Deney 2 Nem Sensörleri

Chapter 7

HUMIDITY SENSOR

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7.1 OBJECTIVES

1. Study the classification of humidity sensors.
2. Study the construction and characteristic of humidity sensors.
3. Study the application of humidity sensors.

7.2 DISCUSSION OF FUNDAMENTALS

Humidity sensors are used for absolute and relative humidity, and dew point measurements. Before proceeding with the principle of sensor, it is useful to classify humidity sensors into seven categories, as either electrolytic; macromolecule; ceramic; oscillating-crystal; semiconductor, thick-film; and dew point sensors. This classification is based on the construction of sensor.

7.2.1 Constructions and principles of humidity sensors

1. Electrolytic Humidity Sensor

   Electrolytic humidity sensors were developed in 1938. Figure 7-1 shows the construction of an electrolytic humidity sensor. The bifilar palladium (Pd) electrodes are wound on a polystyrene cylinder and a hygroscopic film consists of a mixture of a 0.25 to 12.2% aqueous solution of lithium chloride (LiCl) with polyvinyl acetate. When the hygroscopic film is humidified, the impedance between two electrodes will be reduced due to the positive lithium ions move actively. As a result, the impedance change of the electrodes due to a change in humidity could be measured.

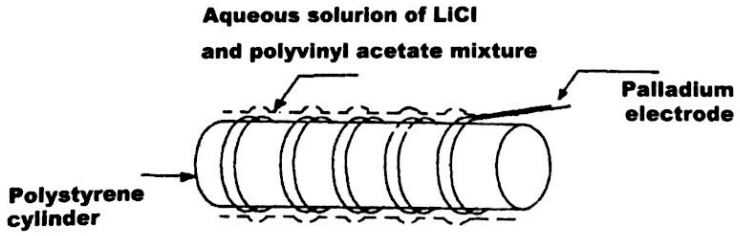


Figure 7-1 The construction of electrolytic humidity sensor

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The amount of LiCl in the hygroscopic film will determine the humidity sensing range of an electrolytic humidity sensor. Characteristic curves of electrolytic humidity sensors with varying levels of LiCl in their hygroscopic film are shown in Figure 7-2. As we can see from the curves, these sensors have very narrow sensing range of approximately 30%RH.

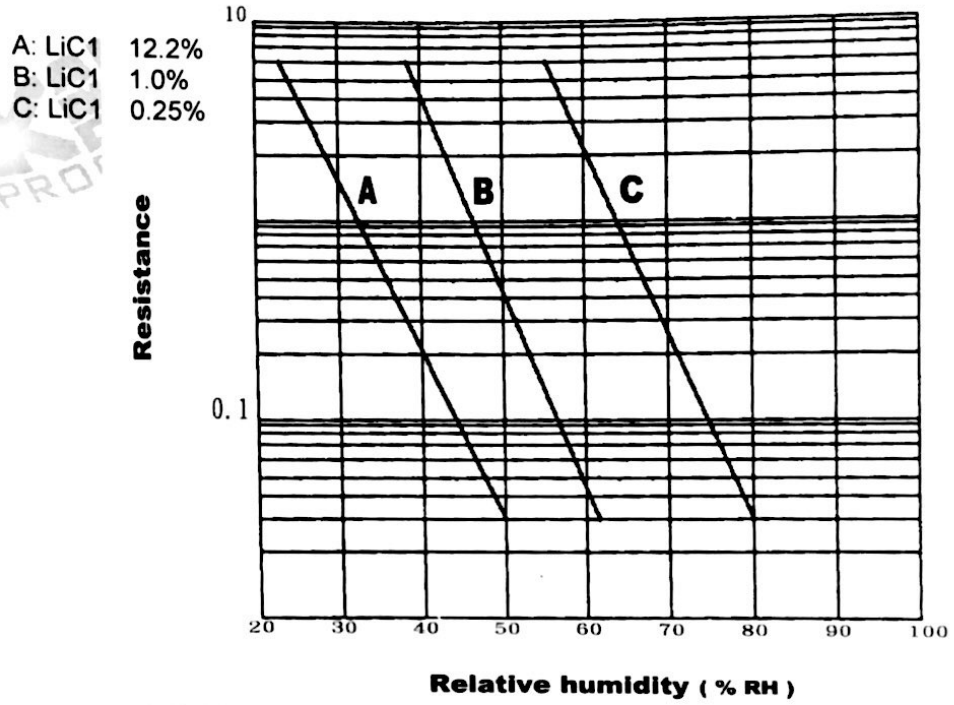


Figure 7-2 Characteristics of electrolytic humidity sensors

2. Macromolecule Humidity Sensor

Macromolecule humidity sensors are generally classified into capacitive and resistance types. Capacitive elements operate on the fixed-electrode/variable -electrode principle. In the example illustrated in Figure 7-3, a hygroscopic macromolecule film is the dielectric between the two electrodes on the bottom and the electrode on top. The top electrode is porous so that it can admit water into the film. The hygroscopic film changes its dielectric characteristics and hence varies the capacitance between the top electrode and one bottom electrode and between the top electrode and the other bottom electrode. This results in a net change in capacitance between the two bottom electrodes.

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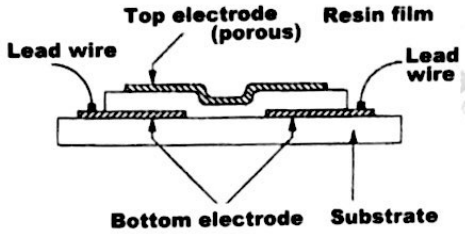


Figure 7-3 Macromolecule humidity sensor (capacitive type)

Figure 7-4 shows the construction of a resistive element. Two comb electrodes are deposited on an alumina substrate and then a polyvinyl alcohol film on the surface acts as a hygroscopic film.

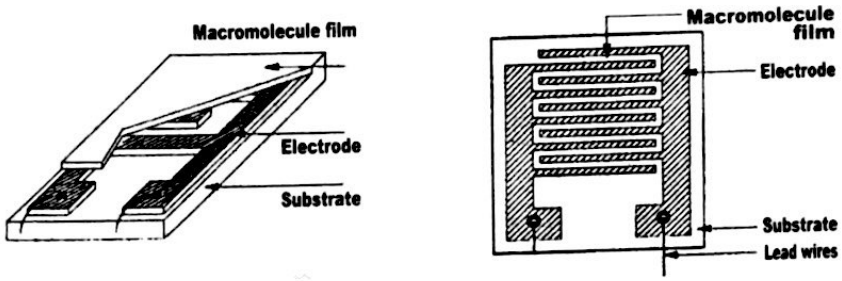


Figure 7-4 Macromolecule humidity sensor (resistive type)

The characteristic of resistive macromolecule element is shown in Figure 7-5. The hysteresis between humidified and dehumidified processes is approximately within 2%.

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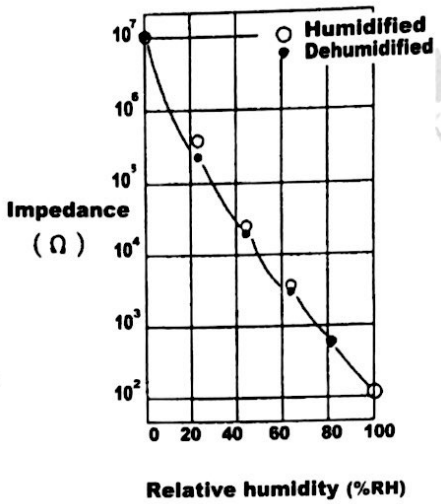


Figure 7-5 Characteristic of resistive macromolecule humidity sensor

3. Ceramic Humidity Sensor

Ceramic humidity sensors are also called metal-oxide humidity sensors. Hygroscopic materials are generally formed by applying pressure to metal-oxide powders and converting into porous ceramic materials, as shown in Figure 7-6. The number of water molecules absorbed on the oxide structure determines the change of the element.

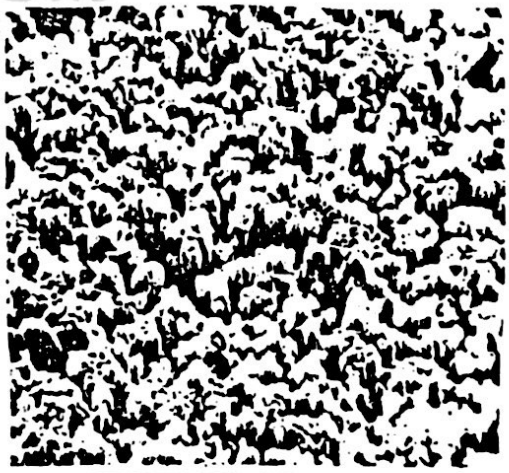


Figure 7-6 Porous ceramic structure (Magnification: X240000)

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Ceramic humidity sensors based on the preceding principles are classified into heating and unheated types. The heating type shown in Figure 7-7 consists of heating, sensing and substrate sections. The hygroscopic material is porous structure made of $Mg.Cr_2O_4$-TiO_2 oxide. Two Pt-Ir wires connect two RuO2 electrodes deposited on the surfaces of hygroscopic film. The heating material is made of Kanthal alloy. Heating and sensing sections are installed on the substrate of Al_2O_3.

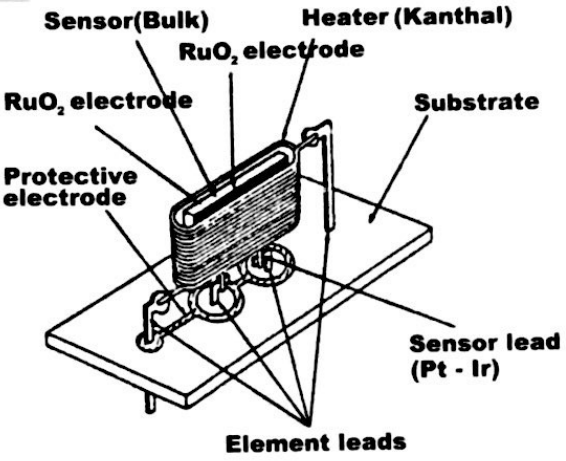


Figure 7-7 Construction of ceramic humidity sensor

The characteristic of ceramic humidity sensors is shown in Figure 7-8. The hygroscopic materials, types I and II are different so that the sensitivity of type I is higher in the low humidity range while type II is nearly linear.

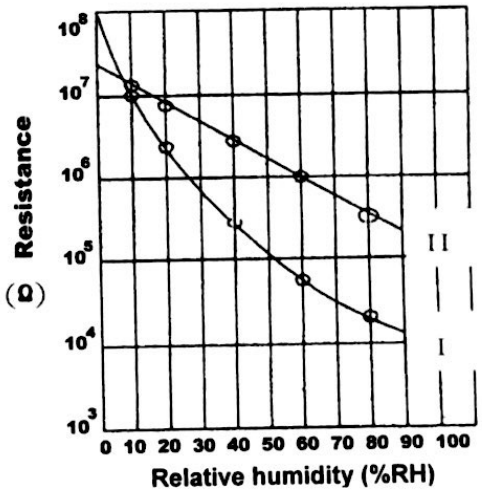


Figure 7-8 Characteristic of ceramic humidity sensor

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4. Oscillating-Crystal Humidity Sensor

Crystals are piezoelectric materials. The oscillating frequency of a crystal is determined by its frequency constant (Hz-m). When a crystal absorbs water molecules, a change in its density will cause a change in oscillating frequency. Figure 7-9 shows the construction of crystal humidity sensor. The hygroscopic film is a polyamide resin film.

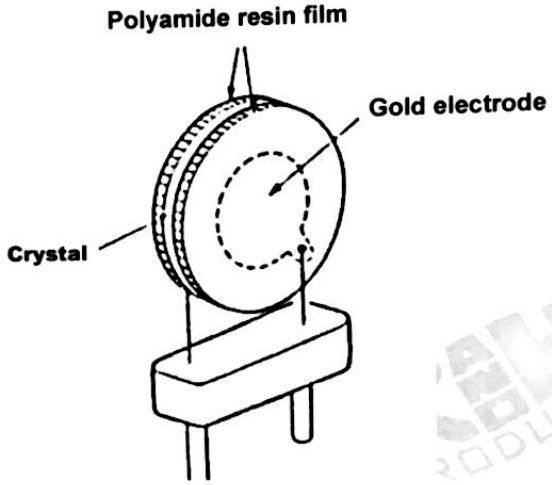


Figure 7-9 Oscillating-crystal humidity sensor construction

Figure 7-10 shows the frequency vs. %RH characteristic of a oscillating-crystal humidity sensor. This sensor has a precision of ±5% and operating frequency at 10 MHz.

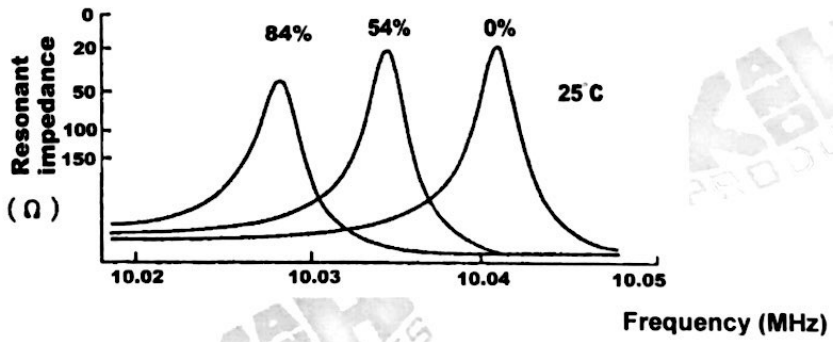


Figure 7-10 Frequency responses

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5. Semiconductor Humidity Sensor

Semiconductor humidity sensors are mostly made of enhanced MOSFETs and humidity-sensitive resin films. This element is called Charge Flow Transistor (CFT) silicon semiconductor as shown in Figure 7-11. The hygroscopic film is a high impedance film of polyamino phenylacetylene (PAPA).

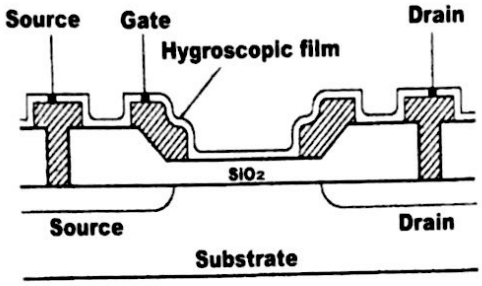


Figure 7-11 Construction of charge flow transistor

When the gate is open, the impedance between source and rain is high and in an open-circuit state (see Figure 7-12(a)). If the gate is closed to a positive potential, the positive charges will diffuse toward the humidity-sensitive film and induced negative charges present in silicon substrate (see Figure 7-12(b)). Hence the impedance between source and drain is low and FET is on (see Figure 7-12(c)). The diffusive ability of positive charges depends on the degree of humidity. The change in impedance is proportional to the change in humidity.

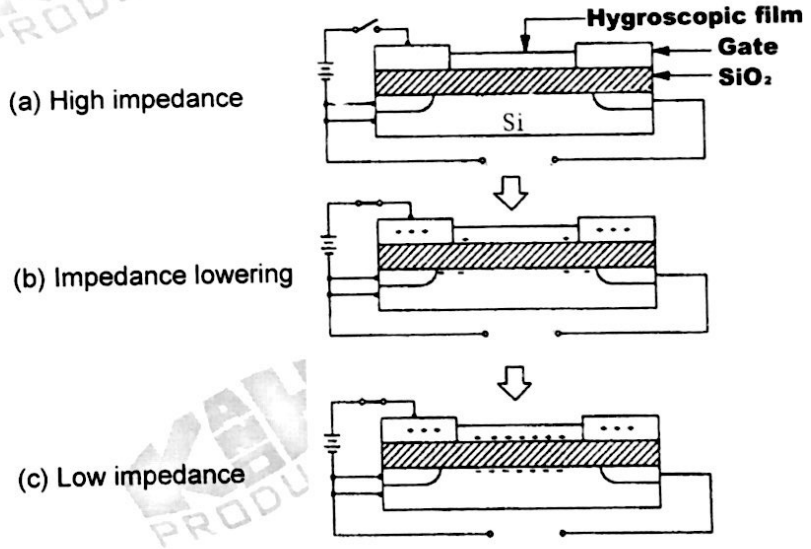


Figure 7-12 Operation of CFT

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6. Thick-Film Humidity Sensor

Thick-film humidity sensors are electric-to-impedance converting sensors, which use thick-film hybrid IC and electron ceramic techniques. Figure 7-13 shows its construction. The two comb electrodes are deposited on the ceramic substrate and a 10μm thick-film hygroscopic layer on the electrodes. Finally, the surface is coated with a porous filter. When the humidity-layer absorbs water vapor, the impedance between the two electrodes reduces due to a increase in the number of hydrogen ion.

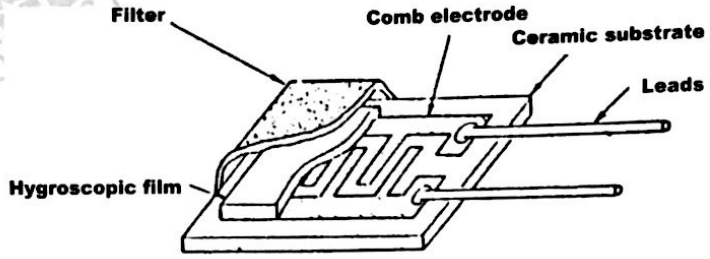


Figure 7-13 Thick-film humidity sensor

The decrease in impedance is inversely exponentially proportional to the increase in relative humidity, Figure 7-14 show the typical characteristic of GH4007-A.

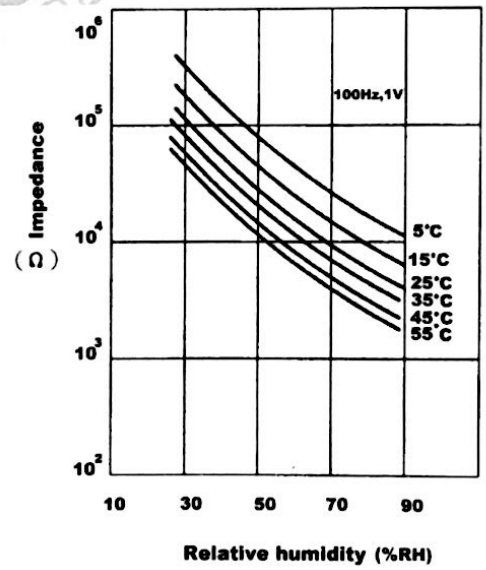


Figure 7-14 Typical characteristic

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7. Dew-Point Humidity Sensor

Figure 7-15 shows a dew-point sensor. The humidity-sensitive film is made of conductive grains and resin. When the film absorbs water vapor, the resistance between the electrodes will increase due to the space between grains enlarged.

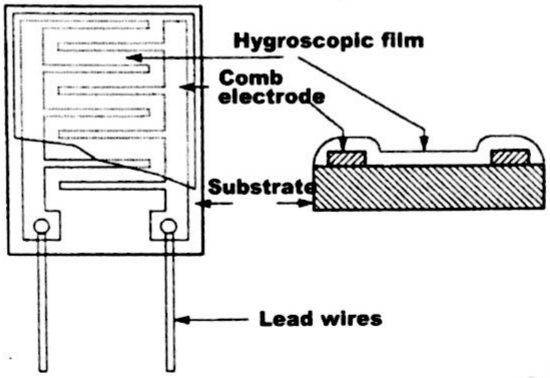


Figure 7-15 Dew-point sensor

Figure 7-16 shows the characteristic of dew-point humidity sensor. When the relative humidity reaches 100%RH, the resistance goes to infinite, called dew point.

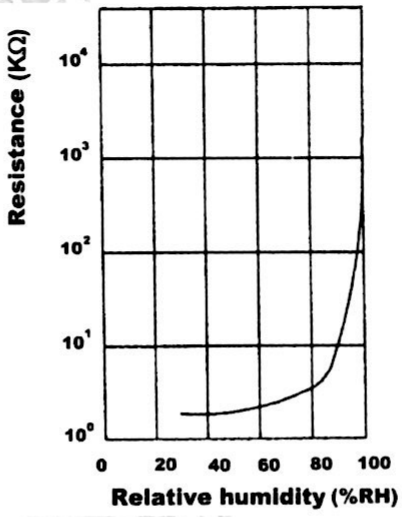


Figure 7-16 Characteristic of dew-point sensor

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7.2.2 Applications of humidity sensors

1. Air-Conditioning Control

Figure 7-17 shows an air-conditioning system. The exciting signal of dehumidifier comes from the output of humidity detector, whereas the exciting signal of the cooling/warming machine comes from the output of temperature detector. Computer controls both of temperature and humidity settings.

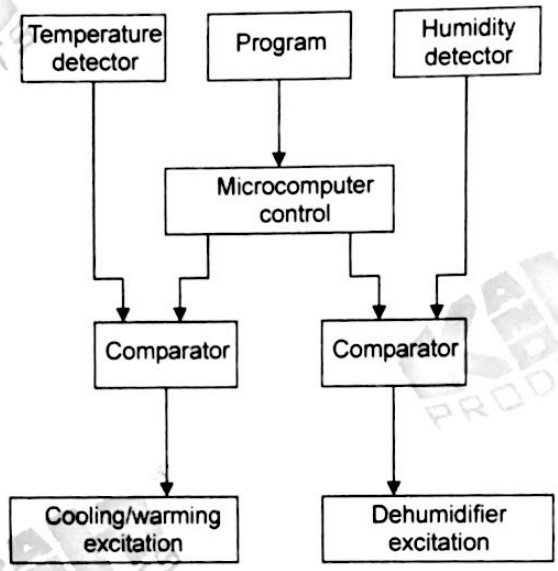


Figure 7-17 Functional diagram of air-conditioning system

2. Humidifier

Functional diagrams of a humidifier are shown in Figure 7-18. The output of pulse generator acts as the excitation source for the humidity sensor. After calibrating temperature, the detected humidity compares to the preset value. If the detected humidity is lower than the preset, the output of comparator will turn on the humidifier.

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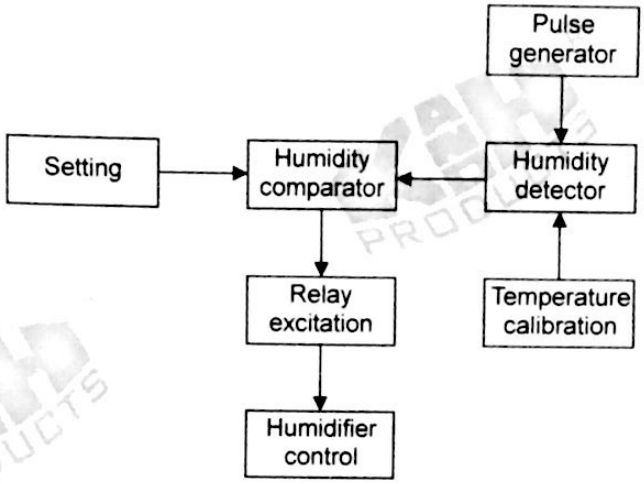
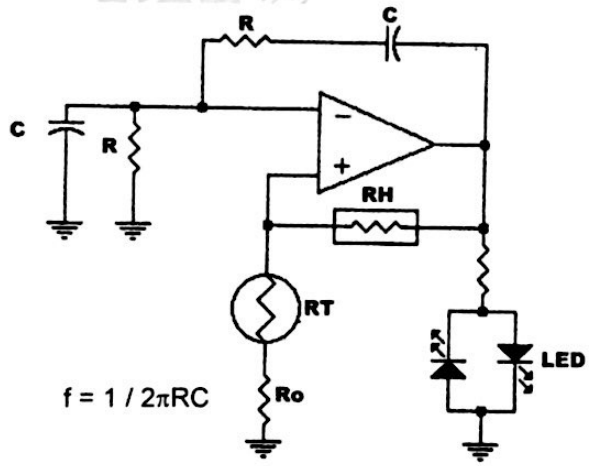


Figure 7-18 Functional diagram of a humidifier

3. Humidity Detector

In Figure 7-19, the humidity sensor RH is a negative-temperature coefficient element. If ambient humidity is lower than the setting, the Wein Bridge starts to oscillating and driving the LED. The resistive temperature sensor RT is used to compensating the characteristic variation of humidity sensor due to the change in temperature.



Oscillating condition

(RH+RT+Ro) / (RT+Ro) >=3

Figure 7-19 Humidity detector

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4. Staged Humidity Detector

Figure 7-20 shows a staged humidity detector. The humidity sensor is excited by an AC signal from oscillator. The sensed signal passes through the voltage follower OPA1 and then D and C2 convert it into a DC voltage applied to the non-inverting inputs of comparators. This DC voltage compares with each reference of comparators and turns on the LED if the DC voltage is higher than the reference.

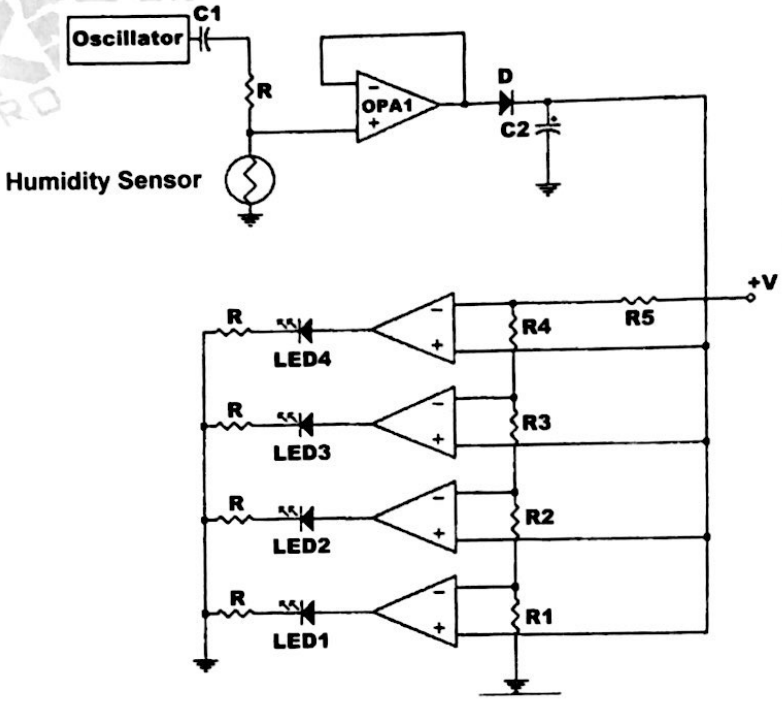


Figure 7-20 Staged humidity detector

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7.3 DESCRIPTION OF EXPERIMENTAL CIRCUITS

7.3.1 Humidity-controlled greenhouse

The circuit of Figure 7-21 is a humidity transducer circuit for this experiment. This circuit consists of two sections:

The first section is an oscillator consisted of U5 and U6.The U6, is a Wein oscillator, which generates a sine wave. The U5 acts as an amplitude limiter to limit the sine wave at 250 Hz and 0.5 Vrms. The second section serves amplification, filtering, and rectification. It consists of U4, C1, and CR2. The magnitude of positive output is proportional to sensed humidity. The R17 is for gain adjustment, the R14 is for zero level calibration and CAL. is for ambient humidity calibration. Figure 7-22 shows the characteristic of humidity sensor.

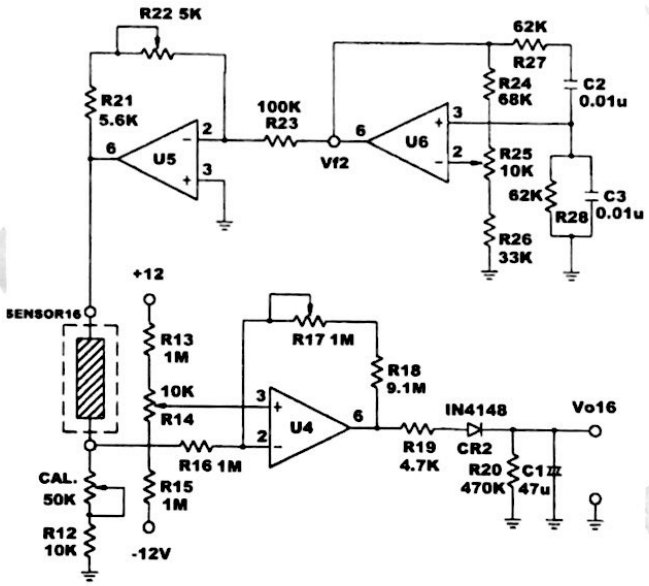


Figure 7-21 Humidity transducer circuit

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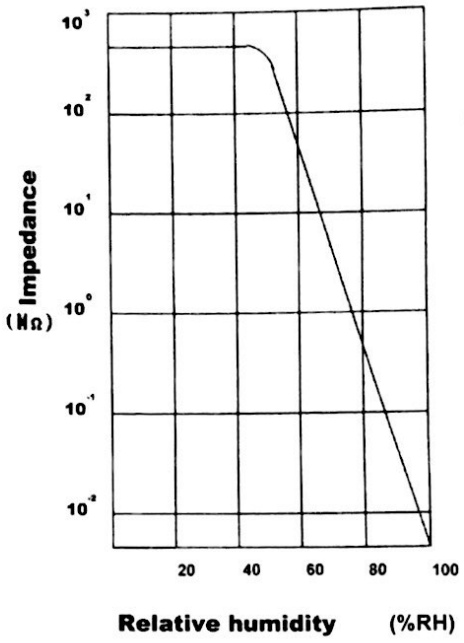


Figure 7-22 Characteristic of C2M3

7.3.2 Hygrometer

In Figure 7-21, we measure the output voltage of Vo16 using DMM or AD converter. Using an AD converter, shift to %RH section the readout represents the value of humidity as follow table. The operating range of C2M3 is from 55 to 100 %RH and a tolerance of ±3 %RH.

DISPLAY	0000	1000	2000	3000	4000	5000
%RH	50%RH	60%RH	70%RH	80%RH	90%RH	100%RH

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7.4 EQUIPMENT REQUIRED

1 - Module KL-64005
2 - KL-61001A Trainer
3 - C2M3 Humidity Sensor
4 - Dual-Trace Oscilloscope(option)
5 - LCR Meter(option)

7.5 EXPERIMENTS AND RECORDS

7.5.1 Basic measurement

1. Set the Humidity Transducer Module KL-64005 Block16 on the Trainer KL-61001A. Supply the power.
2. Using oscilloscope(option), measure and record the signal at Vf2, adjust R25 make waveform max. without distortion.
   f = _____ Hz, Vp-p = _____ V.
3. Using scope, measure and record the signal at SENSOR16.
   f = _____ Hz, Vp-p = _____ V.

7.5.2 Impedance measurement

1. Connect the LCR meter(option) probes to C2M3 lead wires.
2. Set a cup with water. Place C2M3 on the humidity source for Humidified. (Do not let the sensor touch water)
3. Measure the impedance and then record in Table 7-1 at intervals. Refer to the characteristic of C2M3, calculate the ratio of humidity.

Table 7-1

Measurement time	1st	2nd	3rd	4th	5th	6th	7th	8th
Humidified impedance								
Humidity(%RH)								

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4. Set another empty cup. Place C2M3 into the cup for Dehumidified. (Make sure the cup is dry and clean)
5. Measure the impedance and then record in Table 7-2 at intervals. Refer to the characteristic of C2M3, calculate the ratio of humidity.

Table 7-2

Measurement time	1st	2nd	3rd	4th	5th	6th	7th	8th
Dehumidified impedance								
Humidity(%RH)								

7.5.3 Conversion voltage measurement

1. Set the Humidity Transducer Module KL-64005 Block 16 on the Trainer KL-61001A. Supply the power.
2. Zero level calibration: take R16 ground, adjusting R14 to make Vo16 output voltage 0V.
3. Ambient humidity calibration: Connect the HUMIDITY SENSOR leads to SENSOR IN, adjusting CAL. to make Vo16 output voltage 1V.
4. Repeat Step 2 in experiment 7.5.2.
5. Complete Table 7-3.

Table 7-3

Measurement time	1st	2nd	3rd	4th	5th	6th	7th	8th
Vo16(DCV)								
Humidity(%RH)								

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7.5.4 Hygrometer

1. Set the Humidity Transducer Module KL-64005 Block 16 on the Trainer KL-61001A. Supply the power.
2. Repeat steps in experiment 7.5.3.
3. Shift MODE to SENSOR, RANGE to %RH on the trainer KL-61001A, the readout represents the value of humidity as follow table.

DISPLAY	0000	1000	2000	3000	4000	5000
%RH	50%RH	60%RH	70%RH	80%RH	90%RH	100%RH

7.5.5 Computer control

1. Complete the following connections:

SECTION	AREA	SIGNAL	TO SECTION	AREA	SIGNAL
SINGLE CHIP	OUT CONTROL	1	→ AMPLIFIER	ALARM AMPLIFIER	SIN IN
KL-64005	HUMIDITY SENSOR	Vo16	→ A/D CONVERTER	CONTROL	A/D IN
SINGLE CHIP	OUT CONTROL	CTRL	→ A/D CONVERTER	CONTROL	GND

2. Repeat Steps 1, 2 and 3 in experiment 7.5.3.
3. Complete Table 7-4.

Table 7-4

DIP-switch settings	0000 50%RH	0819 60%RH	1639 70%RH	2459 80%RH	3278 90%RH	4095 100%RH
KL-61001A Readout						
OUT CONTROL pin1						
KL-64005 Vo16						

4. Connect the SINGLE CHIP, OUT CONTROL, CTRL to the GND. This step performs the data communications between the transducer circuit and the personal computer via the USB port.
5. Follow the steps for the USB control in experiment 4.5.3.
   (Note: 1V=10%RH)

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