Lecture 9

Transducers – Sensors and Actuators

CC5068NI - Cloud Computing and Internet of Things

Sugat Man Shakya
sugatman.shakya@islingtoncollege.edu.np

Lecture Objectives

- Transducers
- Sensors
- Classification of Sensors
- Some common Quantities and Sensors
- Actuators
- Classification of Actuators
- Relay as an actuator
- Example: Sensors and Actuators with Arduino

Transducers

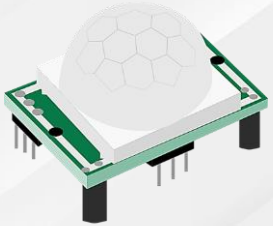
- A transducer is any device that converts one form of energy into another.
- It is a collective term used for both Sensors and Actuators.
- Examples of common transducers include the following:
  - A microphone converts sound into electrical impulses and a loudspeaker converts electrical impulses into sound (i.e., sound energy to electrical energy and vice versa).
  - A solar cell converts light into electricity and a thermocouple converts thermal energy into electrical energy.
  - An incandescent light bulb produces light by passing a current through a filament. Thus, a light bulb is a transducer for converting electrical energy into radiant energy in the form of visible light.
  - An electric motor is a transducer for the conversion of electricity into mechanical energy or motion.

Some Common Sensors and Actuators

Quantity being Measured	Input Device (Sensor)	Output Device (Actuator)
Light Level	Light Dependant Resistor (LDR) Photodiode Photo-transistor Solar Cell	Lights & Lamps LED's & Displays Fibre Optics
Temperature	Thermocouple Thermistor Thermostat Resistive Temperature Detectors	Heater Fan
Force/Pressure	Strain Gauge Pressure Switch Load Cells	Lifts & Jacks Electromagnet Vibration
Position	Potentiometer Encoders Reflective/Slotted Opto-switch LVDT	Motor Solenoid Panel Meters
Speed	Tacho-generator Reflective/Slotted Opto-coupler Doppler Effect Sensors	AC and DC Motors Stepper Motor Brake
Sound	Carbon Microphone Piezo-electric Crystal	Bell Buzzer Loudspeaker

Sensors

- **Sensor** is a device that can sense the changes in physical properties or environmental variables like movement, pressure, temperature, distance, etc., and convert sensed energy into usable electric energy which then can be processed as data to give specific information.
- For example: temperature sensor can sense surrounding temperature and provide electric signal to the processing unit.
- Thermocouples, thermistor, pressure sensors, proximity detection, RFID tags, Light intensity detectors, gyroscopes, etc. are some of the common examples of sensors.

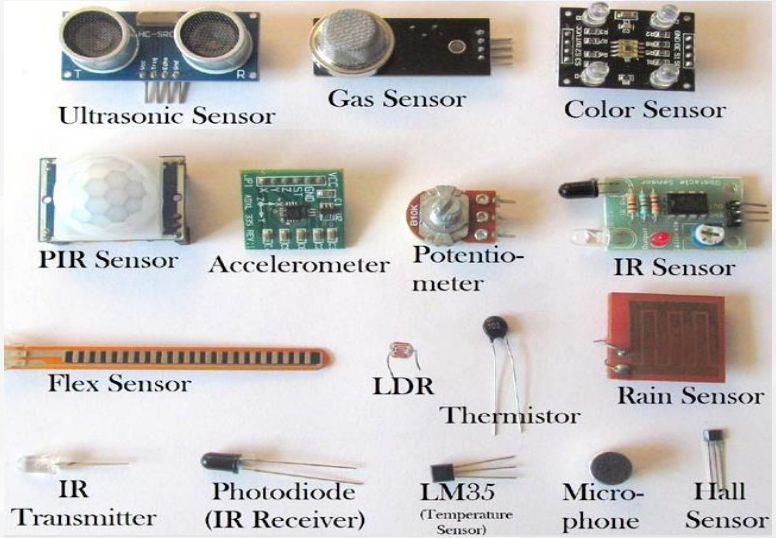


PIR Sensor

Ultrasonic Sensor

Classification of Sensors

- In general, the classification of sensors is given by:
  - Classification based on **energy conversion**:
    - **Active** sensor
    - **Passive** sensors
  - Classification based on the nature of the **output signal**:
    - **Analogue** sensor
    - **Digital** sensors



Active Sensors

- They **generate an electrical signal** (voltage or current or charge) which is a function of the physical quantity being measured or considered.
- They do not require any additional auxiliary source for their operation.
- Normally the output of active sensors is in microvolts (ηV) or microamps (ηA).
- Some examples:
  - Thermocouple: It generates a small voltage when the junctions of two metals are placed at different temperatures (one junction at hot and another at cold).
  - Photovoltaic Cell: It changes solar energy into voltage.
  - Piezoelectric pressure sensor: It generates a voltage across a piezoelectric element while applying stress/pressure on it.
  - Hall effect sensor: It generates a voltage in presence of a magnetic field around it.

Classification based on energy conversion

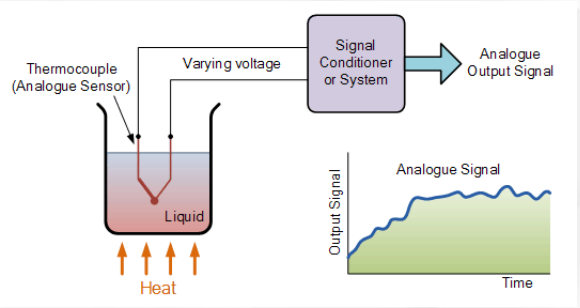
Passive Sensors

- They **modify electrical quantity** based on the input quantity being measured.
- Unlike Active Sensors, they do not produce or generate an electrical signal.
- They produce a change in some passive electrical quantity, such as capacitance, resistance, or inductance, as a result of the stimulation.
- They require external power source.
- Some Examples:
  - Thermistor: Change in temperature leads to change in resistance.
  - Photo Resistor: Change in light leads to change in resistance.
  - Strain gauge: Change in length and position leads to change in resistance.
  - Potentiometer: It is a resistive sensor used to measure rotary motion as well as linear displacements.

Classification based on the nature of the output signal

Analogue Sensors

- The sensors that produce a continuous output signal or electric voltage proportional to the quantity being measured are known as analogue sensors.
- Analogue sensors are used to sense the environment variables like temperature, pressure, speed, displacement, etc. which are continuous in nature.
- Some examples: accelerometers, pressure sensors, humidity sensors, light sensors, sound sensors, temperature sensors, fuel gauges, analogue proximity sensors and so on.

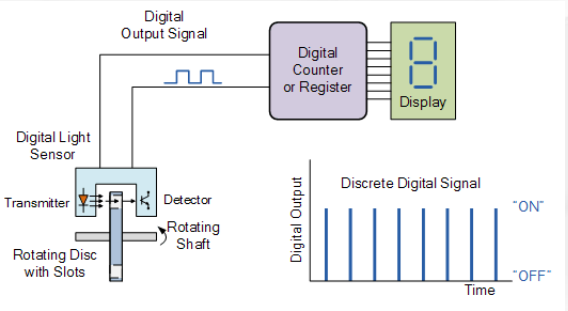


As shown in the figure above, while measuring the liquid temperature using a thermocouple, it produces analogue output signals changing continuously over time.

Classification based on the nature of the output signal

Digital Sensors

- The sensors that produce a discrete (non-continuous) digital output signal or electric voltage to digitally represent the quantity being measured are known as digital sensors.
- Unlike analogue sensors, digital sensors produce a binary output signal (logic '1' or logic '0') in the form of a voltage ('ON' or 'OFF').
- Some examples: limit switches, push buttons, digital proximity sensors, optical sensors, ultrasonic proximity sensors, and so on.



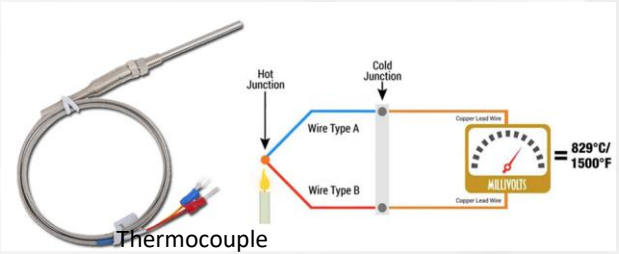
As shown in the above figure, the digital output pulses produced by the sensor are sent to a digital counter which then processes the received data and will produce an output display to display the speed of the shaft.

Some Common Quantities and Sensors

Measurement	*Typical Common Techniques*
Displacement/position	Variable reluctance, Hall effect, optoelectronic
Temperature	Thermistor, transistor V_{be}, thermocouple, infrared (IR)
Pressure	Piezoresistive, capacitive
Velocity (linear/angular)	Variable reluctance, Hall-effect, optoelectronic
Acceleration	Piezoresistive, capacitive, piezoelectric
Force	Piezoresistive
Torque	Optoelectronic
Mechanical impedance	Piezoresistive
Strain	Piezoresistive
Flow	Delta pressure
Humidity	Resistive, capacitive
Proximity	Ultrasonic
Range	Radar, LIDAR (light detection and ranging)
Liquid level	Ultrasonic
Slip	Dual torque
Imminent collision	Radar
Touch	Capacitive, resistive, inductive

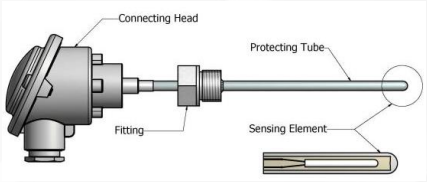
Temperature Sensor

- Thermocouple
- Thermistor
- Semiconductor
- Resistance Temperature Detectors (RTD)

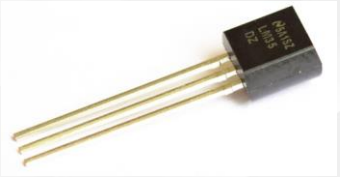


Thermocouple

Thermistor



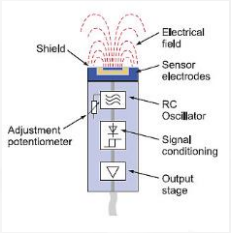
RTD



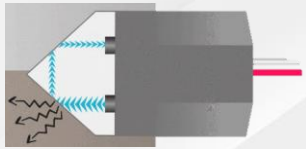
Semiconductor Temperature Sensor (LM35)

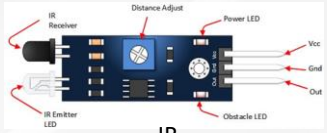
Level Sensors

- Level Sensors can be broken into two classifications:
  1. **Point level measurement**: It can sense the level of an object at a certain point.
     - Examples: Capacitance, Optical, Conductivity, Float switch
  2. **Continuous level measurement**: It can sense the level of an object at variable points continuously as its level changes.
     - Examples: Ultrasonic, IR, Radar

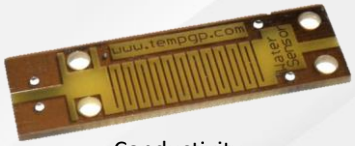


Capacitance


Optical



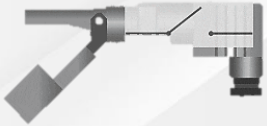
IR



Conductivity


Ultrasonic

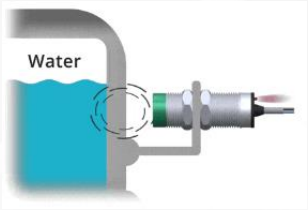

Radar


Float switch

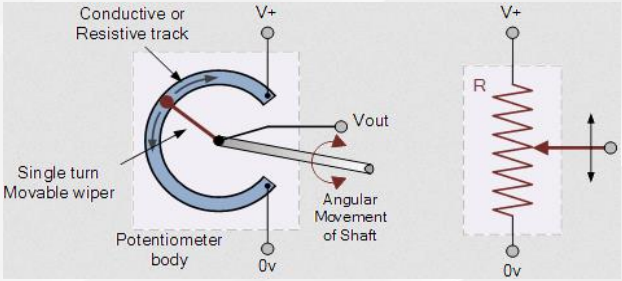
Displacement / Position Sensors

- Resistive [Potentiometer / “Pots”(linear or rotary displacement)]
- Inductive Sensor
- Capacitive Sensor
- Ultrasonic Sensor
- Piezoelectric Sensor
- Optical
- Magnetic [Hall effect]

Inductive Sensor



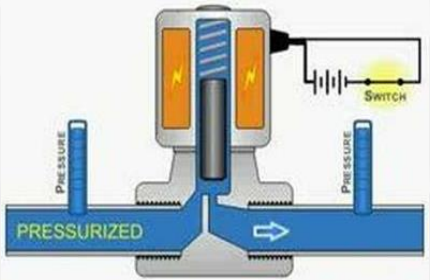
Capacitive Sensor



Rotary and Linear Potentiometer

Actuator

- Actuator is an electrically or mechanically controlled mechanical device that provide some movements or positioning to make the task done in a real environment.
- In simple words, actuators are the devices that respond according to the instruction of the control unit to make something move or operate.
- Electric motor, stepper motor, servo motor, solenoid valve, hydraulic press, air pressure brakes, relay etc. are some of the common examples of actuators.
- Actuators may be powered by pneumatic (compressed air) pressure, electric current or hydraulic fluid.



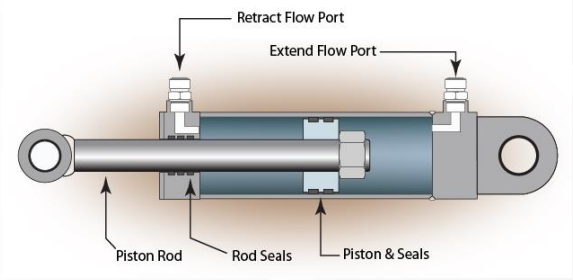
Classification of Actuators

- Classification based on output movement:
  - Linear Actuator
  - Rotary Actuator

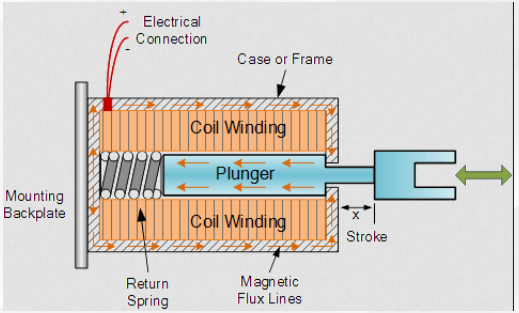
- Classification based on the source of energy:
  - Electrical actuator: controlled electrically or mechanically to make something move in a circular motion with a specific degree.
  - Hydraulic actuator: controlled using a fluid-filled cylinder and a moving piston.
  - Pneumatic actuator: controlled using pressurized gas.

Linear Actuator

- Linear actuators are the actuators that are controlled electrically or mechanically to make something move in a straight line or forward-backwards.
- Solenoid door lock, hydraulic press, air pressure brakes, etc. are examples of linear actuators.



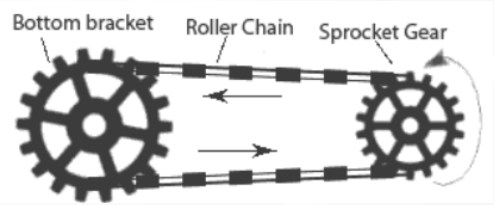
Hydraulic Press



Solenoid

Rotary Actuator

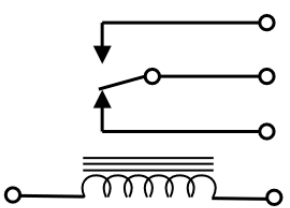
- Rotary actuators are the actuators which are controlled electrically or mechanically to make something move in a circular motion with specific degree.
- Water motor, stepper motor, gear box, etc. are some of the examples of rotary actuators.



Electric Motor

Relay as an Actuator

- Relay is an electrically operated switch that can be turned on or off using a low voltage signal from a control unit.
- It uses a low voltage signal (3.3 or 5V) to change the physical state of the switch.
- The high-voltage side has three connectors: common (COM), normally open (NO) and normally closed (NC).
- The low-voltage side has three connectors: VCC and GND for powering the relay and the IN pin is for controlling the relay switch.

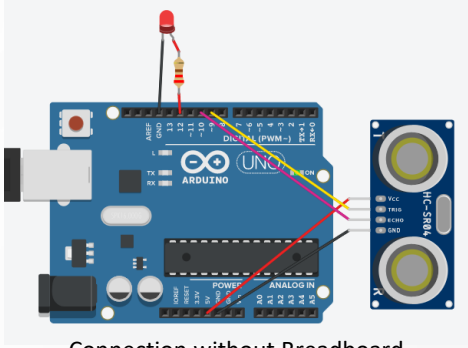


Relay Circuit Diagram

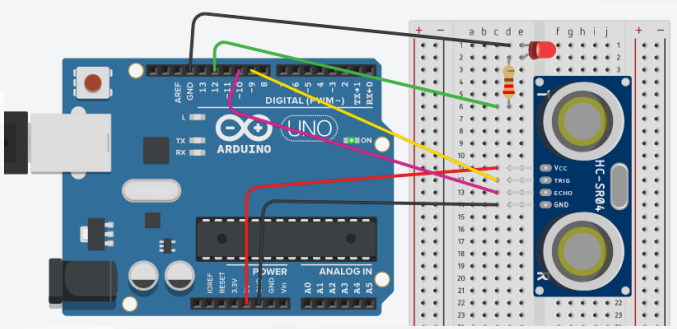
Relay Module

Example: Sensors and Actuators with Arduino

- **Sensor:** Ultrasonic Sensor
- **Actuator:** LED
- **Microcontroller:** Arduino



Connection without Breadboard



Connection with Breadboard

Any Questions?

End of the Lecture