Soil moisture indicator

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Don't drown your plants or dry them out! Take some of the guesswork out of watering with this handy little instrument.

EXPERT GARDENERS can tell by touch when their plants have too little or too much water, but the rest of us could use a little help sometimes. This instrument makes use of the fact that the resistance of soil decreases as the soil gets wetter. A constant current is fed through the soil between the two electrodes of a probe and the voltage drop between them is measured. A line of five light emitting diodes is used to give a simple and robust indicator of the moisture content which can easily be recalibrated to suit different soil types.

For this kind of measurement to work, it is important that both of the electrodes are made of the same metal. Dissimilar metals will set up a small electrochemical cell, generating a voltage which can upset the reading.

Soil and circuitry

If you take an ohmmeter and insert the probes into the soil quite close together the resistance reading you will obtain can vary from as little as 3 k to several megohms. The reading will depend on a number of factors: the distance between the probes, soil density, acidity/alkalinity of the soil, surface area of the probes and the moisture content of the soil. Dissimilar metals in the probe affect the reading as previously explained. If the physical dimensions of the probes are fixed in some way then the greatest variation in soil resistance will be due to the moisture content of the soil. Quite large variations in soil density will have less effect, surprisingly enough.

At first thought, it seems a common moving coil meter could be used in a simple ohmmeter-type circuit. However, with pointer-type displays, non-technical people using the device tend to worry about quite minor variations in the position of the pointer — even if the scale is only calibrated in gross sections. (This gives rise to comments such as: "The needle is two millimetres further up the scale than when I took a reading this morning"). Secondly, the device should be inexpensive and rugged. Whilst we're not accusing gardeners of being clumsy, one must recognise that accidents do happen and few low cost moving coil meters would survive a one metre drop onto a hard floor!

With the probe in 'soggy' soil, only the top LED will light. In 'wet' soil, the top two LEDs will light — and so on until, with the probe in 'parched' soil, all LEDs will light!

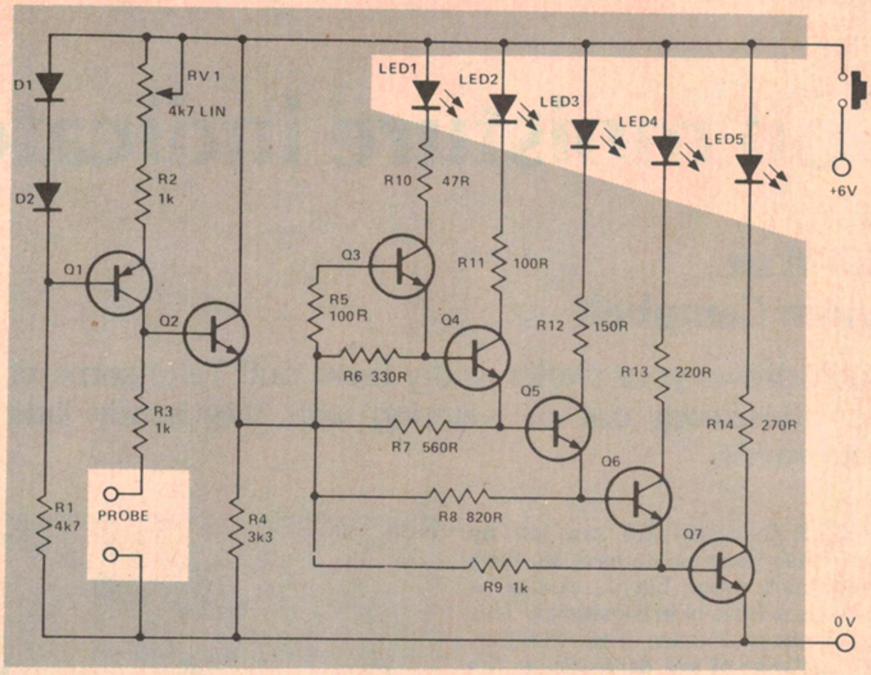
We opted for the 'all solid state' approach and chose to use an LED display arranged as a sort of bargraph. The resulting project is quite a rugged instrument that gives repeatable results, is easy to build and inexpensive. The unit is powered by four AA cells.

The probe problem was neatly solved ▶

using a standard 6.5 mm jack plug. The circuit passes a constant current through the soil via the probe and the resulting voltage drop across the probe connections drives the LED display circuitry. This consists of a series of transistors that turn on in turn as the voltage across the probe connections rises with increasing soil resistance. If the soil is quite dry, all LEDs will light, if the soil is 'soggy' only one (LED5) will light. At this juncture, we should point out that the front panel lettering showing "soggy-wet-moist-dry-parched!" is a little tongue-in-cheek but it does give a general guide as to what the display indicates.

Construction

Our unit was housed in a plastic zippy box measuring 150 mm long by 90 mm wide by 50 mm high. This is a convenient size and the completed unit is easily held in one hand while the probe is inserted into the soil with the other hand.



HOW IT WORKS — ETI 247

The electrical resistance of soil varies primarily with the moisture content. The greater the moisture content, the lower the resistance. If a constant current is passed through two electrodes inserted in the soil, the voltage drop occurring across the electrodes will vary with the soil resistance, increasing with increasing resistance. This fact can be used to indicate moisture content of the soil in conjunction with a suitable display.

The circuit employs a constant current generator to pass current through the probe contacts via the soil. The voltage across the probe contacts is then buffered by an emitter follower which drives the display circuitry. This consists of five transistors, the collectors of each driving a LED, each transistor being connected to turn on successively as the voltage across the probe contacts increases with increasing soil resistance. A block diagram is shown in Figure 1 here.

Transistor Q1 and associated components provide the constant current source for the probe contacts. Figure 2 shows the collector characteristics of a typical silicon transistor. They show that, if you hold the base current constant, the collector current will remain substantially constant for a widely varying range of collector voltage. Figure 3 shows the general circuit of a constant current generator. The voltage between the base and the emitter return (common, the +ve supply line here) is fixed by the zener diode. Thus, the voltage across the emitter resistor (Ve) is fixed at a value equal to the zener voltage (V_Z) minus the base-emitter voltage drop of the transistor (0.6 V for silicon transistors). With a fixed voltage across R_e, the current through it will be constant. Thus, the emitter current, and therefore the collector current, of the transistor will be constant. The resistor supplying current to the zener is generally chosen so that zener current is five to ten times greater than the base current of the transistor.

With this circuit, so long as there is about one volt between the emitter and collector, the collector current will remain constant at the chosen value until a load of too large a value robs the collector of its working voltage.

In the project circuit diagram, two forward-biased silicon diodes are used to 'clamp' the base voltage of Q1 to about 1.2 volts below the positive supply rail. Thus, the voltage across RV1/R2 will be about 0.6 V. The collector current can be adjusted by RV1 between a maximum of 600 µA and about 100 µA minimum.

The collector of Q1 drives the probe contacts via R3. The collector voltage of Q1, which varies with the variation in soil resistance across the probe contacts, drives the base of Q2, which is connected as an emitter follower. The emitter load of Q2 (R4) will thus have a voltage across it directly proportional to the collector voltage of Q1, less the 0.6 V base-emitter voltage drop of Q2.

The voltage across R4 then provides drive to the bases of the display transistors Q3 to Q7.

When the voltage across R4 reaches about 0.6 V, Q7 will turn on and LED5 will light. Now, the emitter of Q6 is connected to the base of Q7 and 'rides' up on the base-emitter voltage of Q7. The voltage across R4 will have to reach 0.6 V above the base-emitter voltage of Q7, or 1.2 V, before Q6 will turn on, lighting LED4. Similarly, the emitters of Q5, Q4 and Q3 each ride up on the base voltage of the previous transistor and the LEDs will light in turn as the voltage across R4 exceeds successive 0.6 V increments. Thus, LED3 will light when the voltage across R4 reaches 1.8 V, LED2 will light when it reaches 2.4 V and LED1 will light when it reaches 3.0 V. The voltage across R4 will be maximum when there is a high resistance across the probe contacts and thus all LEDs will light when the soil in contact with the probe is dry. When the soil is quite wet, the voltage across the probe contacts will be low and the current set by RV1 should be just sufficient to permit LED1 to light.

Resistors R5 to R9 inclusive limit the base current of the display transistors while resistors R10 to R14 limit the current passed through the LEDs. Resistor R9 is a higher value than R5 so that excessive base current does not occur in Q7 as the voltage across R4 increases. Resistors R6 to R8 are successively higher in value than R5 for the same reason.

The collector currents of transistors Q3 to Q7 will vary with the variation in base current as the voltage across R4 rises and falls. Thus, resistors R10 to R14 have values chosen to limit the maximum current through the LEDs to about 10 - 15 mA.

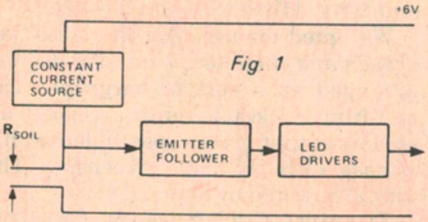


Fig. 1

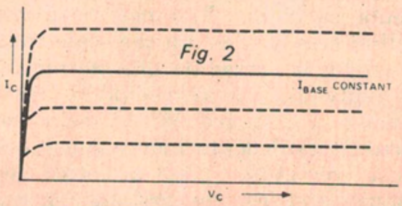


Fig. 2

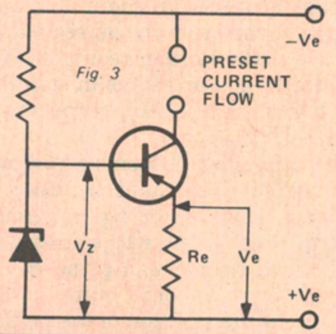
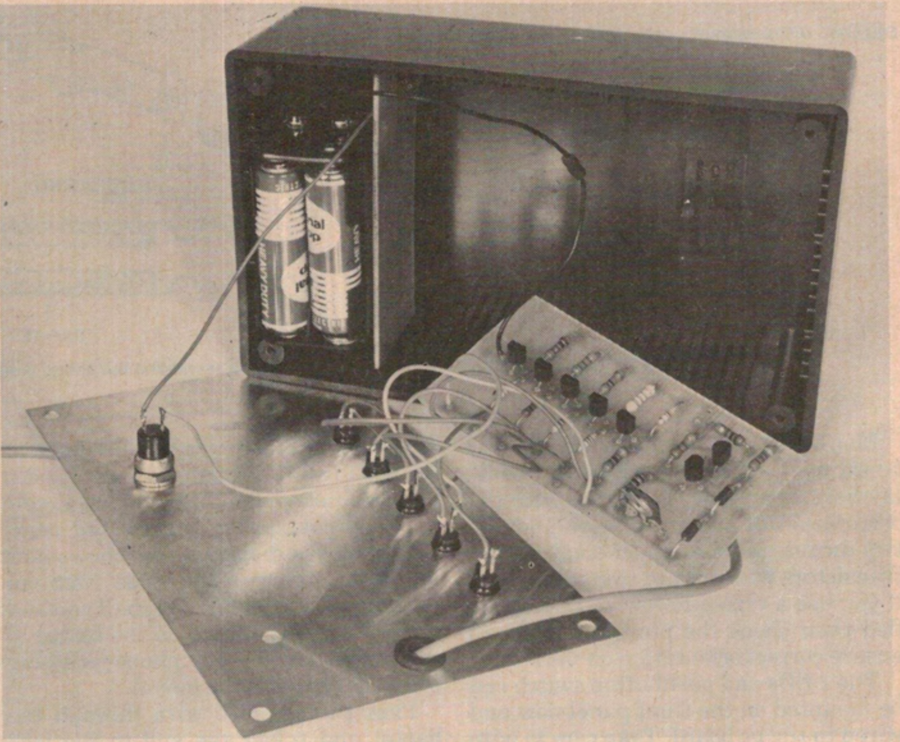


Fig. 3

PARTS LIST — ETI 247

Resistors	all ½W, 5%
R1	4k7
R2,R3,R9	1k
R4	3k3
R5,R11	100R
R6	330R
R7	560R
R8	820R
R10	47R
R12	150R
R13	220R
R14	270R
Potentiometer	
RV1	4k7 min. vert. mounting trimpot.
Semiconductors	
D1,D2	1N4148 or sim.
Q1	BC557, BC 177 or sim.
Q2-Q7	BC547, BC107 or sim.
LED1-LED5	any LED, TIL220R or sim.
Miscellaneous	
PB1	momentary push button switch

ETI-247 pc board; four AA batteries with holder; mono phono plug for probe; Pentel pen type R56 for probe handle (or similar); plastic zippy box to suit.



Internal view. Note how the battery holder is held in place.

The five LEDs and the pushbutton switch are mounted on the aluminium front panel and the probe lead is passed through the panel via a grommeted hole. Another hole in the panel provides access to the SET trimpot so that the unit can be readily calibrated.

All the other components are mounted on a pc board which fits neatly across the box, held in place by the grooves on the walls which are readily seen in the internal photograph. Although this project could be constructed on matrix board or tag strips, we recommend you use the pc board as it helps prevent wiring errors.

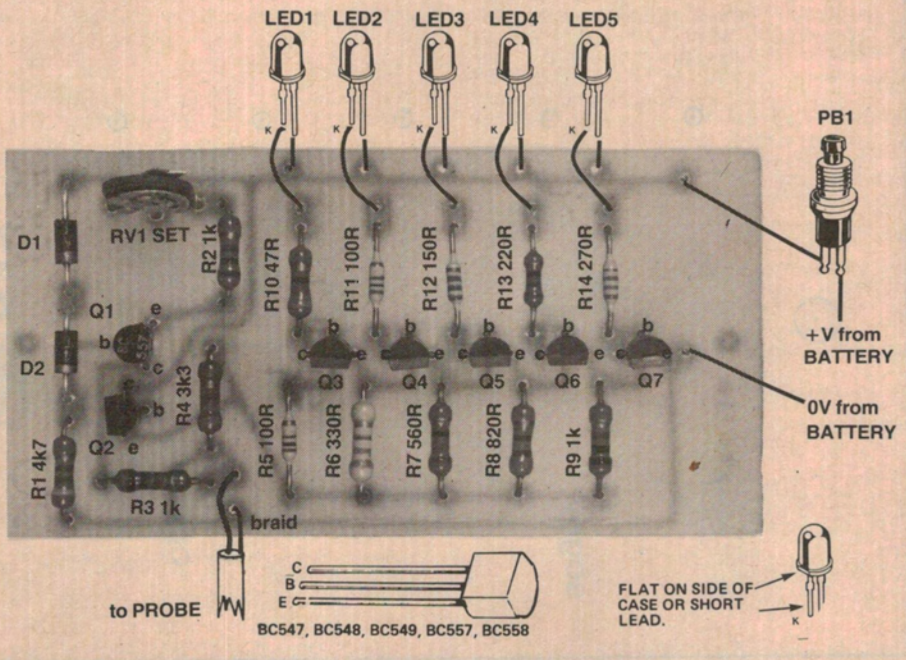
The probe is constructed using a standard 6.5 mm phono jack plug which ensures a constant distance between the electrodes, a uniform contact area to the soil and electrodes of similar material. A ballpoint pen barrel serves as a handle. A piece of pc board with two strips of copper to act as electrodes could equally well be used, but it would be necessary to have the electrodes plated to prevent corrosion which would adversely affect the operation of the project.

It is best to commence construction by drilling the holes in the aluminium panel. We have reproduced the front panel artwork here and you can use that as a guide. There are eight holes altogether. The hole which provides access to the SET trimpot is 4 mm in diameter while all the rest are 6 mm in diameter.

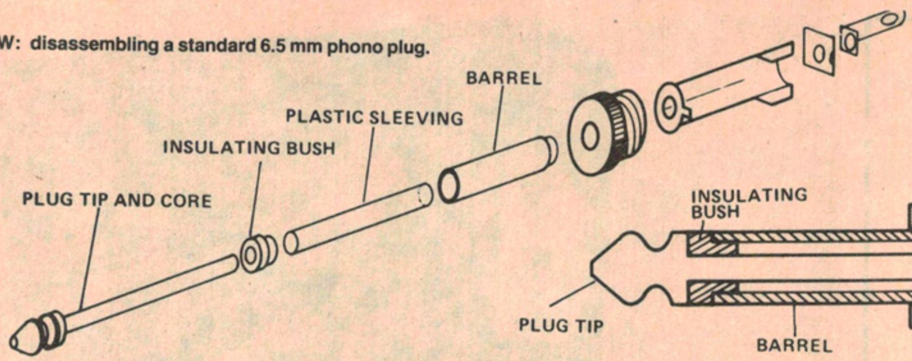
We dressed up our project using a Scotchcal front panel. This gives the unit a permanent finish and a 'professional' appearance. If you are using a Scotchcal front panel then this should be attached to the aluminium panel before any components are mounted on it. Scotchcal panels for this project should be available from a number of suppliers — see Shoparound on page 83.

The next thing to do is trim the pc board to size so that it fits into the box without jamming. You might strike it lucky and find it fits without trimming, but if not, file one end of the board until it slides neatly into place. Using the pc board as a template, mark and cut a scrap of pc board or aluminium sheet to size to act as a retainer for the battery holder. ▶

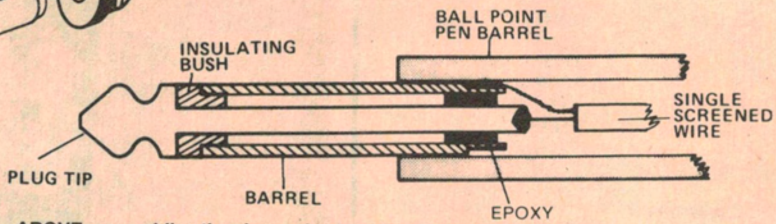
Component overlay for the pc board and external wiring.



BELOW: disassembling a standard 6.5 mm phono plug.



CONSTRUCTING THE PROBE



ABOVE: assembling the phono plug barrel and tip into the pen barrel.

Mount the components on the pc board next, using the component overlay here as a guide. Take care with the orientation of the transistors and the two diodes. Most common small signal transistors will work in this circuit, but if you use a type different to that specified then check the pin connections to ensure correct orientation on the board.

The LEDs and pushbutton switch can be mounted on the front panel now and wired to the pc board. Take care to wire the LEDs correctly. A grommet should be mounted in the hole through which the lead to the probe passes. The probe lead is passed through this hole and wired directly to the pc board. Next wire the leads to the battery holder, making sure you have the polarity correct, insert four AA cells and mount the battery holder in place. Note that the retaining piece securing the battery holder in the zippy box should not be the full depth of the box to allow the battery leads to pass between its top edge and the front panel.

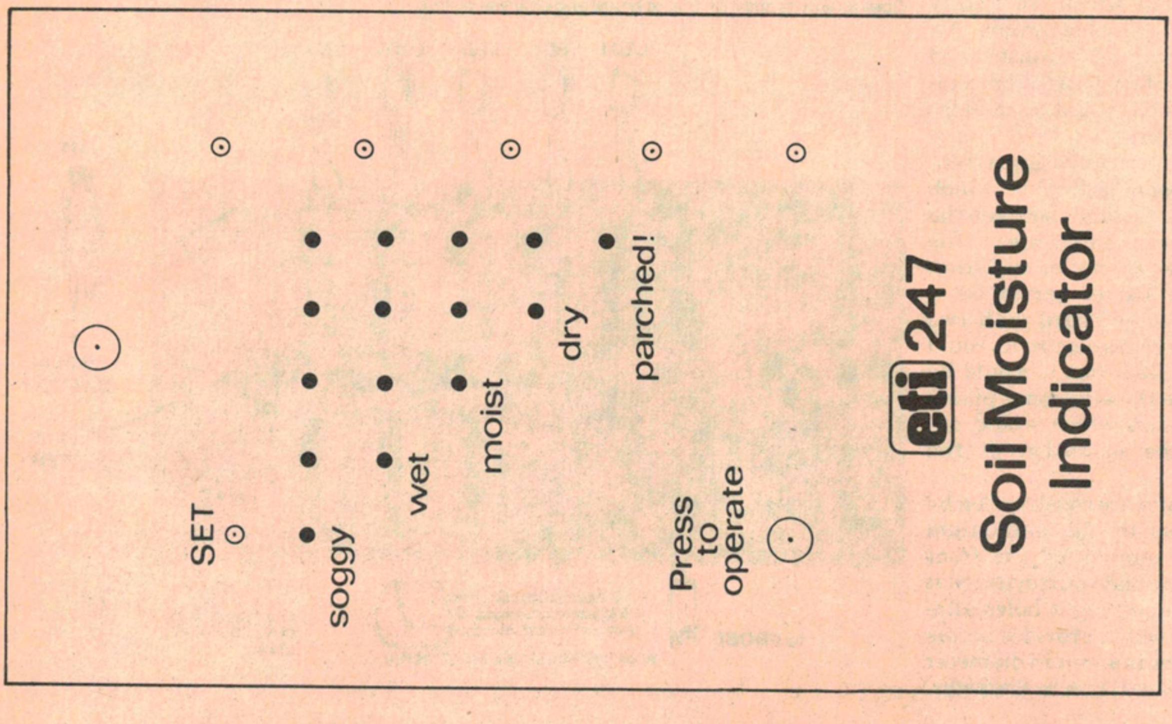
The probe can be constructed next. The exploded diagram here shows how it's done. We cut the ends from an exhausted type R56 Pentel ball pen and used the empty barrel as the barrel of our probe. The 6.5 mm phono jack plug is a neat fit inside the barrel.

Pass the shielded wire through the barrel and solder the end to the jack plug connections as shown in the diagram. Be careful to avoid short circuits between the braid and inner conductor of the cable. Don't use too much heat or the insulation on the inner conductor of the cable will melt back up inside the braid and you may get intermittent short circuits.

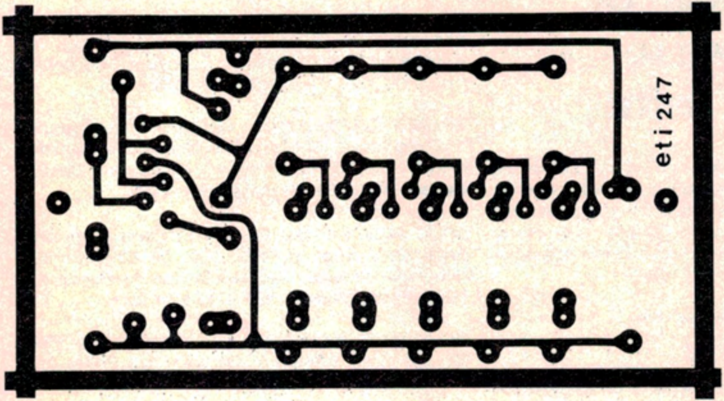
At this stage you can do a dry run (pardon the pun . . . Ed.). Press the pushbutton and most or all of the LEDs should light. If not, try adjusting the SET trimpot. If you still have no joy, check your wiring and the orientation of components on the pc board.

Setting up

The unit needs to be set to give the correct indication. Set up a few pots with earth 'as you like it', ensuring one is thoroughly dry and one is thoroughly wet. Insert the probe in the wet soil and adjust the SET trimpot so that only the top LED (LED 5) lights. Then insert the probe in the dry soil and see that all the LEDs light. Try the probe in soil of varying wetness and you'll get a good idea of how to interpret the display. After all, correct interpretation of the indication is just as important as the operation of the unit. Once set, the unit should not require any further adjustment. ●



Full size reproduction of the front panel artwork. Scotchcal panels will be available from suppliers — see Shoparound on page 83.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