humidity sensor

Somewhat surprisingly perhaps, detecting humidity by electronic means involves a great deal more than meets the eye. In fact, until recently, the few reliable devices that were available were too complex and therefore too expensive for widespread use. The German company, Valvo, recently released details of a capacitive humidity sensor that, inspite of what might be expected from unsophisticated circuitry and low cost, has many advantages. It can be incorporated directly into an electrical measuring circuit, will serve a variety of purposes and is easier to operate, maintain and calibrate than its mechanical counterparts. Not only will it detect humidity in the home, but also in greenhouses or tumble dryers.

Before dealing with the circuit itself, it will be as well to define humidity as such. What is known as the *absolute* humidity is the number of grammes of water per cubic metre of air at a certain temperature. The absolute or maximum relative humidity is exceeded when the atmosphere absorbs greater quantities of water, thereby becoming saturated or 'damp'. How much water is absorbed depends on the ambient temperature of the atmosphere. To give an example, living room windows tend to 'steam up' in winter time, as contact with the outside air makes them much colder in comparison with the room temperature. The amount of moisture in the air is expressed in terms of *relative* humidity. This is calculated by dividing the actual amount of water in the air by the maximum quantity at the same temperature and then multiplying the result by 100%. The relative humidity must be between 40 and 70% for plants, pets and persons to breathe comfortably and so it is important to maintain it at an optimum level. Excessive humidity will cause metals to rust and wood to rot.

For the above reasons, the sensor is designed to respond to changes in the ambient relative humidity. Figure 1 shows that the system consists of a perforated plastic case containing a stretched membrane of non-conducting foil, coated on both sides with gold. The membrane and coating form the dielectric and electrodes respectively of a parallel plate capacitor. As illustrated in the graph in figure 2 the capacitance C_S is determined by the degree of ambient relative humidity H_{rel}. This is because the layer of gold is thin enough to allow moisture to penetrate through to the dielectric, in other words, an increase in humidity will cause the capacitance to rise.

The sensor is reliable within a 10% . . . 90% humidity range. Outside these limits the sensor will have a nominal accuracy of only 5%. However, such levels should only occur in extreme cases.

The measuring circuit

Before dealing with the circuit diagram, the principle behind the operation must be considered. This is shown in figure 3. As can be seen, operation is based on the measurement of pulse width variations. The block diagram shows two synchronized multivibrators M1 and M2, which are connected to a trimmer capacitor C_T and to the

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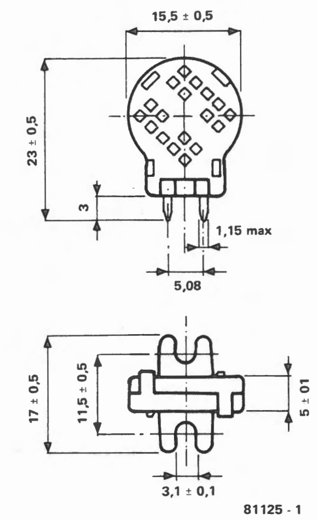

Figure 1. The capacitive humidity sensor as designed by Valvo and its dimensions in mm.

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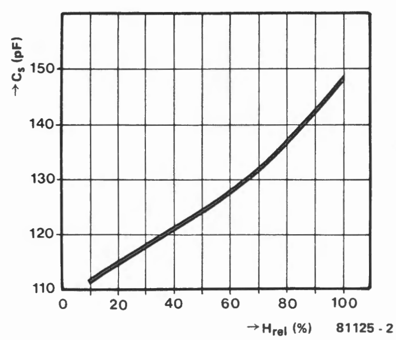

Figure 2. The relationship between relative humidity H_{rel} and sensor capacitance C_S.

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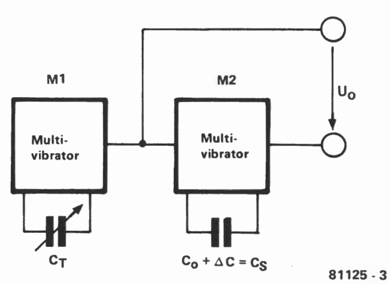

Figure 3. The block diagram of the measuring circuit.

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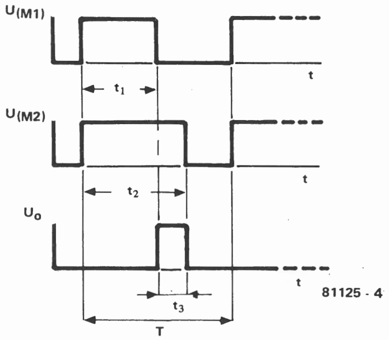

Figure 4. How pulses are formed in the circuit of figure 3. The pulse width determines the degree of humidity H_{rel}.

humidity sensor of capacitance C_s, respectively. The latter comprises a constant contribution C_o and a contribution ΔC dependent on H_{rel}, in other words

$C_s = C_o + \Delta C$.

M1 and M2 produces pulses, t1 and t2 in length, which are proportional to C_T and C_s respectively (see figure 4). What happens is that M1 synchronizes M2, so that the pulse width difference t3 is equal to t2-t1. The length of the pulse width t3 therefore determines the degree of ambient humidity H_{rel}. Thus, if t3 is fairly short, the atmosphere will only be slightly humid, whereas a lengthy t3 would mean a high degree of humidity (as in a botanical garden, for instance).

If M1 and M2 have equal proportional constants and C_T is equal to C_o, t3 will be proportional to ΔC. If the pulse frequency is set at 1/T, where $T = 2t_1$ (figure 4) and all pulses have equal amplitude U_B, then the average output voltage will be:

$\overline{U}_o = (t3/T)\ U_B = (\Delta C/2\ C_o)\ U_B$.

The term t3/T is called the relative pulse width. Its temperature and voltage dependence are very small, provided:

- the characteristics of both multivibrators are identical (constructed for example from a single 4001);
- C_s and C_T have equal temperature coefficents.

Output voltage $\overline{U}_o$ is directly related to the supply voltage which should therefore be stabilized to obtain the best results.

Practical circuit

A design based upon two 4001 IC's is shown in figure 5. The circuit may be either battery or mains powered, depending upon its application.

Multivibrators M1 and M2 are each formed by a pair of NOR gates in the first 4001. 10 kHz pulses produced by M1 and M2 are fed to the second 4001. This generates a pulsed-output voltage with an average value $\overline{U}_o$ proportional to the pulse width difference. The four NOR gates of this IC are connected in parallel to provide low output impedance. Any parasitic oscillations in the circuit will be suppressed by an RC network in the supply line (C5, C6, R3).

Linearizing network

Since the relation between C_s and H_{rel} is non-linear, the pulsed output signal $\overline{U}_o$ is fed to a linearizing network. For clarity's sake this is shown separately in figure 6. Voltage pulses charge capacitor C7 by way of diode D1 and resistor P1. At the same time a discharge current in proportion to the voltage across the capacitor flows through resistors R4 and R5, and an additional current flows from the supply line via resistor R6. Thus, the output voltage U'_o is a non-linear function U_o and with suitable choice of C7, P1 and R4, R5, this function can be profiled to allow the relationship between H_{rel} and U'_o to be substantially linear.

With respect to the circuit in figure 5, the output voltage can vary between 80 mV and 1 V. This can be used either to indicate or to control relative humidity (H_{rel}).

Tumble dryer control

As we mentioned before, the humidity

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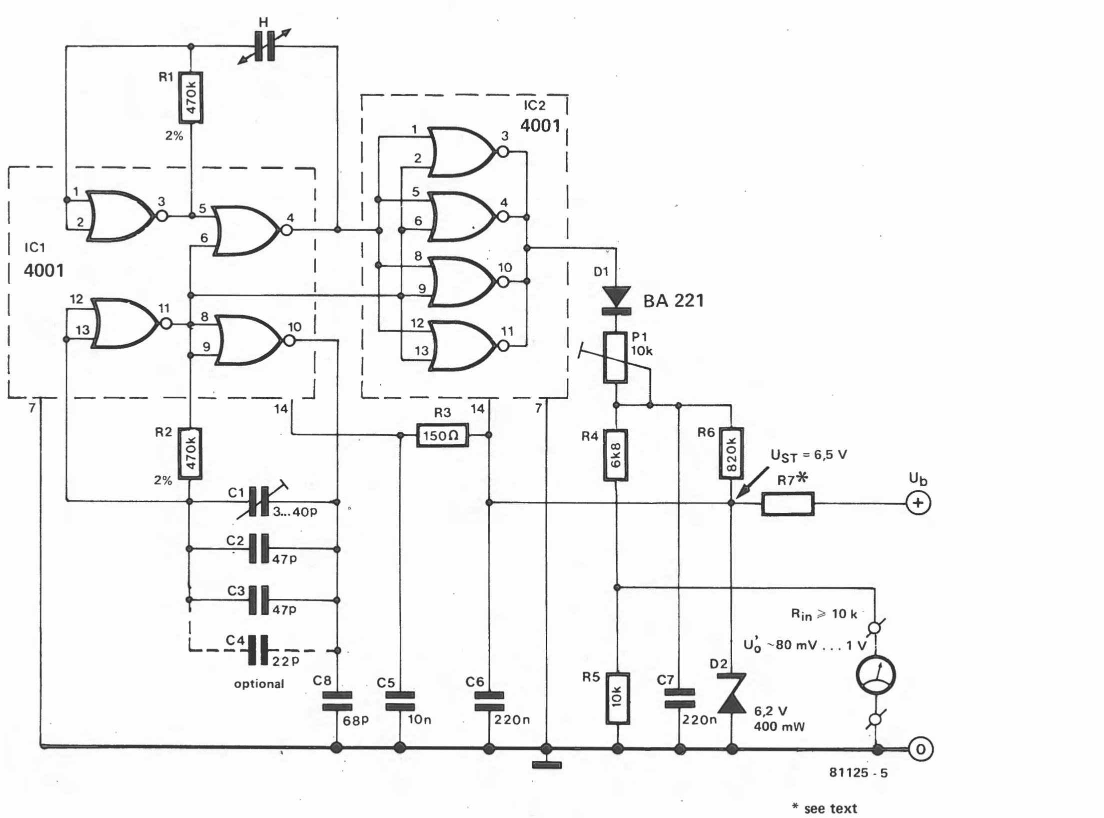

Figure 5. The measuring circuit with linearized output. The circuit can be connected to an external power supply. R7 is chosen so that R7 ≈ (U_B - U_{ST})/2 mA Ω.

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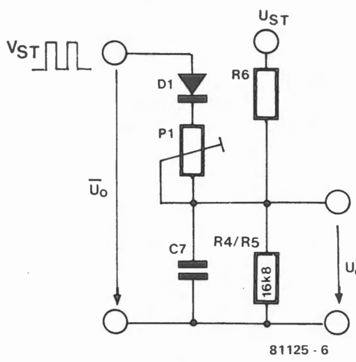

Figure 6. The linearizing network used in figure 5.

indicator may serve a variety of purposes. Let us therefore see what happens in the case of a tumble dryer.

A tumble dryer operates by heating a damp load whilst tumbling it slowly in a rotating drum. The H_{rel} at the air outlet provides a reasonable indication of how damp the load is. The measuring circuit described above can be made to control the dryer, switching it off as soon as the load has reached a certain (preset) level of dryness.

The circuit operates by comparing U'_o with a constant voltage, in this instance a preset voltage that corresponds to the required level of H_{rel} (in other words, the level indicating a dry load).

The humidity sensor is situated in the air outlet of the dryer and an NTC thermistor is located in the drum. The thermistor is used to control the air

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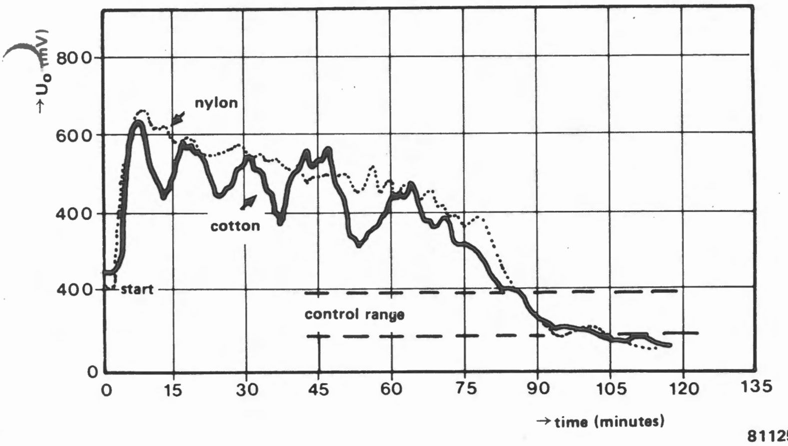

Figure 7. What happens during the tumble dryer control operation. The relative humidity in the tumble dryer falls as the load dries. The curves here relate to a fully loaded standard dryer as used in the home.

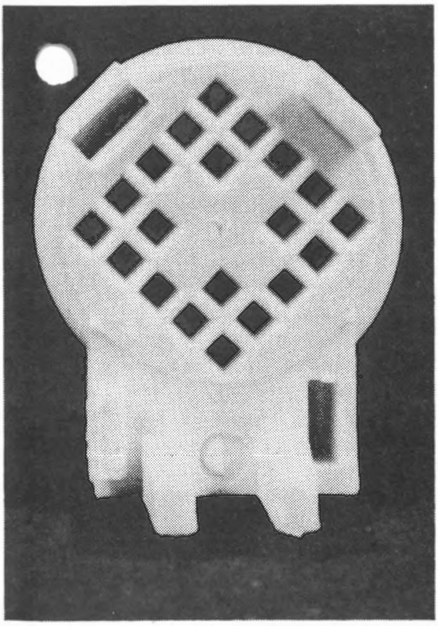

Photo 1. The humidity sensor as manufactured by Philips.

temperature within the drum. When this exceeds 60°C the heater will be switched off and when it drops below 50°C the heater will be switched back on again. The on/off switch is door-operated so that drying starts the moment the door is closed and stops whenever it is opened.

The relative humidity will obviously rise when a damp load is inserted. It must, however, be prevented from rising to such a extent that the dryer is activated. For this reason a delay circuit is included to hold U'_o above the preset voltage for about 2 minutes after the door is closed. The dryer can then start and run for sufficient time for the humidity at the outlet to rise above the preset value, after which the humidity sensor will control the operation.

Figure 7 shows how the relative humidity at the air outlet varies with time. It increases as soon as the motor starts, then gradually falls until the load reaches the required level of dryness and the dryer switches off.

Source: Technical information 063, Valvo Ltd.