

# pH — the acid test

Many chemical and biological systems depend critically on a parameter known as pH. This article explains what pH means, outlines how it is measured and investigates some areas where it is important.

**Elaine Ray &  
William Fisher**

THE IMPORTANCE of acids and alkalis is well known, as is the fact that some acids and alkalis are stronger than others — that is, they react more vigorously with other substances. But what is it that makes sulphuric acid, for example, stronger than acetic acid? And how can we quantify their strengths?

## Dissociation

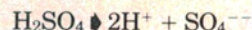
All acids have at least one hydrogen atom that tends to break away from the molecule when the acid is dissolved in water. In doing so it leaves behind an electron and becomes a positively

charged hydrogen ion. It is these free hydrogen ions that are responsible for the chemical properties of acids, and their relative numbers determine the strength of the acid in question.

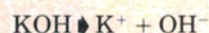
For example, acetic acid ( $\text{CH}_3\text{COOH}$ ) dissolved in water tends to partly dissociate into positive hydrogen ions ( $\text{H}^+$ ) and negative acetate residues ( $\text{CH}_3\text{COO}^-$ ), thus:



and sulphuric acid dissociates almost completely in water into hydrogen ions and sulphate residues thus:



Alkalis are extreme examples of a class of substances known as bases. Bases are like converses of acids. When they are dissolved in water they tend to break up into a negatively charged hydroxyl ion ( $\text{OH}^-$ ) and a positively charged residue. For example the strong alkali potassium hydroxide ( $\text{KOH}$ ) breaks up thus:

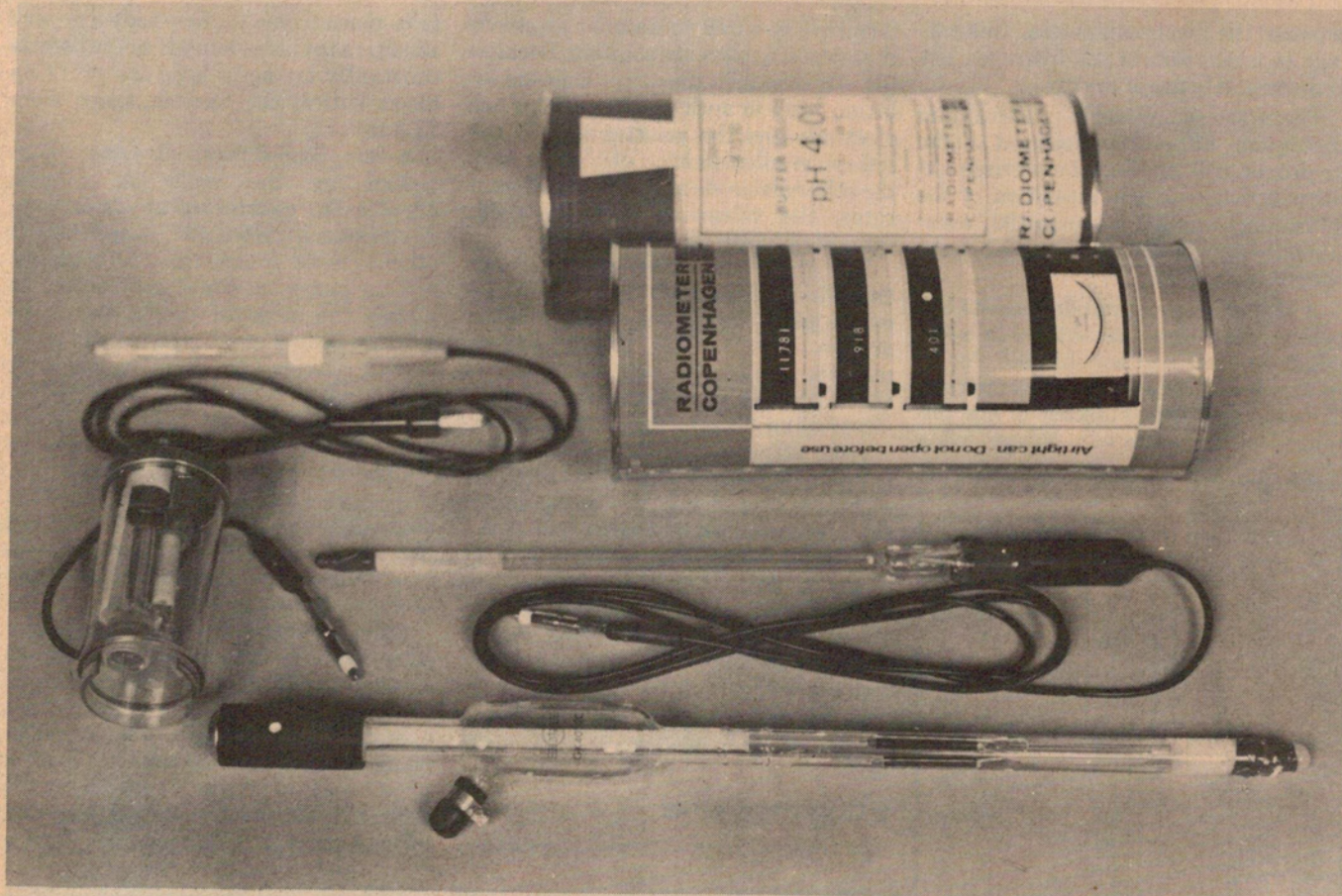


and the weaker base calcium hydroxide (lime) partly breaks up into calcium and

— to page 19 ►

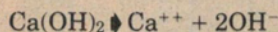


A high quality portable pH meter with a liquid crystal display that directly indicates the pH of the solution under test.

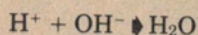


pH electrodes are made in a variety of shapes and sizes to suit different applications. At the rear of the picture are two cans of 'buffer solutions' — liquids whose pH does not change much when they are contaminated. Buffer solutions are used to calibrate pH electrodes.

hydroxyl ions, thus:



Bases and acids in the same solution tend to neutralise each other. The free hydrogen ions from the acid combine with the free hydroxyl ions from the base to form molecules of water, thus:



### Neutrality and activity

The reaction between hydrogen and hydroxyl ions can also proceed in the other direction — that is, water molecules can break up again into free hydrogen and hydroxyl ions. There is only a slight tendency for this to happen, however. In pure water at room temperature only about one water molecule in ten million dissociates into ions. In other words, the concentration of free hydrogen ions in pure water is one part in ten million. This concentration of hydrogen ions is known as a *neutral solution*.

If an acid is dissolved in water, the solution will no longer be neutral — there will be more hydrogen ions because of the dissociation of the acid. Dissolved bases will initially result in a

solution that has more hydroxyl ions than neutral water, but these hydroxyl ions will tend to combine with any free hydrogen ions to form  $\text{H}_2\text{O}$  molecules. The net result is that the number of free hydrogen ions in a basic solution is *lower* than in neutral water.

Clearly if we can measure the number of free hydrogen ions in a solution we can find out if it is acidic or basic, and to what extent. Actually what we will be interested in is not the absolute number of hydrogen ions, but their relative numbers, i.e. their concentration.

For reasons of mathematical convenience and logical purity, chemists prefer to work with a quantity known as the *activity* of hydrogen ions. Since the activity is generally proportional to the concentration, the exact distinction between the two terms need not concern us here.

The range of possible values for hydrogen ion activity is very wide, from  $10^{-14}$  for the strongest acid solution to  $10^{-1}$  for the strongest alkali. This leads to numbers that are awkward to write and even more awkward to speak (try saying  $2.76 \times 10^{-11}$  quickly!).

The pH notation, which was introduced in 1909 by the Danish chemist

S.P.L. Sorensen, makes things a bit easier. It defines pH as the negative logarithm of the hydrogen ion activity, i.e.

$$\text{pH} = -\log A \text{ (where } A \text{ is the hydrogen ion activity)}$$

Low values of pH indicate acidity, high values alkalinity. Neutral water is pH7.

### pH measurement

The best way to measure the hydrogen ion activity of a solution is to use that solution as part of an electric cell. Before 1937 this was commonly done with a 'hydrogen cell'.

When a platinum electrode is dipped into a solution containing  $\text{H}^+$  ions, the positively charged ions tend to attract negatively charged electrons out of the metal. The higher the activity of the ions, the stronger the attraction of the solution for the electrons.

One way to compare the  $\text{H}^+$  activities of two different solutions is to put an electrode into each solution and join the electrodes with a wire. The solution with the higher activity will exert a greater pull on the electrons and a current will flow through the wire. If the wire is broken, a voltage will appear ▶

between the two break points. This voltage is a measure of the hydrogen ion activity and hence of the pH.

There are considerable practical and theoretical difficulties involved in the 'hydrogen cell' method of measurement described above. The invention of the 'glass electrode' pH meter in 1937 overcame these difficulties and was a boon to chemists.

A typical glass electrode consists of a porous glass bulb containing a saturated solution of silver chloride (AgCl) in which a silver electrode is immersed. This electrode is connected to one terminal of a voltmeter, whose other

terminal is wired to another electrode that sits in a reference solution. Because the silver ions in the silver chloride solution tend to suck electrons from one electrode and the positive ions in the reference solution suck electrons from the other electrode at fixed but different rates, the voltmeter normally reads some steady voltage.

The glass bulb containing the silver chloride is immersed in the solution whose pH is being measured. The hydrogen ions in the latter solution migrate across the glass membrane of the bulb and alter the activity of the silver chloride solution, thereby altering the attraction of the silver chloride solution for the electrons in the silver electrode dipped into it. Consequently, the reading on the voltmeter will alter.

Careful design can result in a glass electrode pH meter which generates a voltage that is linearly proportional to the pH of the solution being tested. (Sometimes this linearity is achieved by putting the test solution in contact with the reference solution as well, via a 'bridge' of some electrically conducting salt).

## pH in medicine

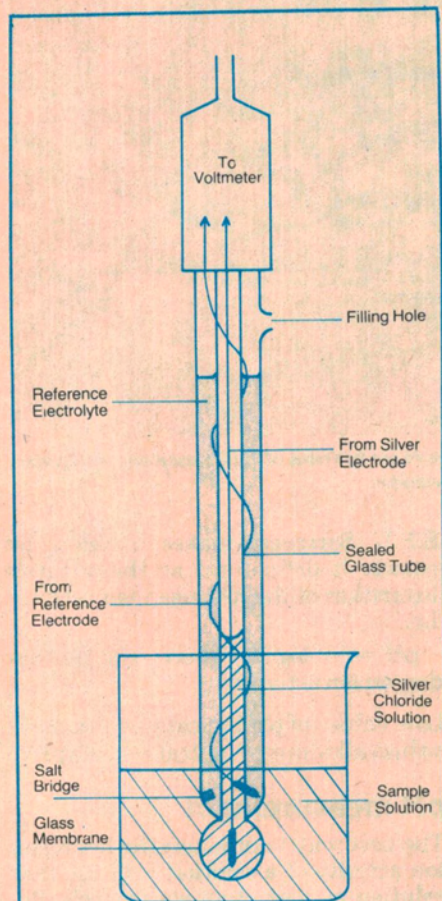
The complex chemical interactions that

take place in the human body are very sensitive to changes in pH so the body is constantly trying to keep the pH of its blood within the narrow range from 7.38 to 7.42.

A complicated feedback system, controlled by the endocrine glands, operates to counteract any abnormal deviations in blood pH, which would otherwise be traumatic. For example, after a heavy intake of alcohol, which makes the blood over-acid, the lungs breathe deeper and faster so as to expel carbon dioxide (which makes carbonic acid when it is dissolved in the blood) and the kidneys extract more carbonic acid from the blood and pass it into the bladder where it can do no harm.

Acidosis and alkalosis, which are the medical terms for abnormally low and abnormally high blood pH, are generally indications of serious diseases like diabetes, kidney or lung failure.

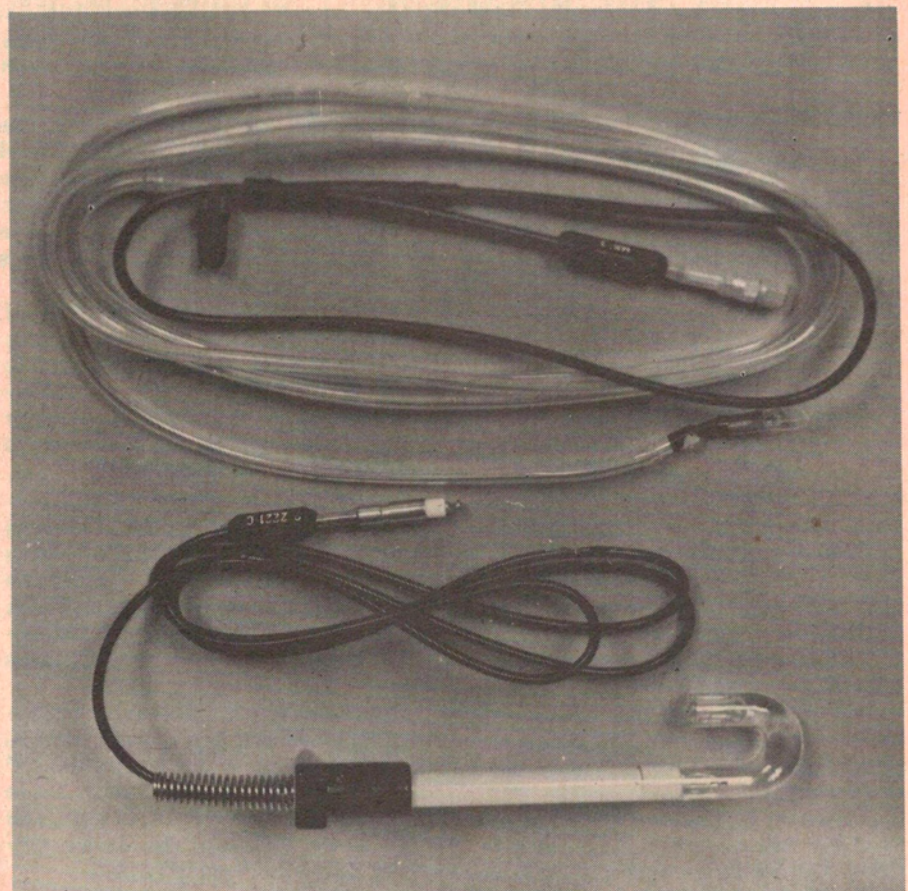
Polio victims and others in artificial respirators sometimes suffer from an excessive build-up of carbon dioxide in the blood (because their lungs cannot excrete it). Fortunately this can easily be detected in time for corrective action to be taken by routinely monitoring the blood pH. The amount of blood required for this purpose is quite small — a few



### A GLASS ELECTRODE

Above is a cross-sectional diagram of a typical pH electrode or 'probe'. It consists of a glass membrane in the shape of a bulb, inside which is a solution of silver chloride and a silver metal electrode. Around the stem of the probe is a refillable reservoir which contains a reference solution and a reference metal electrode.

The two electrodes are connected to the terminals of a voltmeter, which normally reads a steady voltage. When the probe is immersed in the sample solution, some ions from the sample migrate across the glass membrane and alter the activity of the silver chloride, so that the voltmeter reading alters.



Two special pH probes for medical applications. The upper one is a gastric pH probe, designed to pass through a patient's nose and the lower probe is used for blood analysis.

millilitres, which must be syringed directly to a gas analyser because exposure to the air would alter its pH.

The pH level in the stomach is quite different to that of the blood. The gastric juices are rich in hydrochloric acid and vary from pH 1.5 to 3.5. A hormonal feedback control system normally keeps the gastric pH within bounds, but this system can be upset by abnormal secretion of adrenaline in times of prolonged nervous tension. This is why people who live under a great deal of stress tend to have ulcers caused by gastric over-acidity.

There are also some people who have little or no free hydrochloric acid in their stomachs. This group run a very high risk of developing stomach cancers. Clearly the measurement of gastric pH levels is of considerable medical importance and over the years physicians have developed various methods of doing this. Perhaps the commonest technique nowadays is to pass an electrode through the nose and down the alimentary canal into the stomach, to give a fast and accurate indication.

## Soils

Soil acidity or alkalinity is one of the major factors that affect the growth of plants. The pH of a soil is an indication of the extent to which exchange reactions in the soil are preventing nutrients from reaching the roots of plants.

Roughly what happens is this — the fine particles in a soil aggregate into bodies known as colloids, which have an electrical charge distributed over their surface. The water that permeates the soil contains dissolved ions which plants need and which they normally suck up from the solution by capillary action through their roots. However, some of these ions in solution may change places with less valuable ions on the colloid surfaces. Plants can only absorb ions from the aqueous solution surrounding the colloids; they cannot attract them from the colloid surfaces, so the soil is effectively depleted nutritionally.

Plant nutrient ions are commonly attached to the colloids in exchange for hydrogen ions, which pass into solution. Measuring the soil pH obviously gives an indication of the extent to which this has happened.

Plants vary a great deal in the range of pH they will tolerate. Most will flourish somewhere between pH 6 and 8, but some well known plants grow best outside this range. Potatoes and tomatoes, for example, like an acid soil with a pH between 5 and 6, while ca-

mellias, azaleas and other hardy flowering plants cannot tolerate any degree of acidity and do best in alkaline conditions with a pH between 8 and 9.

Acid soils can be neutralised by adding lime and over-alkaline ones will benefit from a dressing of bone meal or any other source of phosphates. If you want to measure the pH of your own soil, you should first make a ten per cent aqueous solution (i.e. 10 grams of soil in 100 millilitres of water) and measure the pH of that.

## Aquariums

Fish are sensitive creatures and won't flourish unless the pH of their environment is correct. Most freshwater fish do best between pH 6.5 and pH 7.5, but goldfish (whether they are cold or warm water types) like their water a little more alkaline, i.e. pH greater than 7.5.

Acidic water in a goldfish tank encourages the growth of fungus and also induces a malady known as 'acid burn',

which makes the fish look as if they have had bites taken out of them. It is advisable to measure the pH of goldfish tanks about once a week, preferably when the water is refreshed.

If you don't have a pH meter you can get some idea of the acidity by inspecting the plants growing in the tank. If they are looking unhealthy, the water is too acid.

## Swimming pools

The recommended pH for swimming pool water is between 7.2 and 7.6. In the summer months when pools are in frequent use the pH should be tested every second day and chemicals added if necessary to keep it within bounds.

Over-acid pool water encourages the growth of algae, whose colour depends on the degree of acidity. First to form are green algae, in sheltered areas around steps or ladders. Brown algae that stain the tiles are the next stage, followed by black.



Chlorinated pools should be maintained at a pH between 7.2 and 7.6. An automatic chlorinator is the best method — see the Pool Magic offer on page 35.

# Digital pH meter is simple and accurate

A pH meter has many applications in widely varying fields of interest; in chemical analysis, in soil analysis (gardening!); swimming pool chlorination; care of tropical fish, etc. This project features a 3½-digit liquid crystal display, simple construction and straightforward operation.

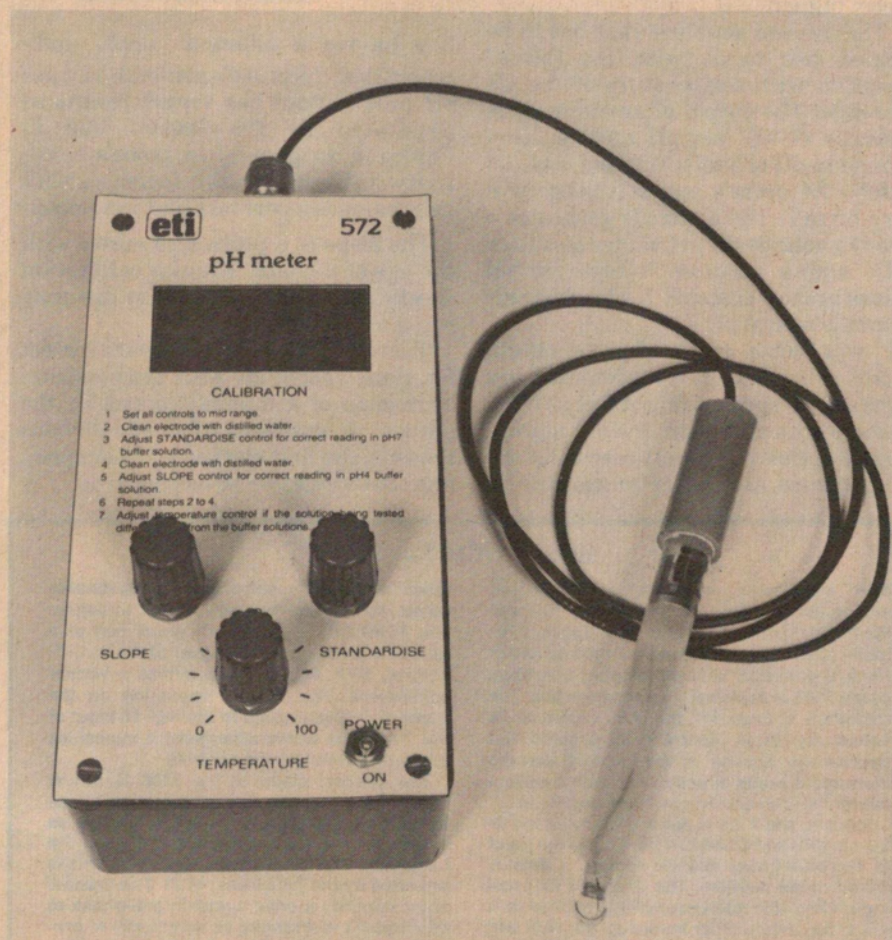
**Peter Eliot  
Phil Wait**

FROM TIME TO TIME readers write or 'phone us with a project suggestion that, at first sight is attractive and practical, but on further investigation runs into what seems insuperable difficulties — generally with the supply (or lack!) of a critical component.

We first looked at this project in response to a spate of reader enquires. They generally pointed out that a pH meter was something we have never done but there were plenty of commercially available models — generally at prices well beyond the hobbyist or student. The electronics for such a project could be designed in several ways and this seemed to present few problems. So, we went looking for a suitable pH electrode.

That's where it all started to come apart at the seams. Our early efforts turned up imported probes costing in the vicinity of \$100 for the least expensive model. We figured the electronics for an analogue readout instrument (using a moving coil meter) would cost around \$30 or so and for a digital readout instrument around \$40 or so. With probes at three times or more the cost of the electronics, a project started to look decidedly unattractive. It almost fell by the wayside.

However, during a conversation one day with Peter Eliot of the Amalgamated Instrument Company, who make and market a range of digital panel meters and portable digital instruments for industrial applications, the editor enquired where he obtained the pH probes for his digital pH instruments, and what did they cost? Peter was using Australian made probes chiefly because they cost less than half the equivalent imported types, and what's more they were readily avail-



able. Quick as a flash, we were talking to the man from Starcross Scientific, who distribute the range of 'Ionode' probes made in Queensland. A suitable probe was priced at around \$40 so we figured a project would be timely and popular. What's more, having already done much of the required development work, Peter Eliot volunteered to provide

us with a circuit and some material to suit our requirements. With some pc board and packaging work from the project staff, this project is the result.

### Principles

An article elsewhere in this issue explains the theory behind the pH index as well as detailing applications of pH ▶

# Project 572

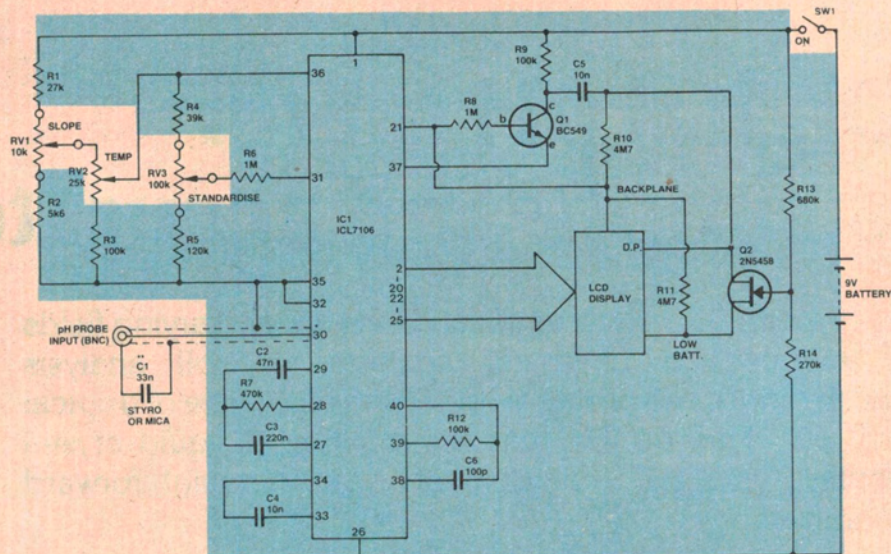
measurement in various fields. This discussion is confined to the principles of operation behind this particular instrument.

The pH electrode or probe consists basically of an electric cell which, when immersed in a solution, will generate a voltage proportional to the hydrogen ion activity of that solution. The voltage generated is a measure of the pH of the solution. Measure the voltage generated by the electrode, display it, and you've got a pH meter. Simple enough, but there are a few difficulties.

First problem is the internal (or source) impedance of the pH probe. It is generally around  $10^9$  to  $10^{10}$  ohms! This means that whatever instrument you use to measure the voltage output of the pH probe needs to have an input impedance at least an order of magnitude (i.e. 10 times) higher.

The second problem that has to be tackled has to do with the "slope" variation with temperature of the pH electrode. The output of an electrode is typically 60 mV per pH unit, i.e. for a change in pH of a solution from, say, 7.5 to 8.5, the probe's output voltage will vary 60 mV. The electrode generates a positive voltage for pH values less than pH 7 and a negative voltage for pH values greater than pH 7. The electrode output is zero at pH 7.

If you plot a graph of probe output versus pH, where pH is represented on a log scale, you get a straight line as illustrated by the unbroken line in Figure 1. However, that line is only correct for one temperature. At another temperature, a



\* PIN 30 DIRECTLY CONNECTED TO SCREENED CABLE  
\*\* C1 CONNECTED DIRECTLY AT BNC CONNECTOR

line having a different "slope", indicating that the probe's nominal "mV per pH unit" output has varied, results as illustrated by the broken line in Figure 1. In general, a probe's sensitivity (mV per pH unit) increases with increasing temperature and vice versa.

The slope of a probe also varies with the age of the unit. Regular calibration checks remove any error that this may bring to the reading.

There are two general ways to correct for slope variations with temperature: by means of a manual control in the circuit, or automatically. For obvious reasons, the first method is the simplest and that's what we've elected to do.

Fortuitously, the input impedance of an ICL7106 analogue-to-digital conversion IC is around  $10^{11}$  to  $10^{12}$  ohms which is just what we need, apart from providing an appropriately scaled digital output to drive a display. Consequently, most of the circuitry for the pH meter is contained within two ICs; the ICL7106 and an LAD204 LCD display. The external circuitry is used to provide the appropriate scaling (so that the display reads directly in pH units) as well as slope and temperature compensation controls.

As this is a battery operated instrument, we thought it would be convenient to have some indication of when the battery was getting low. Surprise, surprise — the LCD display we chose incorporates a little "low batt." warning display in the top left hand corner. This is activated with a little extra circuitry once the battery voltage falls below 8.5 volts.

## The pH probe

The pH probe we obtained for our instrument comes from Starcross Scien-

## HOW IT WORKS — ETI 572

The instrument employs a single-chip analogue-to-digital (A/D) converter IC, type ICL7106, driving a liquid crystal display. Virtually all of the instrument is contained within the A/D converter chip and display. Operation of the 7106 is explained in a separate box. The reference voltage for the A/D converter is varied by three controls to provide the appropriate 'scaling' of the input so that the instrument reads directly in pH units, corrected for "slope" and temperature variations.

Input to the 7106 is applied between the IN LO pin (30) and COMMON pin (32) as the input is negative-going and we require a display which reads positive. The IN HI pin (31) has a portion of the reference voltage applied to it via a resistive divider involving R4, RV3 and R5. This sets the display to read (positive) 7.00 when the input is zero i.e. when the probe is in a pH 7.00 solution.

The A/D converter reference is developed between pins 35 and 36, derived from a resistive divider pick-off between the positive supply rail and the COMMON pin (32).

Varying the reference voltage by a small amount is used to provide temperature and "slope" compensation. The SLOPE control is part of the reference voltage divider and pro-

vides a 'vernier' control over a reasonable range, so making the control easy to adjust. The TEMPERATURE control forms part of a resistive divider from the wiper of the SLOPE control, RV1. Again, this provides a vernier adjustment. The voltage appearing on the wiper of RV2 is applied to the REF HI input of the 7106. The whole arrangement minimises interaction between the controls.

The internal clock of the 7106 is run at 50 kHz for maximum mains hum rejection, as explained elsewhere. The LCD display is driven by a square wave signal between the backplane and the numeral segments. This is provided by the 7106 from pin 21. The decimal point requires a drive signal in anti-phase to this and Q1 is arranged as an inverter to provide the appropriate drive to the decimal point.

The LOW BATT. indicator is activated by Q2. The gate of this FET is biased by a voltage divider using R13 and R14. When the battery voltage falls below about 8.5 V, Q2 turns on and applies the anti-phase backplane signal (from the decimal point drive) to the LOW BATT. pin on the display.

Hum filtering at the input is provided by a 33nF capacitor connected directly across the input socket.

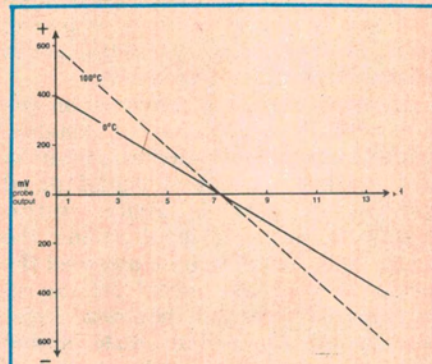


Figure 1. Illustrating how the "slope" of a pH electrode's sensitivity varies with temperature.

tific, P.O.Box 151, Frenchs Forest, NSW 2086. They are available mail order for \$45.70 which includes sales tax and delivery. The probe, designated G101NFE, comes complete with a plastic protector cap, a wetting cap for storage and a comprehensive booklet plus two 200 ml containers of buffer so-

lution, one of pH 6.88, the other pH 4.00. A BNC plug is fitted to the coaxial cable connection. The probe is a "non-flow" or sealed type and will have a long life without needing replenishment of the internal electrolyte.

In addition, Starcross have available accessories such as 100 ml plastic

beakers and plastic wash bottles. They can also supply spear point electrodes suitable for soil analysis.

## Construction

The pH meter is housed in a plastic box measuring 150 x 80 x 50 mm, although a 'zippy' box of similar size having an

### ABOUT THE 7106

The ICL7106 is manufactured by Intersil of the USA and contains all the circuitry for a digital panel meter employing the 'dual-slope integration' technique all housed in a 40-pin dual-in-line package. It is designed to drive any multiplexed 3½-digit liquid crystal display. A companion chip, the ICL 7107 is designed to drive any suitable 3½-digit LED display.

The internal circuitry of the 7106 can be divided into several areas: firstly there's the precision dual-slope integration type analogue-to-digital converter, then display decoder/driving circuitry and display multiplexing.

The precision dual-slope A/D converter is the most important, so let's take a close look at that.

In this method of A/D conversion the analogue input voltage is first converted to a time period which in turn is converted into a binary number by a timer/counting system. Referring to the block diagram here, and the associated timing diagram, the system commences the measurement when the switch connects the analogue signal input to the integrator which commences to 'ramp up'. At the same time the counter begins, from zero, to count the clock pulses. When a predetermined number of pulses, 1000 with the 7106, appear in the counter, the integrator is electronically switched over to the reference voltage. At this point, the integration capacitor, C, has then charged linearly from the input, rising as a ramp voltage to a level decided by the average input signal value over the counter time period (T). As the switch changes to the reference, the counter is reset to zero and commences counting again. The reference, which is of opposite polarity to the input signal, now causes the charged integration capacitor (C) to ramp downward with a fixed slope. When the output of the integrator reaches the zero threshold the counter is stopped and its contents displayed on the digital readout. The count displayed is the ratio of the counts during the 'downward' ramp (over time 't') to the counts during the upward ramp.

Thus, for a limit of 1000 counts

during the upward ramp, a direct reading of input voltage is obtained if the reference voltage is chosen appropriately.

The absolute value of the integration capacitor and the clock frequency are of little significance provided they are stable for the duration of the conversion period.

The relatively long analogue-to-digital conversion period has an inherent advantage in that it ignores noise. When noise is integrated over an extended period, its amplitude tends to zero. Thus, dual-slope integration results in excellent accuracy.

The 7106 has an on-board clock oscillator, the frequency of which is determined by external RC components — R3 and C4 in the circuit here, connected between pins 38 and 39. The clock frequency has been set to 50 kHz for the pH meter project. The oscillator frequency is divided by four internally to give a clock period of 80 us. As the integration period is 1000 clock periods long, the analogue input is integrated over a period of 80 ms. This results in pretty nearly optimum mains hum rejection as any 50 Hz ripple on the input will be integrated over four cycles and will thus have a dc value approaching zero.

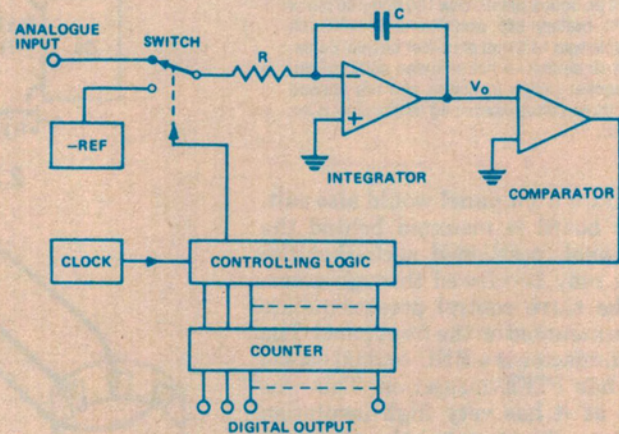
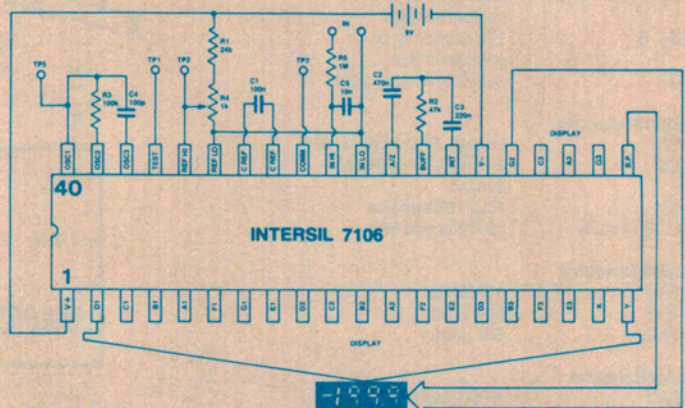
Clock input is to pin 40 (TP5 in the circuit here) and the 7106 may be driven from an external clock if so desired. It requires a square wave drive of 5 V amplitude, positive with respect to the common pin. For external clock drive the clock RC network (R3-C4) is not required.

The A/D converter reference voltage is developed between pins 35 and 36 (REF LO and REF HI respectively). Pin 35 is set internally to be always 2.8 V lower than the positive supply rail applied to pin 1. The full-scale sensitivity of the 7106 can be 'programmed' by setting the value of the voltage between the REF LO and REF HI pins. For 200 mV full-scale sensitivity (reading of 1999 on the display) the voltage between pins 35 and 36 should be set to 100 mV, for 1 V sensitivity it should be 500 mV and so on.

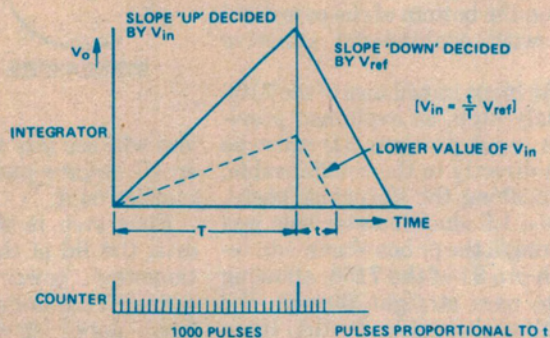
Input current drawn by the 7106 is extremely low, typically one pico-amp (1 pA or  $10^{-12}$  amp as it has an input impedance measured in

Giga-ohms ( $10^9$  ohm)! For this reason, the unit can be used to measure voltage sources having a source impedance up to  $10^{11}$  ohms — making it ideal for application in a pH meter. A useful spin-off from the 7106's high input impedance is that

only quite small value capacitors are required in parallel with the input to provide good hum rejection. In addition, the input impedance is readily defined by using an appropriate value parallel resistor or simple attenuator on the input.



Block diagram of the 'dual-slope integration' technique of analogue-to-digital conversion commonly used in digital meters.



Timing diagram for the dual-slope A/D conversion technique.

# Project 572

## PARTS LIST — ETI 572

### Resistors all 1/2W, 5%

|           |       |      |
|-----------|-------|------|
| R1        | ..... | 27k  |
| R2        | ..... | 5k6  |
| R3, 9, 12 | ..... | 100k |
| R4        | ..... | 39k  |
| R5        | ..... | 120k |
| R6, 8     | ..... | 1M   |
| R7        | ..... | 470k |
| R10, 11   | ..... | 4M7  |
| R13       | ..... | 680k |
| R14       | ..... | 270k |

### Capacitors

|       |       |                                |
|-------|-------|--------------------------------|
| C1    | ..... | 33n styroseal or mica          |
| C2    | ..... | 47n greencap or polycarbonate  |
| C3    | ..... | 220n greencap or polycarbonate |
| C4, 5 | ..... | 10n greencap or polycarbonate  |
| C6    | ..... | 100p ceramic or mica           |

### Semiconductors

|             |       |                           |
|-------------|-------|---------------------------|
| Q1          | ..... | BC549, BC109 or similar   |
| Q2          | ..... | 2N5485, 2N5484 or similar |
| IC1         | ..... | ICL7106 see text          |
| LCD Display | ..... | LAD204 see text           |

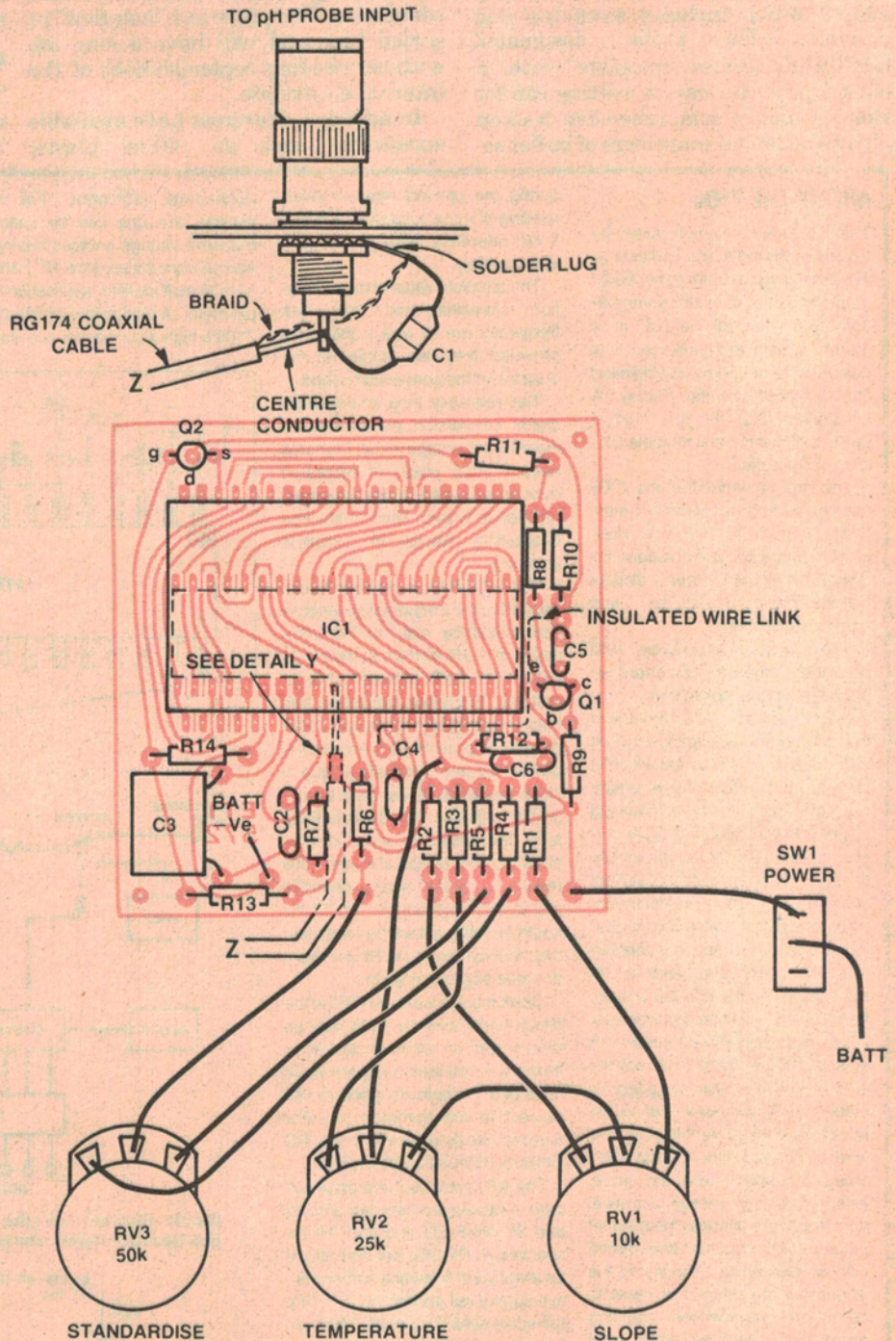
### Potentiometers

|     |       |            |
|-----|-------|------------|
| RV1 | ..... | 10k linear |
| RV2 | ..... | 25k linear |
| RV3 | ..... | 50k linear |

### Miscellaneous

SW1 ..... SPST miniature toggle switch

ETI 572 pc board; plastic box 150 mm x 80 mm x 50 mm; battery clip and No. 216 nine volt battery; length of 4 mm diameter coaxial cable, RG174 or similar — not shielded audio cable; BNC socket (teflon insulated and not second hand); three collet knobs; 40 molex pins; nuts, bolts etc.



aluminium front panel would also suit. The pc board is mounted behind the front panel, positioned such that the display may be viewed through a cut-out. The three control potentiometers are also mounted on the front panel. The input connector is a BNC coaxial socket which has PTFE insulation. This was chosen as it has very high insulation resistance. We mounted the socket on one end of the case and it is connected via coaxial cable. The battery was mounted on the bottom of the case, held in place with double-sided adhesive tape.

Since the input impedance of the 7106 is extremely high, as explained previously, the input pin (pin 31) must be connected directly to the coaxial cable, without touching the fibreglass board. To do this a 1.5 mm diameter hole was drilled through the pc board immediately beneath pin 31 of the 7106, allowing the pin to pass straight through the board where the cable to the input connector can be terminated directly to it. If you look at the pc board artwork,

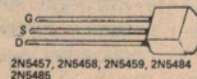
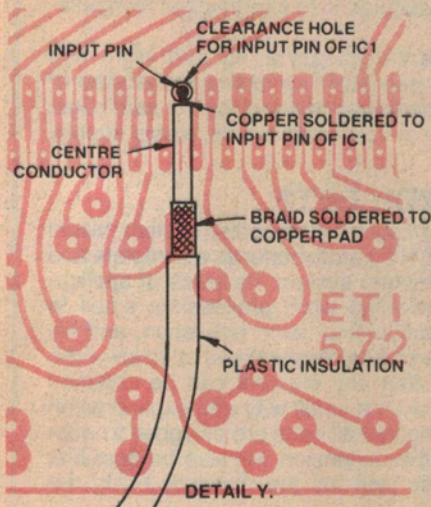
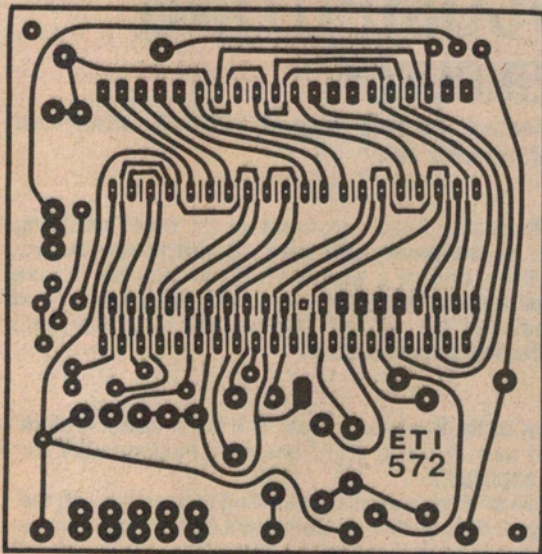
you will see this drill hole marked by a small square pad with a drill centre marked on it.

First step in the construction is to drill the lid of the case for the potentiometers, power switch and display cutout. This is best done by using the front panel artwork as a template. Scribe around the inside of the cutout, then mark a parallel line about 2 mm

inside this. Drill a series of 3 mm diameter holes using this inside line as the drill centre line, and then pop out the centre of the cutout. Use a flat file to smooth off the edges to the first scribed line.

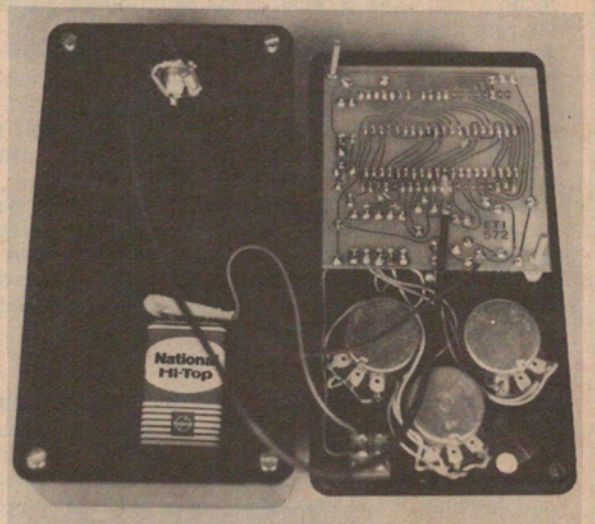
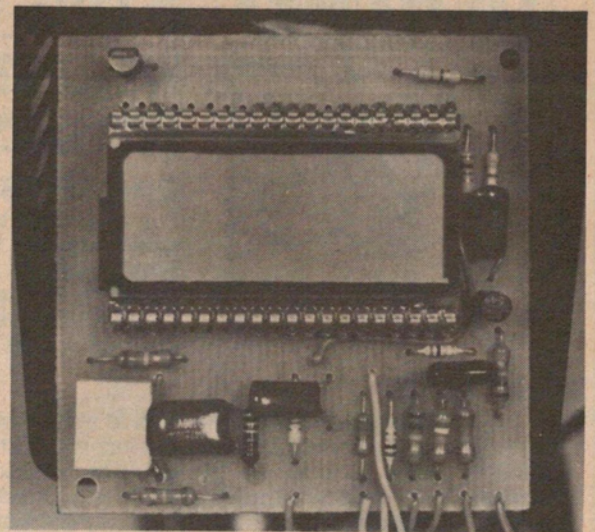
Mark the centres of the potentiometer holes and centre punch them. These holes are drilled to 10 mm diameter. The hole for the power switch should be





Top right: view of the printed circuit board, showing the liquid crystal display.

Right: showing the rear of the pcb, with connections to the probe and potentiometers.



marked in the same way and drilled to 6 mm diameter. Next, mark and drill the hole for the BNC input socket (also 10 mm diameter).

The front panel transfer should not be attached yet. The pc board is mounted behind the front panel using two countersunk-head bolts and nuts either side of the board to position it. Using the unloaded pc board as a template, mark and drill the holes for the bolts that are to hold it. Countersink the holes on the *upper side* of the panel.

The pc board may be tackled next. All the smaller components should be mounted first. The capacitors are bent down onto the board so that they will be lower than the display. Capacitors C2, C3, C4 and C5 can be greencap, polycarbonate or mylar capacitors. If you have bought an Intersil ICL7106EV digital panel meter evaluation kit, some of the components may be used in the project. The clock capacitor, C6, can be either an NPO ceramic type or silver

mica. The evaluation kit uses a 100p silver mica type for this capacitor.

Next mount transistor Q1, and the FET Q2, pushing them hard down on the pc board so the tops of their cases will sit below the display (when it is mounted). The FET has an unusual pin-out configuration so be extra careful that you insert it the right way round.

Mount the 7106 IC as shown in the overlay diagram, being careful to orient it correctly. Forty pin ICs are very hard to get out again!

We mounted the display directly above the 7106 on two rows of Molex pins. This permits quite a compact pc board and elevates the display somewhat above the surrounding components on the board. It may also be unplugged, which might be necessary as we explain shortly.

Insert the two rows of Molex pins, but only solder those pins which are actually used. Those pins not having pc board tracks attached are not used.

When the pins are in place, bend back the steel connecting strip between the pins with a pair of long-nose pliers until the strip breaks off. The unused pins will come away with it.

Some displays do not have pin 1 designated, but if you turn the display edge-on to the light you should be able to see the numerals faintly. Alternatively, you have a 50-50 chance of getting it right (or wrong — but we're optimists!) if you take a guess

Mount and wire the three potentiometers and the power switch next. Connections are indicated on the wiring diagram. The potentiometer terminals are positioned at odd angles so that they can be fitted in the available space. This necessitates the use of collet knobs so that the pointer can be positioned correctly in relation to the shaft. Some small grub-screw knobs will work, but you may have to shop around. Speaking of Shoparound, see page 85 this issue for details on where to buy suitable collet

# Project 572

knobs. Wire the battery clip and power switch last.

At this stage you can check to see if you have the display inserted the correct way round. Temporarily plug in a battery and turn the unit on. If all is well, you will see numbers come up on the display. If not, no numbers will appear. Unplug the display and reverse it if this is the case.

With all the components mounted, the pc board can now be mounted to the front panel. Adjust the position of the board so that the display sits firmly behind the cutout in the panel, but don't strain the board.

Finally, solder the coaxial cable from the input socket to the pc board as indicated in the accompanying diagram. Make sure that you use good quality coaxial cable such as RG174 (4 mm dia.), not ordinary 'shielded cable' as its insulation resistance is not good enough for this application. Also ensure that the PTFE insulation on the BNC socket is clean and free from flux. If necessary, wash the socket in alcohol.

Terminate one end of the cable on the socket being careful not to leave any flux on the socket's insulation, or heat the coaxial cable insulation too much. Use a good hot iron with a clean tip and solder quickly. Use a large solder lug

under the socket's nut for the braid connection or solder the braid to the edge of the nut. Capacitor C1 mounts directly across the input socket and it must be a styroseal or mica type.

Cut the cable to about 150 mm length and terminate the other end to the input pin of the 7106 as shown in the drawing on page 26. Don't let flux flow down onto the hole in the pc board or allow the solder bead at the joint to touch the board.

Now you can plug in the battery and your pH probe and give the unit a try. If all is well, the front panel artwork can be mounted. Scotchcal panels will be available from the usual suppliers (see ETI October 1980, p. 65).

## Using the instrument

Before making a measurement, the instrument should always be 'buffered'. Remove the wetting cap from the probe and attach the plastic protective cap — that little bulb on the end is *very* fragile. Set the TEMPERATURE control to room temperature (say, 25) — the scale on this control is marked in degrees centigrade (°C). Clean the electrode with distilled water if you have used it recently.

You will need two buffer solutions,

one having a pH near 7 and the other a pH near 4. The two most commonly available have a pH of 6.88 and 4.00. Put the probe in the pH 7 solution and adjust the STANDARDISE control for the correct reading according to the marked pH of the buffer. Allow about two minutes or so for the reading to stabilise before finally adjusting the control. Remove the probe and wash it again in distilled water.

Now put the probe in the pH 4 buffer and allow the reading to stabilise. Then adjust the SLOPE control for the correct reading according to the marked pH of the buffer.

Go through the procedure again to ensure correct adjustment. Only then can you take a reading in the solution or solutions to be tested. Wash the probe before making a measurement and between successive measurements.

If the temperature of the solution, or solutions, to be measured differs substantially from the temperature of the buffers, set the TEMPERATURE control to approximately the temperature of the solution to be measured. This control only has a minor effect and its operation is very 'broad'.

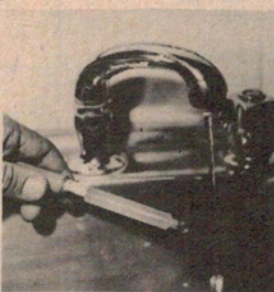
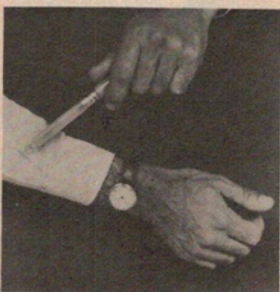
There you have it, your own digital pH meter with an Australian-made probe to boot!

## THE CARE & FEEDING OF YOUR pH ELECTRODE

To ensure the maximum life and best response from your pH electrode, the following procedures are recommended.



Store the pH electrode with its tip soaking in distilled water, use the protective shield and rinse with distilled water between measurements.



NEVER clean a pH electrode on a rag, or on your sleeve, or under a running tap.

1) When not in use the pH electrode should be stored with its tip soaking in distilled water. It is important that the porous glass membrane and salt bridge are *not allowed to dry out*. If for some foolish reason this does occur the electrode will require soaking in distilled water for 24 hours before it can next be used.

2) For long term storage, cover the glass bulb with a 'wetting cap' containing distilled water. (Note that plastic wetting caps are supplied with the Australian-made Ionode pH electrodes).

3) When in use, the electrode should be rinsed thoroughly with distilled water (preferably applied with a fine-nozzled wash bottle — see the accompanying illustration) between successive readings and between buffer calibrations.

4) If the electrode is used with non-clean or organic solutions the electrode may require extra cleaning from time to time. The most common method used is to soak the electrode for 24 hours in a '0.1 normal' hydrochloric acid solution. Alternatively, simply soaking the electrode in a mild solution of household detergent and distilled water will generally emulsify the contaminants and restore the electrode to normal.

5) Always be careful not to touch, scratch or damage the porous glass membrane. It is advisable to use a plastic protector cap as shown in the accompanying illustration. (These are supplied with the Ionode electrode).

6) Generally, a sluggish response from the electrode will indicate that it needs cleaning.

For troubleshooting other problems it is best to consult the instruction booklet supplied with the electrode or the supplier from whom you purchased the electrode.