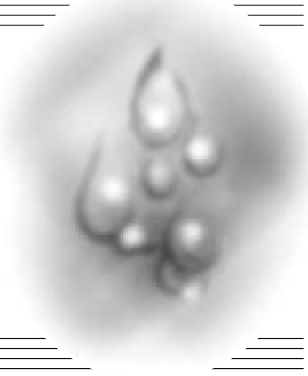
Constructional Project



RH METER

BILL MOONEY

Uses a capacitive sensor to measure the Relative Humidity (RH) of air.

ALTHOUGH we consider air to consist of nitrogen, oxygen and a little carbon dioxide, one other component is essential for normal life, namely water. Too much or too little water in our atmosphere soon leads to discomfort and even serious health problems.

Static charge build-up with all its consequences is directly related to low humidity. Air humidity also has large effects on many engineering and building materials in everyday use. Also, without water in the atmosphere we wouldn't have weather, as we know it.

The RH Meter (Hygrometer) described here uses a new capacitive RH (relative humidity) sensing element to give an accurate measure of the relative humidity of air. The sensor contains on-chip integrated signal processing to give a d.c. output proportional to RH. The element is laser trimmed to a preset output span so that a simple but very effective RH meter can be produced without the need for calibration in standard atmospheres.

The traditional analogue meter readout is a visually comfortable way or representing the ambient RH. But a ground referenced analogue output is also provided for PC or PIC recording, processing or data logging.

HUMIDITY

Relative Humidity is a measure of the amount of water in air. The scale covers from 0% which is "bone" dry to 100% when the air is referred to as "saturated''. We are used to living in an atmosphere between about 30%RH and 70%RH.

Above 70% RH things are getting a little humid and over 80% it is downright uncomfortable and rain-forest like. Humid air feels warmer than it really is because of the reduction in evaporative cooling of the skin. In very high humidity conditions, moulds and fungi proliferate but dust mites prefer it slightly less humid at around 60%RH.

There are many other effects of high RH such as breakdown of materials like insulating foams releasing toxic gases and increased warping and break-up of chip board and similar cellulose building composites. At high RH we run the risk of a small drop in temperature suddenly taking the air above saturation. This means condensation or liquid water everywhere. Water in this state is very corrosive, metals rust, paint flakes off, materials which should never get wet irreversibly distort.

LOW LEVEL

Below 30% RH we start to dry out and it feels cooler than it really is because of increased ease of skin evaporation. Humans perceive humidity in part as a temperature effect. Many houses hit 15% RH or lower in late autumn when the central heating comes on. This results in various infections as the protective mucus linings of our mouth and airways dry out.

Apart from low oxygen content a major enemy of Everest climbers and arctic explorers is low RH. The atmosphere is freeze-dried and the human skin becomes dehydrated and brittle and finally cracks.

Similarly, frosty nights can easily result in unhealthy low RH levels. At low RH the electrical resistivity of most materials increases to greater than a million megohms per square ($10^{12}\Omega$). This results in huge static electricity generation and charge build-up. Shocks and discharges from carpets, clothing and cars, become intolerable and, of course, there are increased fire risks.

Atmospheric humidity is particularly important to timber merchants. When we buy wood from the DIY we must select inside or outside conditioned timber. Try using wood which is seasoned and cut outside for your inside shelves and they will warp and crack unacceptably.

MEASURING RH

There are several ways of measuring and expressing the amount of water in the air, including dewpoint, vapour pressure and wet bulb depression or psychrometery. But Relative Humidity (RH%) is by far the widest used and most familiar descriptor for moisture in air.

The RH scale also corresponds well to our perception of moisture level. RH is defined as the ratio (expressed as percent) of the actual partial vapour pressure to the saturated vapour pressure at the prevailing temperature. Without the temperature RH does not define the actual water content as the water content increases with temperature.

A more intuitive definition of RH is the ratio of the water content of air to its water content at saturation expressed as a percentage. Or simply how close we are to saturation. An example will put some reality into this. One cubic meter of air at 40%RH weighs about 1kg at 10°C and contains about 3 grams of water.

The interplay between Temperature, RH% and actual water content is complex but well known and tables can be consulted to get values for specific conditions. At some point the amount of water in air reaches a limit which we recognise as saturation or 100% Relative Humidity.

Another example will give a feel for what this means in reality. Taking one cubic meter of air at 50% RH and 20°C, it contains 7g of water. If water is added to this air it will reach saturation or 100%RH at a water content of 14g.

Taking this sample of air at 50% RH/20°C containing 7g of water per cubic meter, if we increase the temperature to 25°C it would need to contain 10g of water to maintain the same 50% RH. This is why many commercial RH meters also contain a thermometer. But even if the temperature is not known the RH figure tells us how "wet" the air is, which is what we need to know and is therefore a great way of expressing this property.

Finally, and probably to add to the confusion, it must be pointed out that when we refer to the capacity of air to "hold" water and similar phrases we are not strictly correct in physics terms. But it is a useful model. In fact, water vapour behaves quite independently of the other gases so that you could have an RH value for just water vapour in a space. The prevailing pressure of the air/water system is the sum of the partial (independent) pressures of each of the gases.

CAPACITIVE SENSOR

Dew point, Psychrometery, and vapour pressure measurements give accurate direct measures of RH. But these methods require us to take some action such as twirling a wet and dry bulb psychrometer for several minutes just to get a single figure.

Automatic measures which give a varying voltage representing RH are required for control, data logging and automatic PC processing. Such sensors have been around for some time in the form of conductive cells. But the latest capacitive sensors are particularly easy to use, yet give instrument quality accuracy and long term reliability.

The Honeywell HIH3605 device is a good example as it contains on-board interfacing electronics to produce a linear voltage/RH output. The internal elements and the construction of the HIH3605 are shown in Fig.1.

It contains a small planar capacitor made from an absorptive polymer dielectric with porous platinum plates. A top layer of porous polymer on the surface protects the sensor from dust, dirt, and oily contamination. But it should still be treated with care.

When moisture enters the dielectric the capacitance changes in proportion to the mass of water present. The sensing capacitor and the small interfacing circuit are integrated on a ceramic base with just three pins to supply power and for output.

If a stable supply of exactly 5V is used, the output voltage span is from 0·80V to 3·90V for 0%RH to 100%RH at 25°C. The change in this span with temperature is small enough to be ignored for this project, see Fig.2. For example, the 100%RH value drops to 3·50V at 85°C which is a higher temperature than likely to be encountered with this meter. But automatic temperature correction is a simple matter for high temperature applications.

It is usually possible to be confident in the RH readings to within 5%RH, with a little care such as allowing enough settling down time. This is very adequate for our RH Meter and in fact most conditioning systems work to this accuracy. Small fluctuations in RH of 1% or so can still be detected for comparative purposes. Getting very accurate RH measurements is difficult and usually means invoking a complex set of corrections.

CIRCUIT DESCRIPTION

The full circuit of the RH Meter is shown in Fig.3. After initial setting up, the RH sensor's output (X1) is connected to the non-inverting input at pin 3 of IC1a. This is a voltage follower and faithfully delivers the sensor output to the moving coil meter MEl.

The output of IC1a is also the take-off point for output socket SK1 when the signal is required for external processing. A low value resistor R8 protects the i.c. from accidental shorts and has no effect on high impedance loads.

For 0%RH the meter must read 0V but this corresponds to 0·80V output from the sensor X1. A potential divider network consisting of resistors R3, R4 and preset

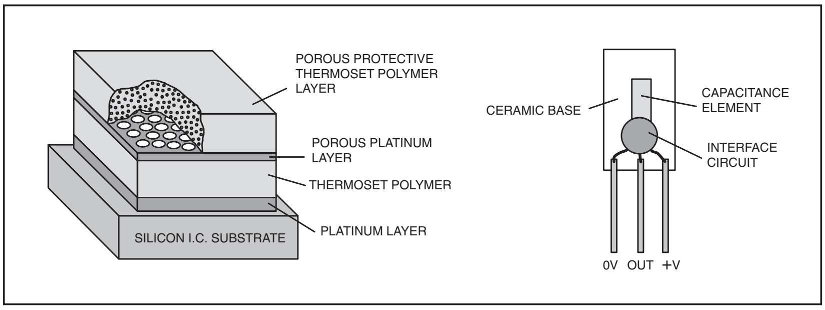
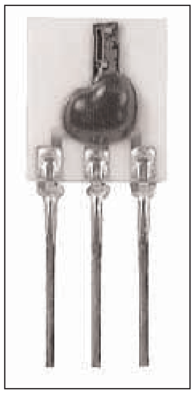


Fig.1 (above). Internal elements and construction of the HIH3605 capacitive RH sensor.



(Right). The Honeywell HIH3605 capacitive RH sensor.

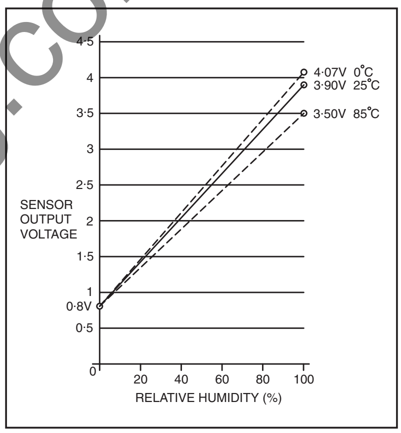


Fig. 2. HIH3605 output voltage for 0% to 100%RH.

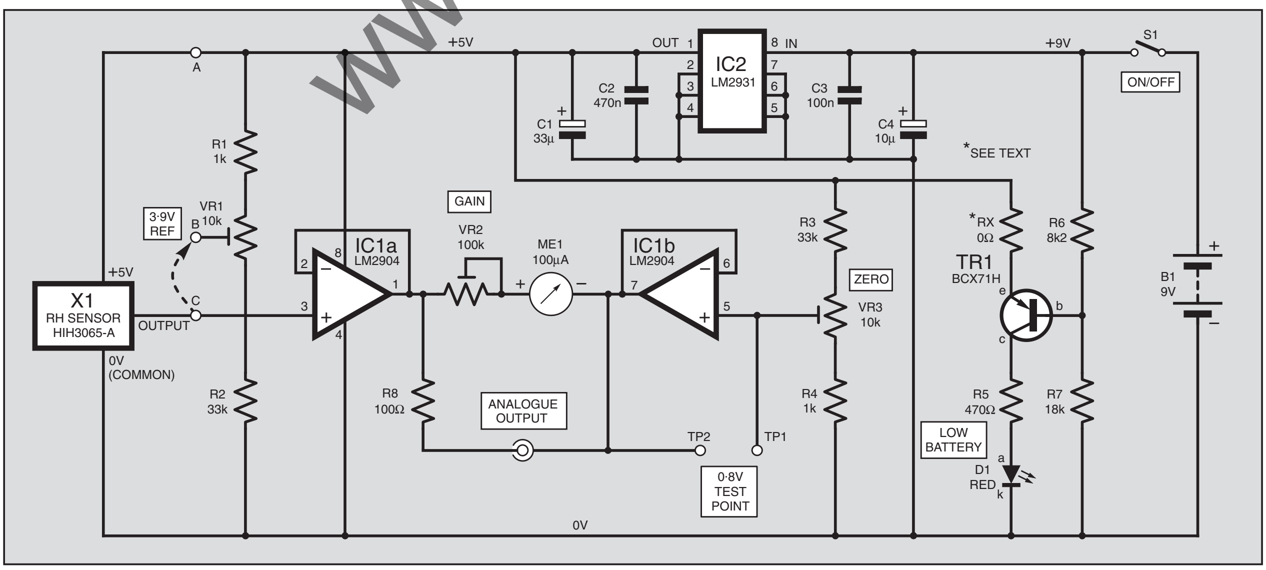


Fig.3. Complete circuit diagram for the RH Meter. Resistor RX is a "zero ohm jumper" but can be an SMD resistor having a value less than 10 ohms or be just a link wire.

VR3 is set to exactly 0·80V and after isolation by IC1b provides a steady 0·80V to meter ME1's negative terminal. When the sensor output is at 0·80V i.e. 0%RH, the meter therefore has 0·80V on *both* terminals and reads 0%RH.

The potential divider made up of R1, VR1, R2 is used as a 3·90V reference for setting up. The output socket, SK1, ground is connected to the output of IClb (at pin 7) and the RH signal is taken from IC1a pin 1 so that a span of 0V to 3·1V represents the full RH scale. Preset VR2 is used for setting the meter ME1 gain to give 100% RH reading at full-scale, see later "Setting Up''.

REGULATED SUPPLY

The published calibration for the sensor, which we rely on for this project (it's largely what we pay for) assumes an exact 5V supply. This is provided by IC2 which is a low dropout, low quiescent current, regulator designed for battery equipment. The array of capacitors (C1 to C4) on its input and output pins are essential for its stability.

The LM2931 can operate down to 5·2V thus squeezing the last bit of charge from a PP3 type battery. With a total current drain of just 1·4mA the RH Meter should give up to 400 hours service from an alkaline PP3 battery.

Transistor TR1 drives the low battery indicator l.e.d. D1. Its emitter (e) is connected to the 5V stabilised line. But its base (b) is connected to the unregulated 9V supply through a potential divider made up of resistors R6 and R7. With the values shown, the base reaches 0·6V lower than the emitter at about 5·6V from the battery. At this point TR1 turns on and starts to supply l.e.d. current. The increased internal resistance of the battery and the increased current drain results in a sharp end point.

In the prototype the l.e.d. began to light about 10 hours before a final rapid drop in meter reading and shutdown over a few minutes. This gives sufficient warning that the battery needs changing whilst maintaining an accurate reading.

CONSTRUCTION

The RH Meter is built on a small "surface mount'' printed circuit board and the component layout is shown twice-size in Fig.4 for clarity. A full-size (1 to 1) copper foil master pattern is also included in this diagram. Note that the components are mounted directly on the copper pads.

The construction method described here uses surface mount components (SMDs) and some care is needed, particularly with the i.c. leads, when soldering them in place. Although not essential, the application of a non reactive flux pen to the p.c.b. before placement of the SMDs will ensure good solder wetting.

A simple method of placing chip components is to solder one end first. Align the component on the pads and hold it in place by gently pressing it onto the pads. One end can now be soldered to fix it in place. The second end can then be soldered with ease.

Try to use minimal solder and in fact to remove any excess with a solderwick. Minimal solder reduces stress on the chip, which is particularly important for chip capacitors. Particular care should be taken with the high value ceramic capacitors C2 and C3. They can easily crack and the end contacts can detach.

The component marked RX is a zero ohm jumper which is used here for neatness. These devices are used in mass production for minimal inductance which is not important in this application. A low value resistor, less than 10 ohms, could be used or even a wire link for the non-perfectionist.

The two i.c.s can be soldered by fixing pins 1 and 8 first. Pin 1 can be marked on the SO8 i.c. package in several ways,

COMPONENTS

See SHOP TALK page

Resistors

R1, R4	1k (2 off)
R2, R3	33k (2 off)
R5	470Ω
R6	8k2
R7	18k
R8	100Ω
Rx	zero ohm jumper or wire link (see text)

All SM case size 1206

Potentiometers

VR1, VR3	10k (2 off)
VR2	100k

All SM min. preset type 3204 (4mm)

Capacitors

C1	33μ SM tantalum, 16V
C2	470n SM ceramic, case size 1206
C3	100n SM ceramic, case size 1206
C4	10μ SM tantalum, 16V

Semiconductors

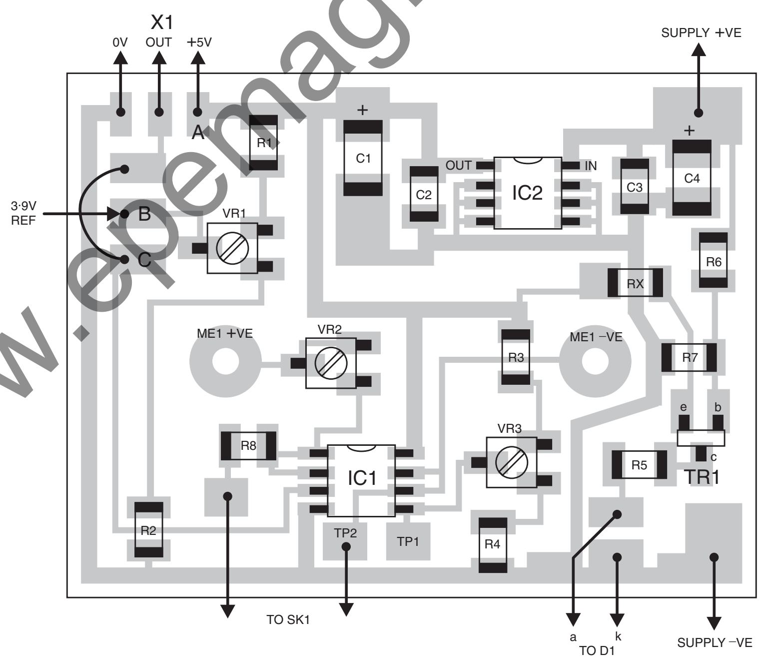
D1	3mm red l.e.d.
TR1	BCX71H *pnp* transistor, SM case SOT23
IC1	LM2904 dual op.amp SM case size SO8
IC2	LM2931 5V regulator SM case size SO8
X1	HIH3605-A capacitive RH sensor

Miscellaneous

S1	s.p.d.t. sub-min. slide switch
SK1	phono socket, chassis mounting
ME1	100μA moving coil panel meter, calibrated 0 to 100, with 60mm x 46mm face
B1	9V battery, with PP3 type connector lead

Printed circuit board available from the *EPE PCB Service*, code 338; plastic case, with brass-threaded inserts for lid, size 79mm x 61mm x 40mm approx.; 3-pin in-line socket for RH sensor; 10mm x 10mm x 1mm thick aluminium angle bracket; multistrand connecting wire; solder etc.

Approx. Cost Guidance Only **£29** *excluding meter & batt.*



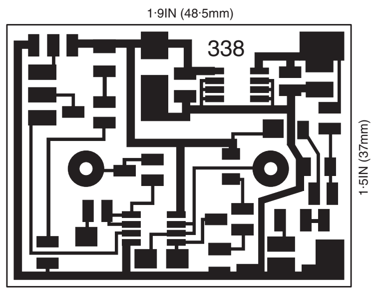


Fig.4. RH Meter surface-mount printed circuit board component layout shown twice full-size for clarity. The full-size master pattern is shown on the right.

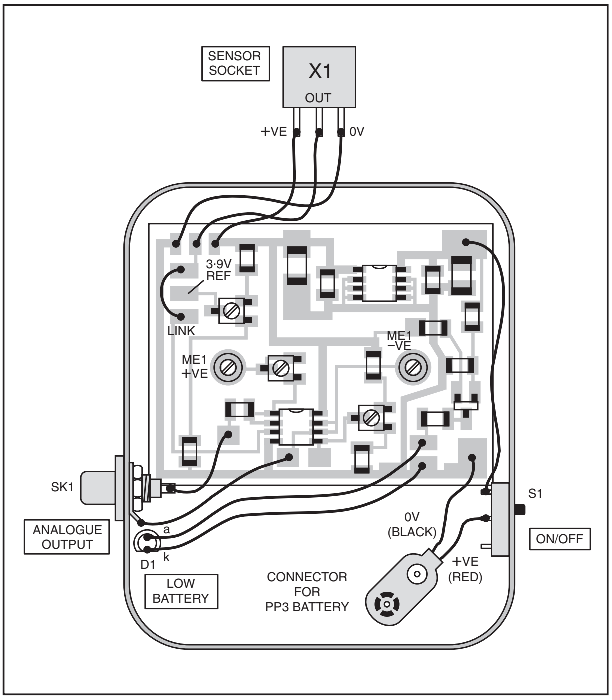
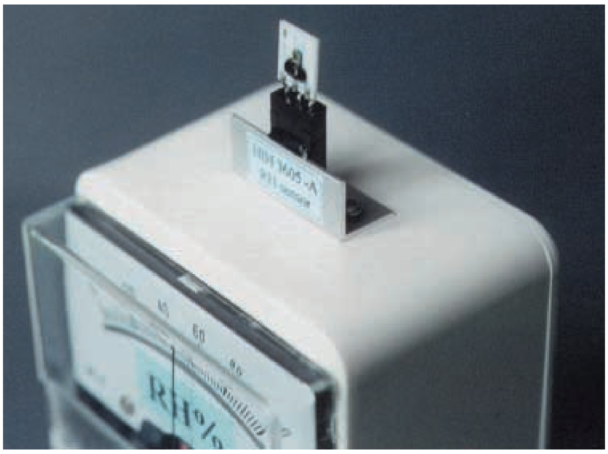


Fig.5. Interwiring from the circuit board to off-board components.



(Above). The sensor plugged into its socket on the top of the meter case.

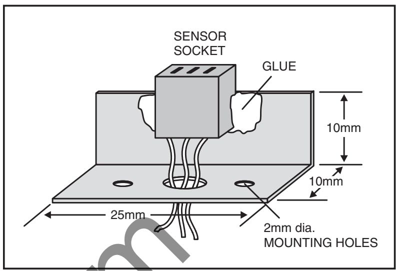


Fig.6 (right). Details of the sensor mounting bracket.

usually by a light band across the pin 1 end. Most SO packages also have a chamfered edge along the pin 1 side. The i.c. pins are very close and a magnifier will be a help to check for any solder bridges.

Transistor TR1 also needs care as the SOT23 case is quite small and any magnetism of the tweezers is quite a nuisance.

FINAL ASSEMBLY

The p.c.b. conveniently fits onto the back of the 100μA moving coil meter, MEl. The 3mm bolts hold the p.c.b. in place and electrically connect the meter to the circuit. The meter suggested is a very common type with 26mm spacing. If a different meter is preferred, the connection can be made by soldering leads from the meter to the circular p.c.b. pads.

Select a project box (prototype size approx. 79mm × 61mm × 40mm) with metal screw holes for the lid rather than self-tap types as regular access is required for changing the battery. A small piece of sponge on the inside of the lid can be used to hold the battery in place.

The positioning of the off-board components within the plastic case should be finalised and the box drilled out to take these parts. You will need to drill a series of small holes around the required meter cutout and the jagged edges around the resulting larger hole should be smoothed down with a file. The components can now be mounted on the case; the prototype model layout is shown in the photographs.

Prototype model showing general layout inside case.

The interwiring inside the case is shown in Fig.5. The battery condition l.e.d. D1, output socket SK1 and the On-Off switch S1 are all readily accessible and can be wired up after the p.c.b. is fixed in place.

SENSOR

The meter reads up to 100%RH and it is easy to get to this reading in various circumstances. But for extended periods it is probably not so good for the ink-jet decoration on the case, not to mention condensation on the p.c.b.

Monitoring high RH inside test chambers, animal cages and so-on is best done by extending the sensor probe with a 3-way lead. The recommended HIH3605-A sensor comes in a 0·1inch pitch, 3-pin single-in-line (SIL) format. It can be plugged-in or soldered. If a socket is used, it is easy to add a small extension lead when required.

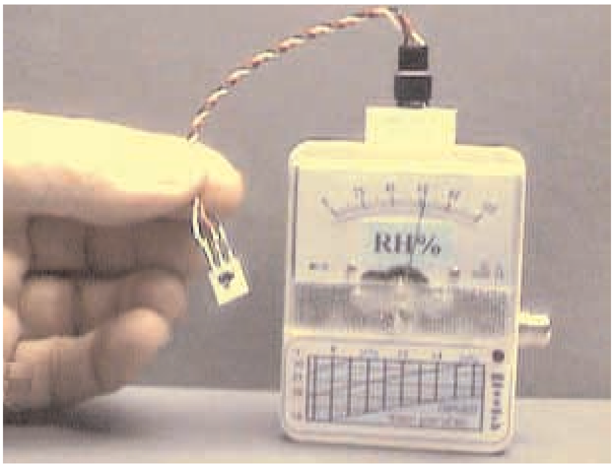
Suitable 0·1in. pitch pre-wired plugs and sockets can be selected from the popular Futaba and other makes used for model radio control work. These are widely available from model shops. It is convenient to cut the socket along with a short length of lead from a ready-made extension. Choose a socket which makes a tight fit.

Run the sensor wires from the circuit board through a small hole in the case "top" to the sensor SIL socket. The socket can be fixed to a short length of 1mm thick, 10mm × 10mm, aluminium angle bracket using rapid setting epoxy, as shown in Fig.6. This bracket can be fixed to the case with two 2mm bolts, see photographs.

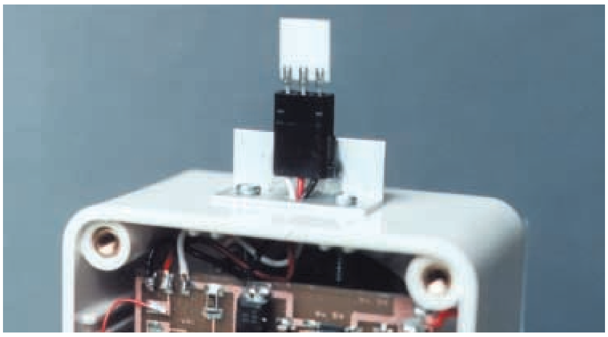
The data sheet suggests that the HIH3605 capacitive humidity sensor is light sensitive. In practice this means direct sunlight. The naked sensor seems insensitive to changes at normal room light levels.

Moving it into weak sunlight from a window causes a small increase in indicated RH%. But bright summer sunlight causes a sudden switch-off. For these conditions therefore, a shield should be made and a black or even translucent 35mm film-tub is ideal. Drill several holes in the cover to ensure good air circulation yet provide shade from direct light.

Finally, the decorative graph, Fig.7, gives useful information on RH, temperature and air moisture content. The RH sensor output pin should not be connected to the p.c.b. meter input, pad C, until the calibration sequence has been completed.



Using an extension lead for non-friendly environments.



Sensor socket glued to the mounting bracket.

SETTING UP

After a really close check on the wiring, the supply current should be checked on first switch-on. There is some spread in the i.c. current drain specifications but the total current should be around 1·4mA.

The first operation is to set the 0·80V reference. Connect a good quality high impedance voltmeter between the test point TP1 on the circuit schematic, which is the VR3 slider, and the 0V (battery –ve) line. Using a small well-fitting screwdriver adjust preset VR3 until the voltmeter reads exactly 0·80V. This should be very simple to achieve if the preset is in good mechanical condition.

Miniature presets like the specified type 3204 have a limited number of reset cycles before the moving contact works loose and the "resistor" value changes a little. Once it is set, VR3 should not need further adjustment. If IC1 operation is correct, this 0·80V reference should appear at IClb output pin 7, which is marked as TP2 on the circuit. This is also a check on the voltmeter and whether it is loading the potential divider chain.

To set meter ME1 to full-scale deflection (f.s.d.) it is necessary to use an accurate 3·9V source. This is provided by the potential divider network around preset VR1 and is available at pad B. Connect the voltmeter between pad B and 0V line and adjust VR1 to give exactly 3·90V, again assuming the test meter does not load the potential source. This should also be stable and need not be set again.

Now solder a temporary link from IC1a input, pad C, to the 3·9V Ref, pad B. This 3·9V signal represents 100% RH and meter ME1 f.s.d. should now be set to 100% using preset VR2.

Moving coil meters require the mechanical zero, on the face of the meter, to be set. Present day meters can be a bit marginal in quality and this adjustment may need to be repeated. This adjustment must be made with the meter held in the vertical position as the makers seem to have lost the art of balancing the meter movement.

Similarly the readings should also be made with the meter vertical. The temporary link from pad C to B can now be removed and the sensor X1 output pin connected to the meter input, pad C. If a meter with a 0 to 100 calibration is used the RH Meter should now be reading the ambient humidity in RH%.

IN USE

Given the many variables, including the analogue output meter mechanics and settling down time, the RH Meter should easily read the actual RH to within a 5 per cent band. The moving coil meter graduations are at 2% intervals so small relative values can be tracked. This is a very small change in RH terms and is more than adequate for most purposes.

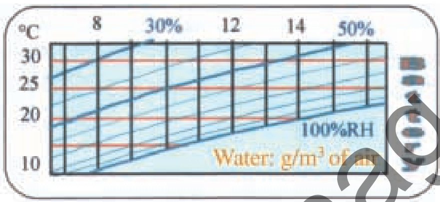


Fig.7. Room temperature RH graph for mounting on the meter case.

Determining absolute RH more accurately than this gets difficult. Individually certified versions of the sensor can be obtained for scientific and close-in control purposes. The fact that the manufacturers can do this is a good indication of the excellent quality and reliability of HIH series technology. Taking the output to a PC using a DAC will allow much smaller changes, from around 1%RH up to the full 100% RH range to be investigated with almost perfect linearity.

To check the operation of the RH Meter and underline our confidence in the calibration it is useful to check the operation. A few simple experiments will get you started in the world of RH.

The sensor is described as chemically resistant and durable in harsh environments. However, it is suggested that the sensing area is treated with care and not handled directly.

The first test is to put a finger tip up close to the sensor, not actually touching it. After a second or so the reading usually rises by about 10% from the body's near-skin humidity. Breathing on the sensor will drive it to about 80%RH, the normal RH of the breath. However, getting in close will drive the reading up to 100% due to condensation as when breathing on a mirror. The meter will stay at 100% for several seconds and will then drop back to the original reading.

Prolonged exposure to such high humidity or contact of the sensor with liquid water for any length of time, results in a temporary 3% shift in the RH reading. In this case the sensor will need to recondition over 30 minutes or more.

The RH of air reduces if the temperature is increased. An example of this is the air flowing through a computer monitor or TV. On a humid day when the ambient humidity was 70% the warm air from the monitor was reading 40%RH. Another example of reducing RH consisted of blowing air from a hair dryer in a room where the ambient RH was 65%. In this case the warmed air passing through the dryer dropped to about 25%RH.

Again a few minutes is needed for the reading to get back to the ambient value. If the sensor itself is warmed it will momentarily loose heat to the air within a couple of millimetres of the sensor reducing its RH.

This kind of experiment soon gives the user a feel for response times, re-settling times and other sources of error. There are many charts available linking RH, moisture content and temperature depending on the particular end use. The small chart shown in Fig.7, and suggested as a decoration for the meter front panel, is useful for getting a general view of the relationship between RH and moisture over typical room temperatures. □