Lecture 10
Humidity Sensing and Flow Sensing
Humidity Sensing
Humidity Sensing

Q: What are we measuring?
A: Water vapor content in air and other gases.

Usually measured as,
1) Absolute humidity (ratio of mass of water vapor to volume of air or gas)
2) Dew point (temperature or pressure at which gas turns into liquid)
3) Relative humidity (ratio of moisture compared to saturated moisture level at the same temp or pressure)

SI Units: % RH, %

Please see: Sound Waves and Sources (1950), https://www.youtube.com/watch?v=Nh6Fig5jkI
Humidity Sensors

**Capacitive Humidity Sensors**

- Sensirion SHT75 - Digital Humidity Sensor
- E+E Elektronik HMC01

**Resistive Humidity Sensor**

- Ohmic Instruments UPS-650
- Aosong HR202L hygristor

**Thermal Conductivity Humidity (Absolute Humidity) Sensor**

- Ohmic Instruments ABS-300
- Honeywell HIH6100 Temperature and Humidity Sensor
Applications of Humidity Sensors

HVAC Systems

Provide precision RH and temperature measurement in air conditioning/air movement systems to maintain low energy consumption, and storage humidity/temperature
Applications of Humidity Sensors

Incubator and NICU

Provide optimal temperature and RH levels to support critical processes
Applications of Humidity Sensors

Weather Station

Provide precision RH and temperature measurement in ground-based and airborne weather stations, allowing real time and highly accurate monitoring/reporting of actual weather conditions.
Applications of Humidity Sensors

Windshield Defoggers

Humidity sensor takes in windshield temperature, air temperature and air humidity to turn the defogger fan on and off.
Applications of Humidity Sensors

Food Processing Plant

Humidity sensors allow measurement of the drying climate to regulate the drying process optimally: food quality can be controlled.
Humidity Sensor Considerations

- Accuracy
- Interchangeability
- Repeatability
- Stability
- Condensation recovery
- Contaminant resistance
- Size and packaging
- Cost effectiveness
- Cost to replace sensor
- Calibration
- Complexity and reliability of signal conditioning and data acquisition circuitry
Types of Humidity Sensors

- Relative Humidity Sensors
  - Capacitive Humidity Sensors
  - Resistive Humidity Sensors

- Absolute Humidity Sensors
  - Thermal Conductivity Sensor
**Capacitive Relative Humidity (RH) Sensor**

**Most Widely Used RH Sensors**

1. Hygroscopic dielectric material sandwiched between a pair of electrodes forms a capacitor.
2. In absence of moisture, the dielectric constant of the hygroscopic dielectric material and the sensor geometry determine the value of capacitance.
3. At normal room temperature, the dielectric constant of water vapor is larger than the dielectric constant of the sensing material.
4. Polymer/Hygroscopic material absorbs water molecules until the vapor content is in equilibrium with the ambient air or gas.
5. Absorption of water vapor by the sensor results in an increase in sensor capacitance.

Diagram: 1 Water vapor permeably electrode, 2 Humidity sensitive polymer, 3 Backplate electrode, 4 Basesubstrat, 5 Pin – capacitive measurement, 6 Pin – temperature measurement.
**Capacitive RH Sensor**

The change in dielectric constant is directly proportional to the humidity.

1. Capacitance is usually between 100 pF-500 pF at 50% RH at 25°C.

2. Typical change in capacitance is 0.2-0.5 pF for 1% RH change.

3. Capacitive RH sensors have low TC (Temperature Coefficient).

4. Can function up to 200°C.

5. Can recover from condensation and resist chemical vapors.

6. Typical response time is 30-60 seconds for about 63% RH change.
Capacitive Relative Humidity Sensor

**Governing Equations**

\[
\kappa = 1 + \frac{211}{T} \left[ P + \frac{48P_S}{T} H \right] 10^{-6}
\]

- \(\kappa\) = dielectric constant
- \(T\) = absolute temperature in Kelvin
- \(P\) = pressure of the moist air in mmHg
- \(P_S\) = pressure of saturated water-vapor at \(T\) in mmHg
- \(H\) = relative humidity in %

\[
C_h \approx C_O \left( 1 + \alpha_h H \right)
\]

- \(C_O\) = capacitance at \(H=0\)
- \(H\) = relative humidity in %
- \(\alpha_h\) = constant related to dielectric constant and humidity
Capacitive RH Sensor Circuit

Capacitive RH Sensor System and Circuit

Change in Humidity level

Continuous Triggering Pulse → Capacitive RH Sensor → Low Pass Filter → Amplifier → Voltage Output

(1) The sensing capacitor charges through $R_1$ and discharges through $R_2$
(2) The duty cycle can be precisely set by the ratio of these two resistors

$$f = 1 + \frac{1}{[C(R_1 + 2R_2)\ln 2]}$$
Types of Humidity Sensors

- Relative Humidity Sensors
  - Capacitive Humidity Sensors
  - Resistive Humidity Sensors

- Absolute Humidity Sensors
  - Thermal Conductivity Sensor
Resistive Relative Humidity (RH) Sensor

**Resistance of polymer is inversely proportional to Humidity**

1. Also known as Hygristor

2. Polymer allows water molecules

3. The resistivity between two electrodes changes
Resistive RH Sensor Circuit

Wheatstone Bridge

\[ R \quad R \quad R + \Delta R \quad R \]

Hygristor
Types of Humidity Sensors

- Relative Humidity Sensors
  - Capacitive Humidity Sensors
  - Resistive Relative Humidity Sensors

✓ Absolute Humidity Sensors
- Thermal Conductivity Sensor
Thermal Conductivity Humidity Sensors

Measures the absolute humidity by calculating the difference between the thermal conductivity of dry air and humid air

(1) Two tiny NTC thermistors are supported by thin wires
(2) The left thermistor is exposed to outside air through small venting holes and the right thermistor is hermetically sealed in dry nitrogen
(3) In a Bridge circuit, thermistors are self-heated by passing current in dry air
(4) A difference in resistance between the two thermistors develops as the left thermistor is exposed to humidity (After saturation point, as the temperature drops resistance goes up and voltage goes down)
Flow Sensing
Flow Sensors

**Electromagnetic Flow Sensors**

- Keyence FD-Q Clamp-on Flow Sensor

**Turbine-based Flow Sensors**

- Sea YF-S201 Hall Effect Flow Sensor

**Thermal Transport Sensors**

- Sensirion Hydrocarbon-based SLQ-QT500 Liquid Flow Meter

**Ultrasonic Flow Sensors**

- Endress-Hauser Flow 91W Clamp-on Flow Sensor
Applications of Flow Sensors

Oil/Gas Pipeline Flow Rate
Applications of Flow Sensors

Mass Airflow (MAF) Sensor in Cars
Applications of Flow Sensors

Portable respiratory equipment
Types of Flow Sensors

☑ Electromagnetic Flow Sensors

☐ Thermal Transport Flow Sensors

☐ Ultrasonic Flow Sensors
Electromagnetic Flow Sensors

Based on Faraday's Law of Induction

(1) When conductive fluid crosses magnetic flux lines, EMF (voltage) is generated
(2) The EMF (V) is proportional to the velocity (v) of moving fluid

\[ V = 2aBv \]
Thermal Transport Flow Sensors

**Hot Wire Thermal Anemometer**

1. Wire (dim=0.004 m dia, 2 mm length, is heated to 200-300° C, No temperature change = No resistance change
2. Wire is dipped in the fluid; stronger the flow cooler the wire
Time of Travel Ultrasonic Flow Sensor

1. Two Piezoelectric transducers placed on two sides of the pipe: one transmits ultrasonic waves, the other one acts as a receiver.
2. Moving medium causes the transmitted pulse to slow down (upstream) and to speed up (downstream).
3. Ultrasonic Flow Measuring Principle
   https://www.youtube.com/watch?v=Bx2RnrFLkQg