing diagram assumes the same funnel dimensions as our prototype. If the same funnel is unobtainable, the dimensions of the funnel have been shown so that you can make your own from light gauge aluminium.

Alternatively, another funnel can be used and the dimensions of the housing adjusted to suit. A round funnel could also be used and the formula for calculating the volume caught with 1mm of rain in this case is: $\pi r^2 \times 0.1$, where r is the catchment radius in cm. The answer is in ml.

The depth of the housing should be such that, with the funnel stem mounted directly over the spoon measuring assembly, there should be sufficient room for the spoon to tip fully without touching the base of the housing.

Note that the stem of the funnel is cut off so that it only extends 5mm. The grille within this stem keeps large objects (leaves etc) out of the spoon and breaks up large raindrops which could tip the spoon prematurely. The grille was made using short lengths of tinned copper wire pushed through holes drilled in the stem sides.

Spoon assembly

The spoon assembly diagram shows the dimensions of the spoon, shaft and grommet items. Note that the spoon handle must be bent as shown so that the centre of gravity is lowered. This ensures that the spoon will return correctly from the tipped position after it has emptied the water.

The spoon is bent by first using a piece of hot metal to soften the plastic at the bending point. Once the plastic has softened sufficiently, the spoon is bent by hand and held in the required position until the plastic rehardens.

Cylindrical magnets for the spoon counterweight were obtained from the magnet assembly of a surface mount reed/magnet set used for home burglar alarms. We used four magnets from the six provided. A plastic grommet holds them in position.

If an alternative method is used to secure the magnets, it is important that only one magnet sits above the spoon handle. The remaining three must be secured beneath the spoon handle to keep the centre of gravity low.

The spindle is manufactured from the straight section of a large paper clip and is secured by first soldering it to a small brass plate. This, in turn, is attached to the handle with screws and nuts.

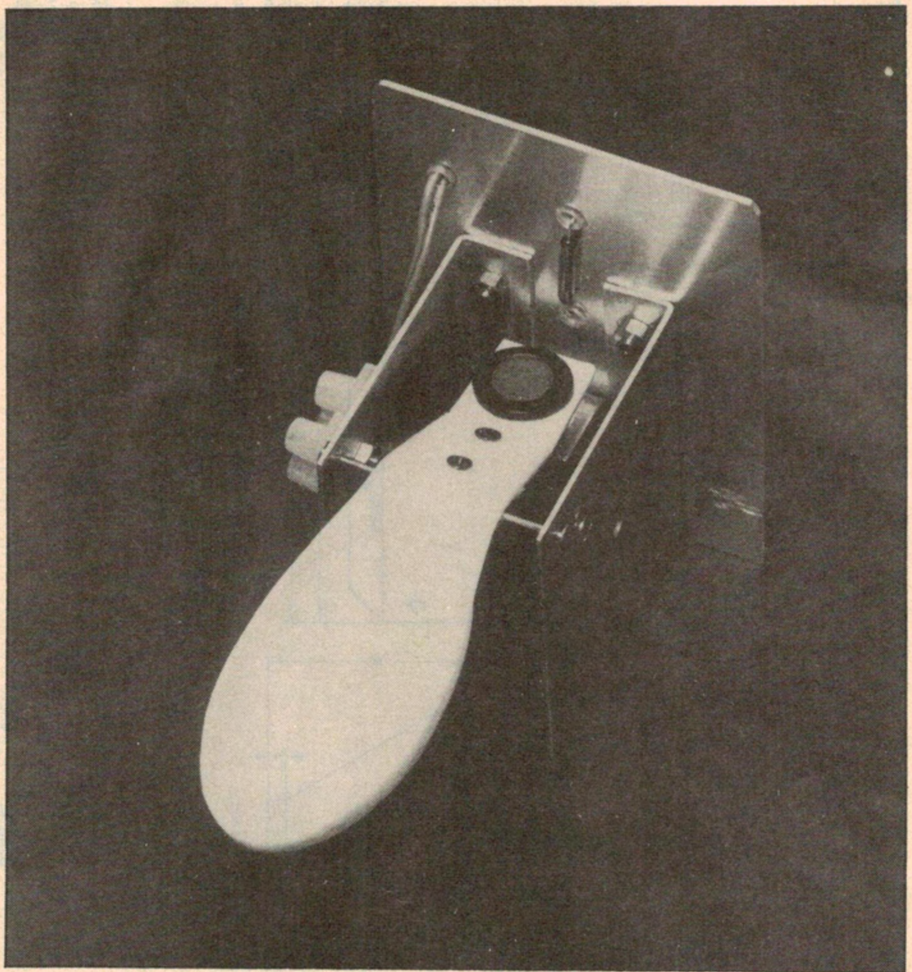
The next job is to make the support panels and attraction plate. The three panels (two side, one backing) can be made from light gauge aluminium but note that the attaction plate must be made of steel. The M4 screw and nut must be made of brass.

Once the various pieces have been fabricated, bolt the side supports and the attraction plate to the backing panel (see Fig.1). We used two solder lugs (with their holes soldered over) to retain the spindle. The spindle is installed by carefully springing open the side panels and adjusting the solder lugs to give about 1mm of free play.

The spoon should now freely pivot. Check that the reed switch closes as the magnet swings by — if you listen carefully you will be able to hear the contacts click as they open and shut. Alternatively, you can use a multimeter switched to a low ohms range to check the switch action.

Insulating bushes are used to isolate the reed switch wiring from the backing plate. These should be a tight fit into the holes so that they do not fall out. Note that the reed switch must be installed so that its contacts are "flat on" to the magnets and rear panel. If they are oriented side on, the magnet may not close them.

Hookup wires are soldered to the reed switch wires at the rear of the



The completed spoon assembly, prior to installation in the rain collector housing. Note the use of grommets to insulate the leads of the reed switch.

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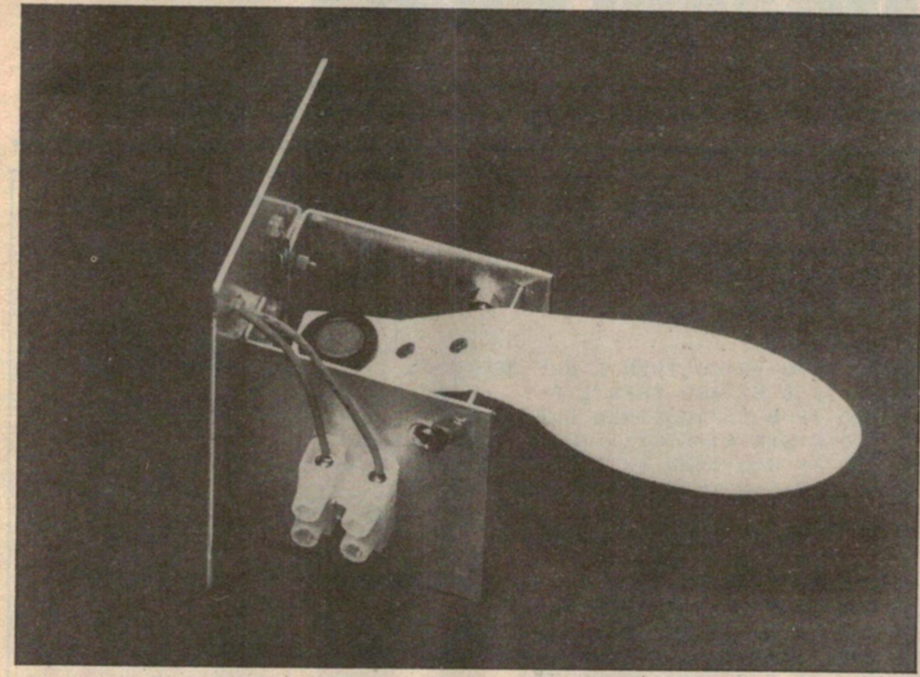

This view of the spoon assembly shows how the leads from the reed switch are terminated in the two-way terminal block. The spoon is positioned in the housing, directly beneath the funnel.

backing plate and pass through a third, insulating bush (see Fig.1) to a terminal block. This is screwed to the left side support and is also used to terminate the leads from the counter circuit.

Testing

The mechanism can be checked by slowly trickling water into the spoon until it tips. Initially, the brass screw should be adjusted so that the spoon sits fairly level. Check that the spoon empties all the water when it trips and that it correctly returns to the rest position (ie, with the magnets sitting on top of the brass screw).

If the spoon does not tip when filled with water, adjust the brass screw so that the magnets are spaced further from the attraction plate. If necessary, remove some of the counterweight mass (eg, one of the magnets).

To calibrate the unit, adjust the brass screw until the spoon tips with the volume of water that the funnel will provide for 1mm of rain (see above). In our case, we adjusted the mechanism to tip at 5.625ml.

The measurement mechanism is bolted within the funnel housing such that the spoon sits directly beneath the funnel. It is a good idea to arrange matters so that the funnel protrudes into the spoon by about 2mm to prevent water spillage. Don't forget to connect the leads from the counter before finally installing the spoon assembly.

Final calibration

Best accuracy is obtained if the rain gauge is calibrated with a large quantity of water. This should be a multiple of the amount required to indicate 1mm of rain. All you have to do is feed the water slowly through the gauge, note the reading, then adjust the screw accordingly and repeat the procedure if necessary.

For example, our prototype requires 5.625ml of water to indicate 1mm of rain on the display. Consequently, 56.25ml of water should give a reading of 10mm. One litre of water should indicate 177mm.

During this procedure, it is important to drip the water very slowly into the funnel otherwise the spoon could falsely trip due to the momentum of the water rather than the actual accumulated volume.

Adjust the brass screw on the attraction plate clockwise if the reading is too low and anticlockwise if the reading is too high.

Installation

The rain measurement gauge should be located in a clear area free from trees, shrubs and so on which may shield the gauge from rainfall. A short pole can be used to support the gauge above the ground. Alternatively, it could be located at the peak of the roof of your home.

Run the leads between the gauge and display unit and carefully route them so that it is not possible for anyone to trip over them. They should either be run underground, supported high aboveground, or routed around the walls of the house.

PARTS LIST

- 1 PCB, code 87rg1, 82 x 55mm
- 1 Scotchcal front panel, 127 x 64mm
- 1 plastic box, 130 x 67 x 43mm
- 1 4 AA-size battery holder
- 1 battery snap
- 3 AA alkaline cells
- 0.8mm aluminium sheet, 400 x 340mm
- 1.6mm steel, 11 x 40mm
- 1 7 x 17 x 1mm brass shim
- 3mm red perspex, 45 x 20mm
- 1 15mm-long 4mm brass bolt plus nut
- 1 plastic funnel, 75mm square (see text)
- 1 2-way insulated terminal block
- 1 surface-mount reed switch/magnet set (DSE Cat. No L-5210 or equivalent)
- 1 15ml "Ai.De.Chef" measuring spoon set (from hardware stores)
- 1 10mm ID plastic grommet
- 3 insulating bushes
- 2 solder lugs
- 1 large plated paper clip
- 4 9mm spacers
- 2 PCB-mounting momentary contact pushbutton switches (Jaycar SP-0721 or equivalent)

Semiconductors

- 3 FND500 or equivalent common cathode 7-segment displays
- 1 74C926 4-digit decade counte
- 1 7555 CMOS timer
- 3 BC338 NPN transistors
- 1 1N914, 1N4148 silicon diode

Capacitors

- 1 100μF 16VW PC electrolytic
- 1 33μF 16VW PC electrolytic
- 1 1μF 16VW RBLL electrolytic
- 1 0.01μF metallised polyester
- 2 0.001μF metallised polyester

Resistors (0.25W, 5%)

1 x 1MΩ, 1 x 10kΩ, 1 x 4.7kΩ, 1 x 2.2kΩ, 7 x 56Ω

Miscellaneous

Machine screws and nuts, solder, hookup wire, etc.