13.2 Capacitive Sensors

An air-filled capacitor may serve as a relative humidity sensor because moisture in the atmosphere changes air electrical permitivity according to the following equation [5]:

$$\kappa = 1 + \frac{211}{T}\left(P + \frac{48P_s}{T}H\right)10^{-6} \tag{13.5}$$

where T is the absolute temperature (in K), P is the pressure of moist air (in mm Hg), P_s is the pressure of saturated water vapor at temperature T (in mm Hg), H is the relative humidity (in %). Equation (13.5) shows that the dielectric constant of moist air and, therefore, the capacitance are proportional to the relative humidity.

Instead of air, the space between the capacitor plates can be filled with an appropriate isolator whose dielectric constant changes significantly upon being subjected to humidity. The capacitive sensor may be formed of a hygroscopic polymer film with metallized electrodes deposited on the opposite sides. In one design [6], the dielectric was composed of a hygrophilic polymer thin film (8–12 μm thick) made of cellulose acetate butyrate and the dimetylephtalate as plasticizer. The size of the film sensor is 12 × 12 mm. The 8-mm-diameter gold porous disk electrodes (200 Å thick) were deposited on the polymer by vacuum deposition. The film was suspended by a holder and the electrodes were connected to the terminals. The capacitance of such a sensor is approximately proportional to relative humidity H

$$C_h \approx C_0(1 + \alpha_h H), \tag{13.6}$$

where C_0 is the capacitance at $H = 0$.

For the use with capacitive sensors, a 2% accuracy in the range from 5% to 90% RH can be achieved with a simple circuit as shown in Fig. 13.1. The sensor and the circuit transfer characteristics are shown in Fig. 13.2. The sensor's nominal capacitance at 75% RH is 500 pF. It has a quasilinear transfer function with the offset at zero humidity of about 370 pF and a slope of 1.7 pF/% RH. The circuit effectively performs two functions: makes a capacitance-to-voltage conversion and subtracts the offset capacitance to produce an output voltage with zero intercept. The heart of the circuit is a self-clocking analog switch LT1043, which multiplexes several capacitors at the summing junction (virtual ground) of the operational amplifier U_1. The capacitor C_1 is for the offset capacitance subtraction, whereas the capacitor C_2 is connected in series with the capacitive sensor S_1. The average voltage across the sensor must be zero; otherwise, electrochemical migration could damage it permanently. The nonpolarized capacitor C_2 protects the sensor against building up any dc charge. Trimpot P_2 adjusts the amount of charge delivered to the sensor and P_1 trims the offset charge which is subtracted from the sensor. The net charge is integrated with the help of the feedback capacitor C_3. Capacitor C_4 maintains the dc output when the summing junction is disconnected from the sensor.

A similar technique can be used for measuring moisture in material samples [7]. Figure 13.3 shows a block diagram of the capacitive measurement system where the dielectric constant of the sample changes the frequency of the oscillator. This method