SOIL MOISTURE TESTER

by Gavin Cheeseman

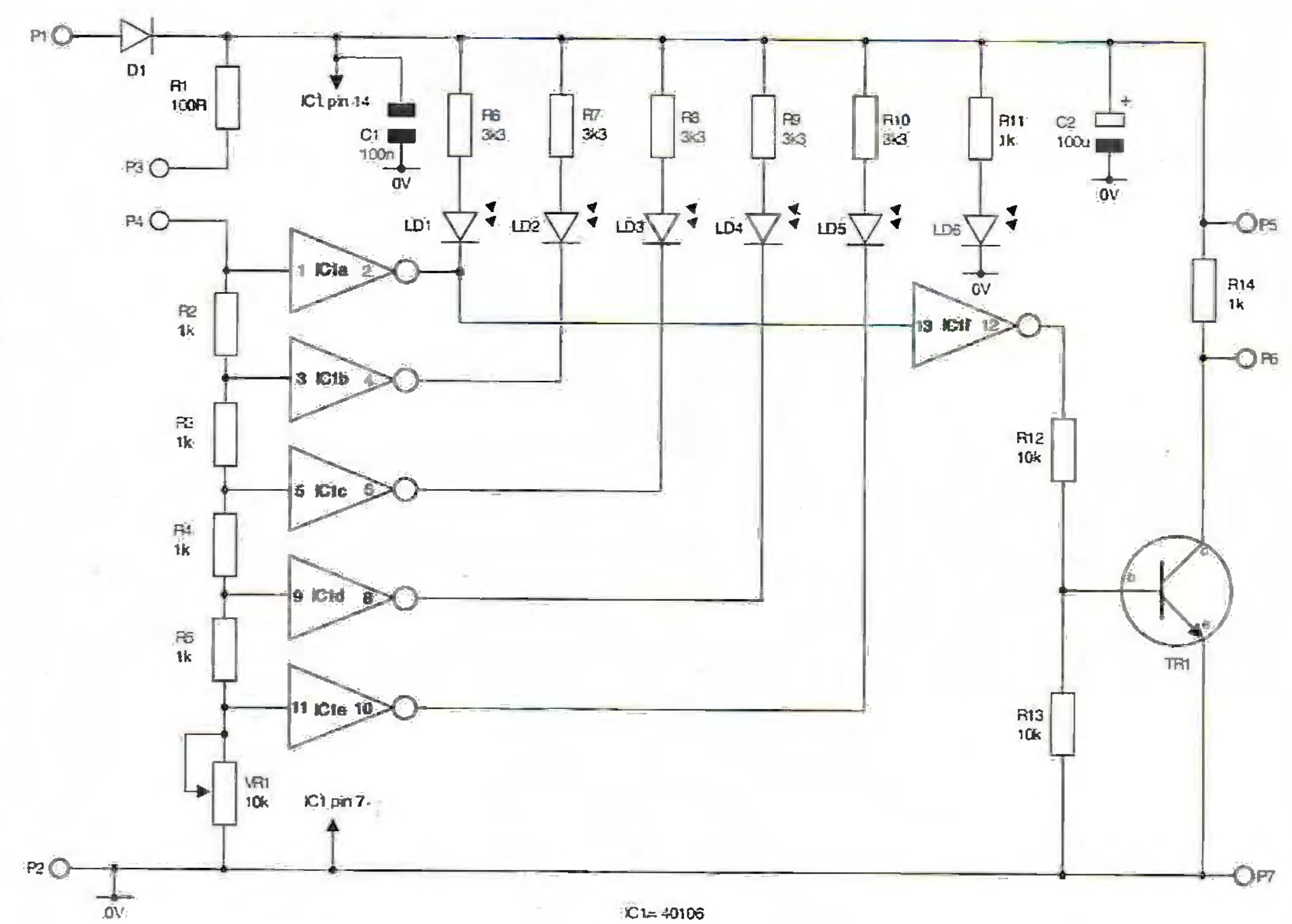

Figure 1: Circuit diagram

HAVE YOU EVER WONDERED HOW TO TELL IF YOUR HOUSE PLANTS NEED WATERING OR NOT. WELL, HERE IS A PROJECT THAT MIGHT HELP YOU DECIDE.

This simple circuit gives a rough indication of the relative moisture content of the soil based on electrical resistance.

How does it work?

The circuit is effectively a kind of resistance meter. Depending on the resistance between the two probes, between one and five LED's illuminate. The more LED's that light up, the lower the resistance between the probes.

The resistance of the soil is dependant on a number of factors including the moisture content. It is not possible to make a definitive measurement of moisture content based on a resistance reading alone, as factors such as salt content and physical structure also influence the result. However it is possible to obtain a relative idea of whether the soil is dry, damp or wet. Also, quite often the soil on the surface may appear dry when the soil below is actually quite moist. Because the probes penetrate the surface layer, the meter will indicate the condition of the soil beneath.

Circuit Description

It may be seen from Figure 1 that the circuit is based around the 40106 Hex Schmitt Trigger IC. One advantage of 4000/40000 range CMOS technology is its wide power supply voltage range. Whereas many other types of logic require a nominal 5V supply, these devices will work happily at voltages as high as 15V making them ideal for 9V battery operation without the need for a regulator.

Diode D1 offers reverse polarity protection should the battery be accidentally connected

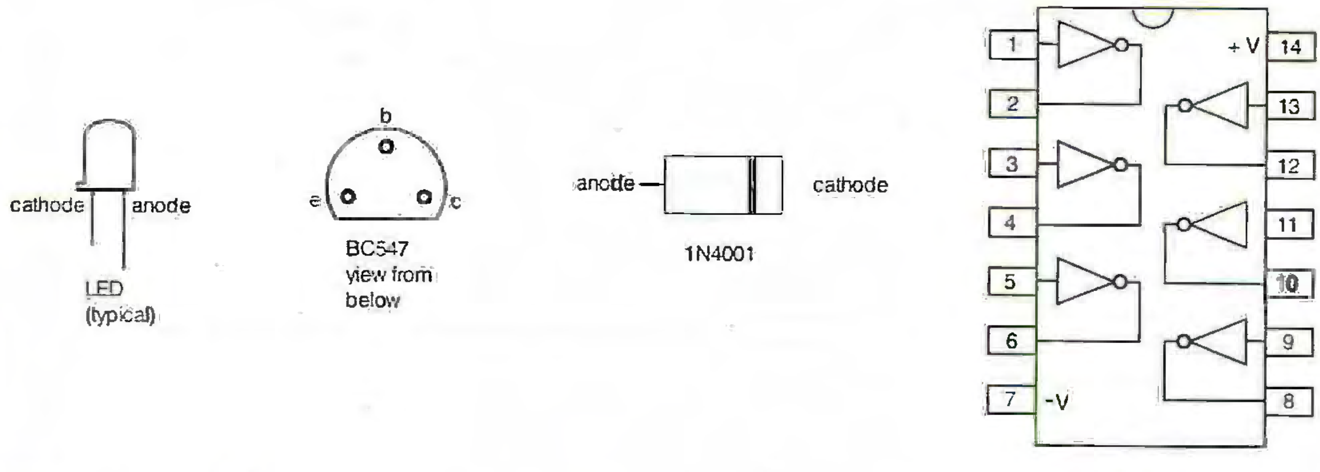

Figure 2. Semiconductor pin-outs

the wrong way round. Capacitor C1 is used to filter the power supply close to IC1 and C2 provides general supply de-coupling.

Two conductive moisture probes are connected to terminals P3 and P4. Resistors R1 to R5 together with variable resistor VR1 and any resistance between the moisture probes form a potential divider. The voltage at any point in the chain is determined by the resistance values in the potential divider. R1 to R5 are fixed and once aligned VR1 does not usually require any further adjustment. So in normal operation, the only variable quantity is the external resistance between the probes (P3 and P4).

The inputs of IC1a to IC1e are connected to different points in the potential divider chain. Each gate has a specific input threshold at which the output (normally high) switches low. When nothing is connected between the probes (i.e. there is an open circuit), the voltage at the inputs of gates IC1a to IC1e is equal to 0V. Therefore the outputs of all five gates remain in a logic high condition. When the probes are inserted into the soil, the voltage at each of the gate inputs will rise by an amount dependant on the resistance between the probes. So in dry soil where there is a high resistance, only a small current flows and the voltage rise is small. In wet soil the resistance is comparatively low and the voltage rise is much greater. Because the voltage is different at each point on the potential divider, as the resistance between terminals P3 and P4 is reduced, the gates connected higher up the chain will switch first. So the most sensitive gate is IC1a followed by IC1b and so on to IC1e.

When the gate switches, the associated LED (LD1 to LD5) illuminates. LD6 is the power on indicator and is not switched by a gate. The current through the LED's is controlled by R6 to R11. The values of R6 to R10 are kept relatively high to maintain a low current consumption. The value of R11 is less, so as to make the power on indicator brighter and more obvious.

The input of IC1f is connected to the output of IC1a acting as both a buffer and inverter. The output of IC1f is used to drive transistor TR1 via R12 and R13. This provides a switched output on terminal P6 that may be used to drive a small buzzer or other low current external equipment.

Constructing the circuit

The circuit may be constructed using any of the usual circuit board techniques including matrix board or strip board. The circuit is not particularly layout critical but it is sensible to mount capacitor C1 electrically close to IC1.

All of the usual precautions apply with regard to soldering. Take care with the polarised components. Semiconductor pin-out information is shown in Figure 2. Capacitor C2 must also be connected the right way round. The negative lead is usually marked by a minus symbol (-) on the case of the capacitor and is usually the shortest of the two leads. A similar system is often used for LED's whereby the shortest lead is usually the cathode (negative). The cathode

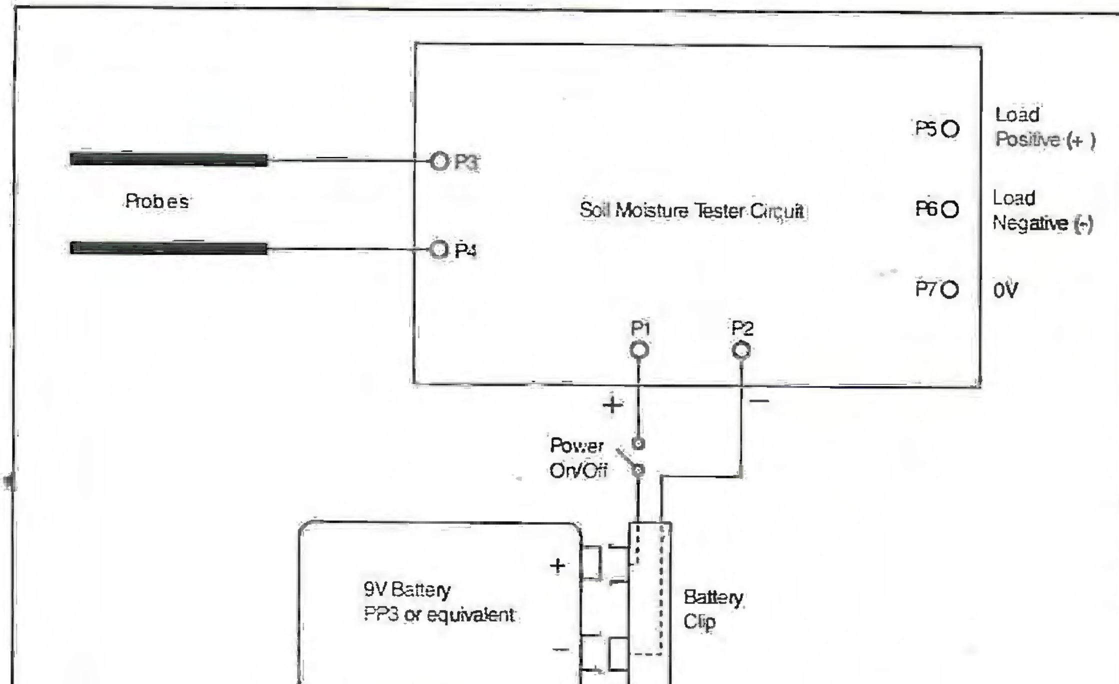

Figure 3. Connection diagram

may also be marked by a flat edge on the LED case. However, with both capacitors and LED's, the marking systems may vary with different manufacturers and types, so always make sure before the component is fitted in place.

It is probably best to mount the LED's directly onto the circuit board but if required they can be connected off board using short lengths of insulated wire. The choice of colours is up to the individual constructor and is not critical to the correct operation of the circuit. LD1 illuminates at the highest probe resistance (comparatively dry) and LD5 lights when the probe resistance is low (including short circuit). A typical colour scheme might be LD1 - orange, LD2 - orange, LD3 - yellow, LD4 - yellow, LD5 - green. Power indicator LD6 could be red as it is easily seen and also if the probe is inserted into the soil and LD6 is the only LED lit this indicates that the soil may be very dry.

It is also necessary to fit a battery clip wire, connect the probes to the circuit board and fit a power switch. Pay attention to the power supply polarity when connecting the battery clip wires. The positive lead connects to terminal P1 and the negative lead to P2. Wiring information is shown in Figure 3.

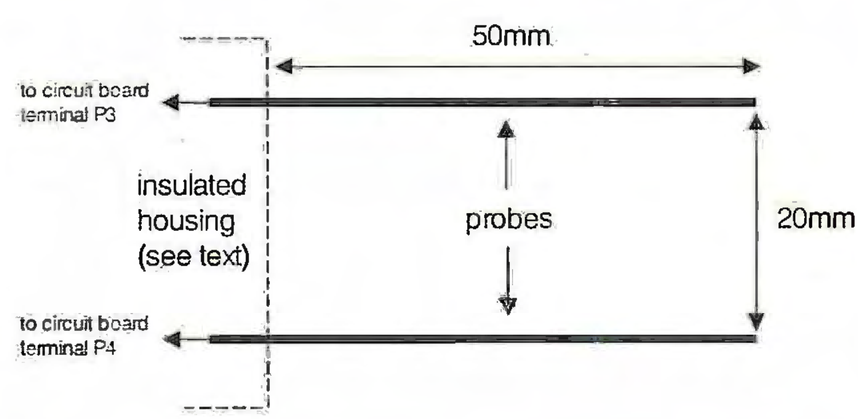

Figure 4. Typical probe arrangement

Probe construction and housing

The probe and housing arrangement may be chosen by the constructor as long as the relative size and spacing of the probes is approximately correct. A small plastic hand held case is ideal for housing the unit. It is necessary to be able to access the battery. Also a small hole should be drilled in the case to allow access to VR1.

As the circuit is detecting comparatively large changes in resistance, a small amount of variation in the probe dimensions will have little practical consequence. The probes should be approximately 50mm long and 20mm apart and may be made from rigid copper wire (at least 16 swg or thicker). A typical probe arrangement is illustrated in Figure 4. They may be soldered directly to the terminal pins or alternatively may be fixed to a separate assembly and wired onto the PCB. Avoid long lengths of wire (over about 1 metre) as these may be prone to picking up external signals. Other types of probes such as those used for multimeters may be used as long as they are fixed a set distance apart. The required spacing will change if the length of the probes is significantly different.

Testing

The circuit may be tested without any special equipment. However, it is useful to connect a multimeter set to read current in series with the positive power supply line when first switching on, just to make sure that the current consumption is not excessive. Take care that the meter is set to an appropriate current range.

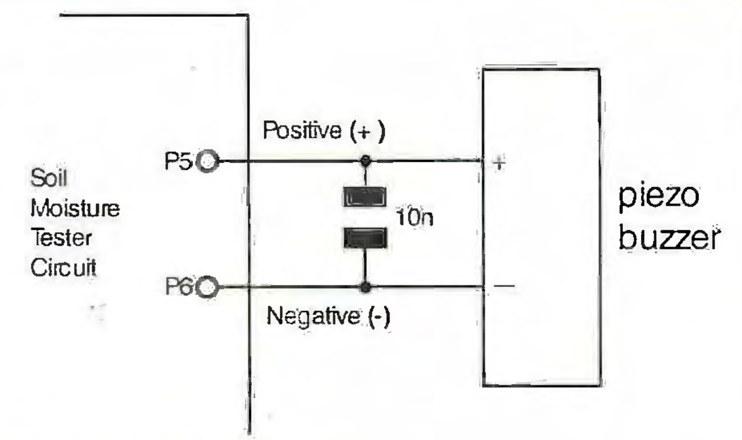

Figure 5. Connecting an external piezo buzzer

Connect a 9V battery (PP3 or equivalent) and set the power switch to the 'on' position. LD6 should illuminate. If the current consumption is greater than about 40mA at any stage, switch off as this suggests there is a problem with the circuit (often an incorrect or shorted connection).

If all is satisfactory, connect a short circuit between terminals P3 and P4. Adjust variable resistor VR1, observing LED's LD1 to LD5. Start with VR1 set to minimum resistance and slowly increase the setting until just past the point where all five LED's are lit. Disconnect the short between P3 and P4 and connect a 2k2 resistor in its place. Now only some of the LED's should light. If a range of resistors or a variable resistor (22k or 47k) is available, try connecting different resistance values between P3 and P4, observing which LED's if any illuminate. Note that because IC1 is a schmitt trigger, there is some hysteresis. Therefore, the circuit responds slightly differently when the resistance between the probes is being reduced, to when the resistance is being increased. This was not found to present a problem in practice.

The output at terminal P6 can be tested by connecting a multimeter set to read voltage between P6 (positive lead) and P7 (negative lead). The multimeter should be set to a suitable range to read 9V. When terminals P3 and P4 are open circuit the meter should read approximately 9V or maybe slightly less allowing for the voltage drop due to D1. When P3 is connected to P4, the voltage on the meter should drop to almost zero.

Using the tester

In use, the test probes are briefly inserted into the soil to obtain a reading. Very dry soil will light no LED's (except the power LED which remains illuminated whenever the unit is switched on). Very wet soil will light all of the LED's. Conditions in between these two extremes will light between 1 and 4 LED's.

One point to be aware of is that the unit is intended to act as a guide and does not determine the moisture level in the soil with absolute certainty. To get the best from the tester it is important to know its limitations and to become familiar with the sort of readings you get under different circumstances with different types of soil. Also other factors are involved such as how easy it is for the plant to suck the water out of the soil. For example heavy clay soil may have a high moisture content but very little of the water is available to the plant.

Try testing a range of different soil types, some completely dry, some moist and some wet. Adjust VR1 to give the best range of readings based on the different examples tested. Only allow the probes to become damp. Never let the battery, circuit board or components come into direct contact with water.

The component values are not necessarily optimised for every situation. For those who wish to experiment, the values of resistors R2 to R5 and VR1 may be modified to change the resistance range over which the tester operates. For example, if all of these components are increased in value by a factor of 10, the tester will then respond to a much higher resistance between the probes.

Important Note:

Do not leave the test probes in the soil for any longer than is necessary to take a reading (less than 5 seconds). Also, although the probe voltage never exceeds that of the battery (9V) and does not pose an electric shock hazard, it is recommended that the probes are not touched when moist. As the tester uses a simple DC voltage at a relatively high level, electrolysis will start to take place. Leaving the probes in the soil under these conditions will result in corrosion and poor performance due to the production of gas around the probes.

It is interesting to note that probes intended for accurate long term analysis of soil moisture content are usually driven with a low level AC waveform to avoid this effect and are usually embedded in a block of permeable material such as gypsum. This helps to minimise the effect of physical variations in the soil. However these are specialised techniques and their application to a simple tester of the type described here would lead to increased cost and complexity.

Using the switched output

The switched output on terminal P6 can be used to drive a small piezo buzzer as illustrated in Figure 5 (recommended current <20mA). The buzzer must be suitable for 9V operation and should contain the necessary drive circuit. The output is DC only and therefore will not drive a simple piezo transducer. The positive (+) lead of the buzzer should be connected to terminal P5 and the negative (-) lead should be connected to P6.

Parts List

Resistors (minimum 0.5W metal film)

R1	100R	1
R2-5		
11, 14	1k	6
R6-10	3k3	5
R12,13	10k	2
VR1	10k variable trimmer	1

Capacitors (minimum voltage rating 16V)

C1	100nF ceramic disc	1
C2	100uF radial electrolytic	1

Semiconductors

D1	1N4001	1
TR1	BC547	1
IC1	HCF40106BE	1

Miscellaneous Items

Circuit board (eg strip-board)		
14 pin DIL socket		1
P1 - P7	PCB pins	7
SPST toggle switch		1
LED's (see text)		6