Sensors & Actuators

Unit - II

Topics to be covered

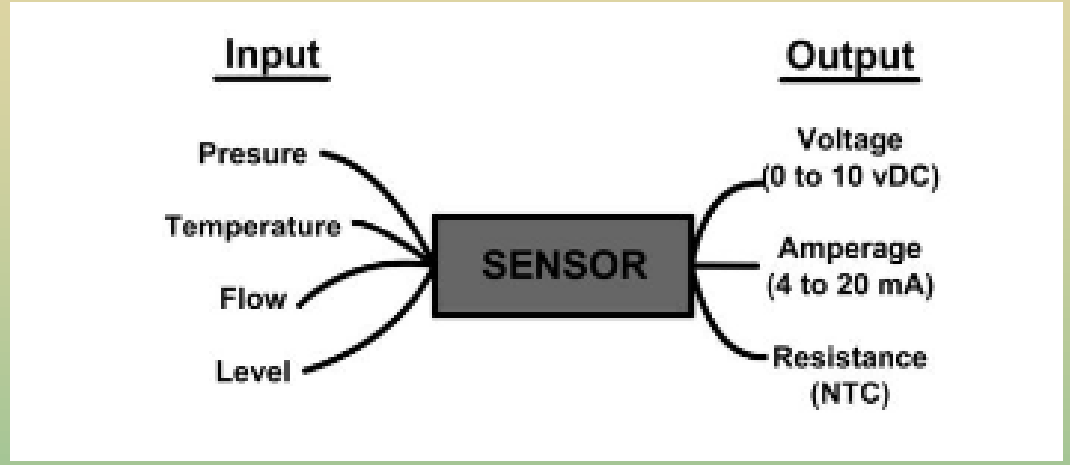
- Voltage requirements for Sensors
- Working of Sensors
- Need of ADC while working with Analog Sensors
- Working of Actuators
- Need of relay while working with Actuators

Voltage considerations for Sensors

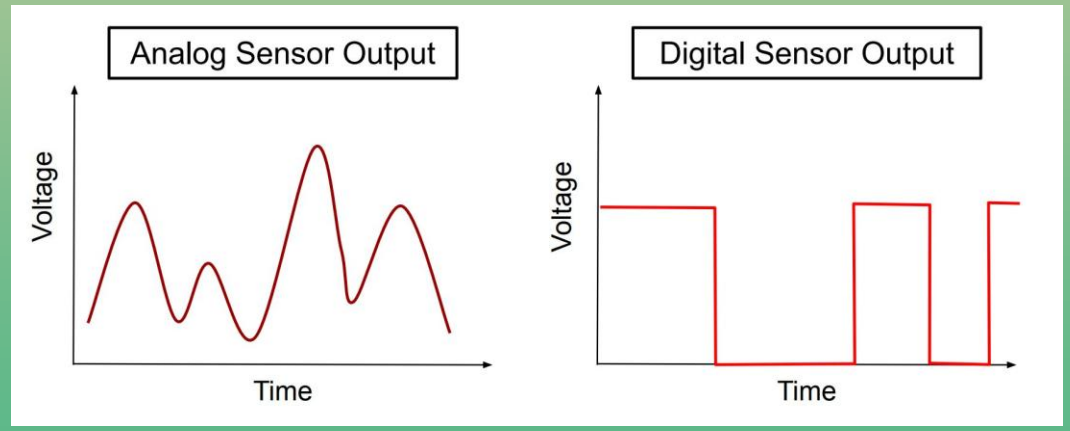
- **Transducers:** A Transducer basically converts some form of energy into some other form, includes sensors used to measure temperature, pressure, force, strain, liquid levels and flow rates and electrical conductivity.
- Sensors come with 2 different operating voltage rating: 3.3 V & 5 V.
- Some sensors and actuators are of 12V or using AC voltages as well.
- Which might not be compatible with what Arduino generates.
- Arduino Uno board has 2 different pins available for 5V and 3.3 V, which should be provided accordingly to the sensor while interfacing it with the Arduino board.
- If we apply the wrong Vcc pin to the sensor, its working capability may affect and we may get the wrong output, or the sensor could stop working altogether.

Sensor Classification

- Sensors can be classified into 2 categories based on its output signal type:
  - **Analog Sensors:** Gives an analog voltage as an output, usually some conversion to digital is needed while interfacing this signal with some processor boards, because processor boards are digital devices.
    - Example: Sharp IR Sensor, Accelerometer, LDR, Sound Sensors etc.
  - **Digital Sensors:** Gives binary or digital data as output. No conversion is needed.
    - Example: PIR Sensor, Digital Accelerometer, Digital Temperature Sensor etc.

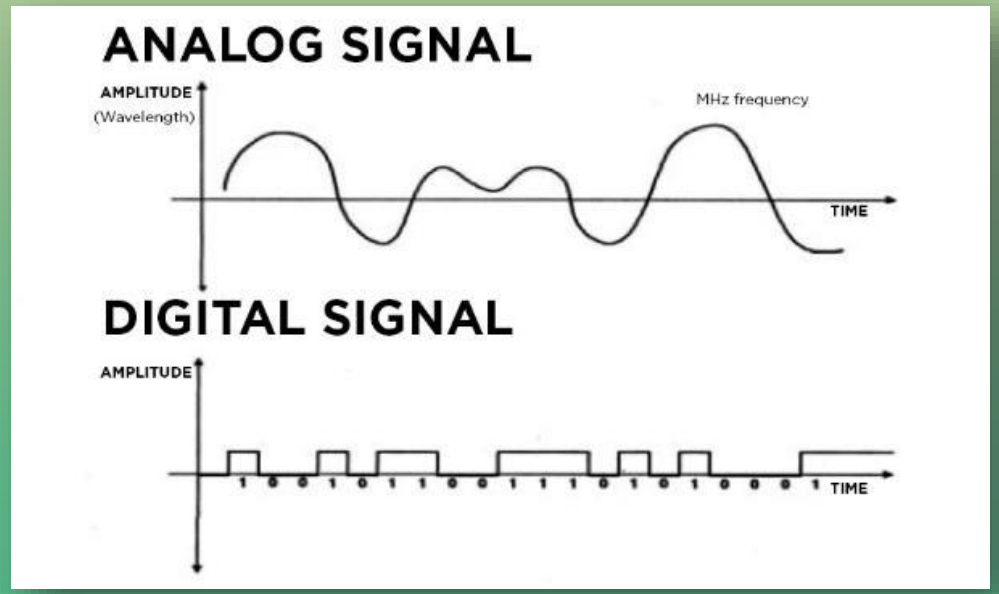


- Sensors can also be classified into 2 categories based on power source:
  - **Active Sensors:** Active sensors provide their own source of energy to illuminate the objects they observe
    - Example: Sharp IR Sensor, Active Speed monitoring sensor, Ultrasonic Distance Sensor etc.
  - **Passive Sensors:** passive sensors detect energy emitted or reflected from the environment
    - Example: PIR Sensor, LDR etc.



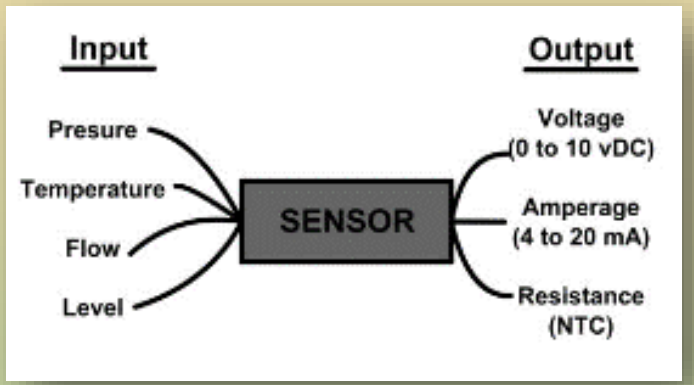
Generic working of Sensors

- Sensors identify the presence of energy or changes that occur or to allow the transfer of energy.
- Sensors receives signal through a Transducer and starts responding by converting into validate output to be easily understood.
- Commonly sensors change over a perceived signal into an analog or digital signal.



Sensor Classification: Analog Sensors

- An analog sensor will usually have two or three wires.
- Physical quantities such as Temperature, Speed, Pressure, and Displacement are all analog quantities due to their continuous nature.



- **Pros:**
  - Less quantization errors, low cost and requires less b/w
  - Accurate since recording data is done through continuous wave forms to represent information.
  - Configuring fault components is easier
  - Good lifespan
  - Low Weather dependencies
  - Not expensive and easy to handle
- **Cons:**
  - Analog sensors have unwanted variation when noise gets added.
  - Due to the noise effect its consistence will be reduced and being reduced to its quality also.
  - Transmitter and Receiver should be configured if there is a change in the deployment level.
  - Security isn't there for transmitting data.

Sensor Classification: Digital Sensors

- Digital Sensors produce discrete digital output signals or voltages that digitally represent the measured quantity.
- Responses with binary values
- output as a single “bit” (serial transmission), or by combining the bits to produce a single “byte” output Ex: 0 , 1, or 01011110

- **Pros:**
  - Easy to implement, free from observational errors
  - Noise immune without any deterioration
  - Fast handling, less demanding for storage, resistance to noise, conceivable outcomes, simple convey ability
  - Flexibility with framework change, utilization of receiver and Transmitter
  - Security includes great encryption transmission
  - Spare the information and recover when required

- **Cons:**
  - Less accurate because it samples analog wave forms into few numbers and records them
  - Higher cost and depends on weather conditions
  - Have quantization errors, less accurate to finite set of data
  - Sampling error is most basic on many cases

Sensor Comparison: Analog v/s Digital

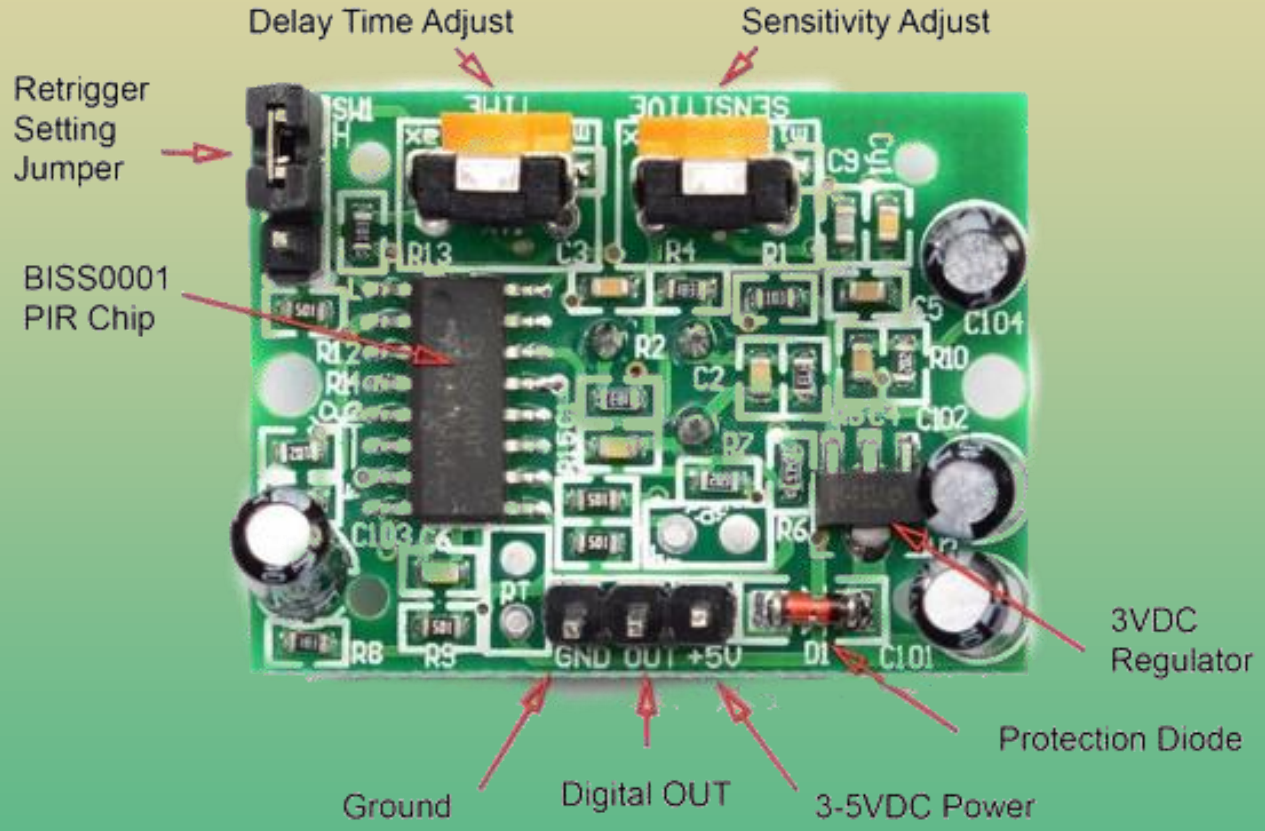
	Analog Sensor	Digital Sensor
Signal	Continuous Signal	Discrete Signal
Representation	Continuous value to represent info.	Discrete value to represent info
Data Transmission	Prone to noise while transmission	Can be noise immune
Technology	Records signal/waveform as it is	Sampling of waveform
Uses	Light, sound, pressure sensing	Temprature
Bandwidth	Consume less bandwidth	Consumes more bandwidth
Memory	Stored as waveforms	Stored as binary information
Cost	Low	Higher
Power	Use Large power	Use very less power
Noise Response	Noise may affect waveform	Immune to noise during transmission
Error	Observational/Measurement error	No observational error
Example	LDR, sound sensors, pressure sensors, and analog temperature sensors	Humidity sensor, Flow sensor, Accelerometer, Level sensor

Sensor Classification

- Sensors can also be classified into different categories based on type of working or the technology used for sensing the data:
  - **IR Sensors**
  - **Ultrasonic Sensors**
  - **Light Sensors**
  - **Speed Sensors**
  - **Sound Sensors**
  - **Image Sensors**
  - **Proximity Sensors**
  - **Temperature/Humidity Sensors**
  - **Touch Sensors**
  - **Pressure Sensors etc.**

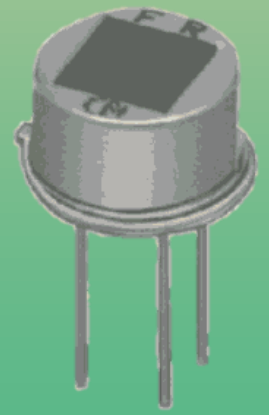
Sensors: PIR Motion Sensor

- Passive Infrared Motion Sensor
- Used to detect motion.
- Digital sensor, output can be read from Digital OUT pin
- Sensitivity: up to 20 feet (6 meters) 110° x 70° detection range, can be adjusted by potentiometer
- Pins:
  - VCC (Power Input) : 5V
  - GND (Ground)
  - OUT (Digital Output - Motion Detection)



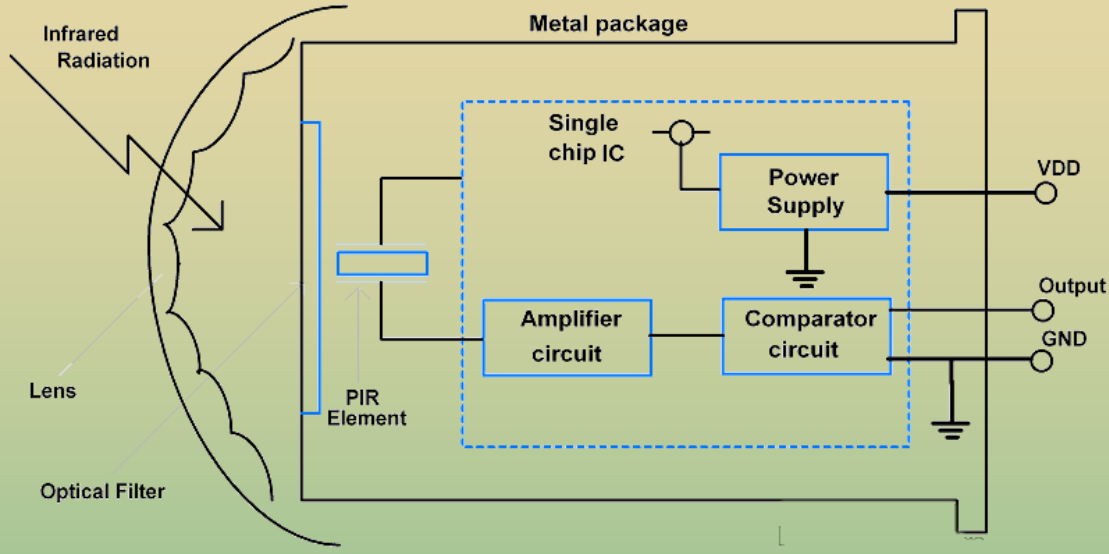
Sensors: PIR Motion Sensor

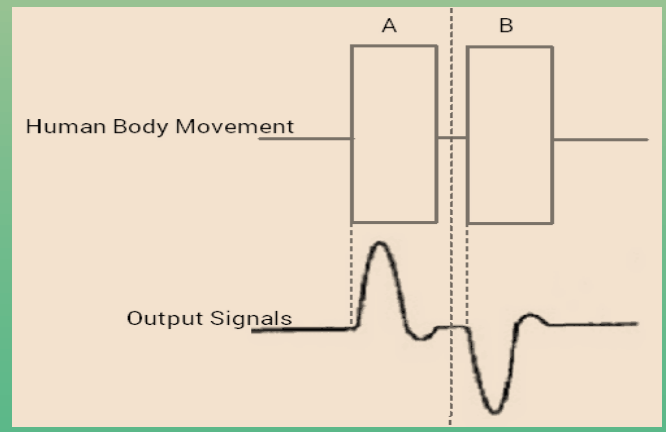
- All living objects emit heat in terms of infrared radiation, thermal radiation
- Passive Infrared Sensor detects such infrared radiation
- PIR Sensor does not generate or radiate any energy for detection purposes.
- made of a pyroelectric sensor, detects levels of infrared radiation.
- Every object emits some low-level radiation and the hotter
- objects emit more radiation.



Sensors: PIR Motion Sensor

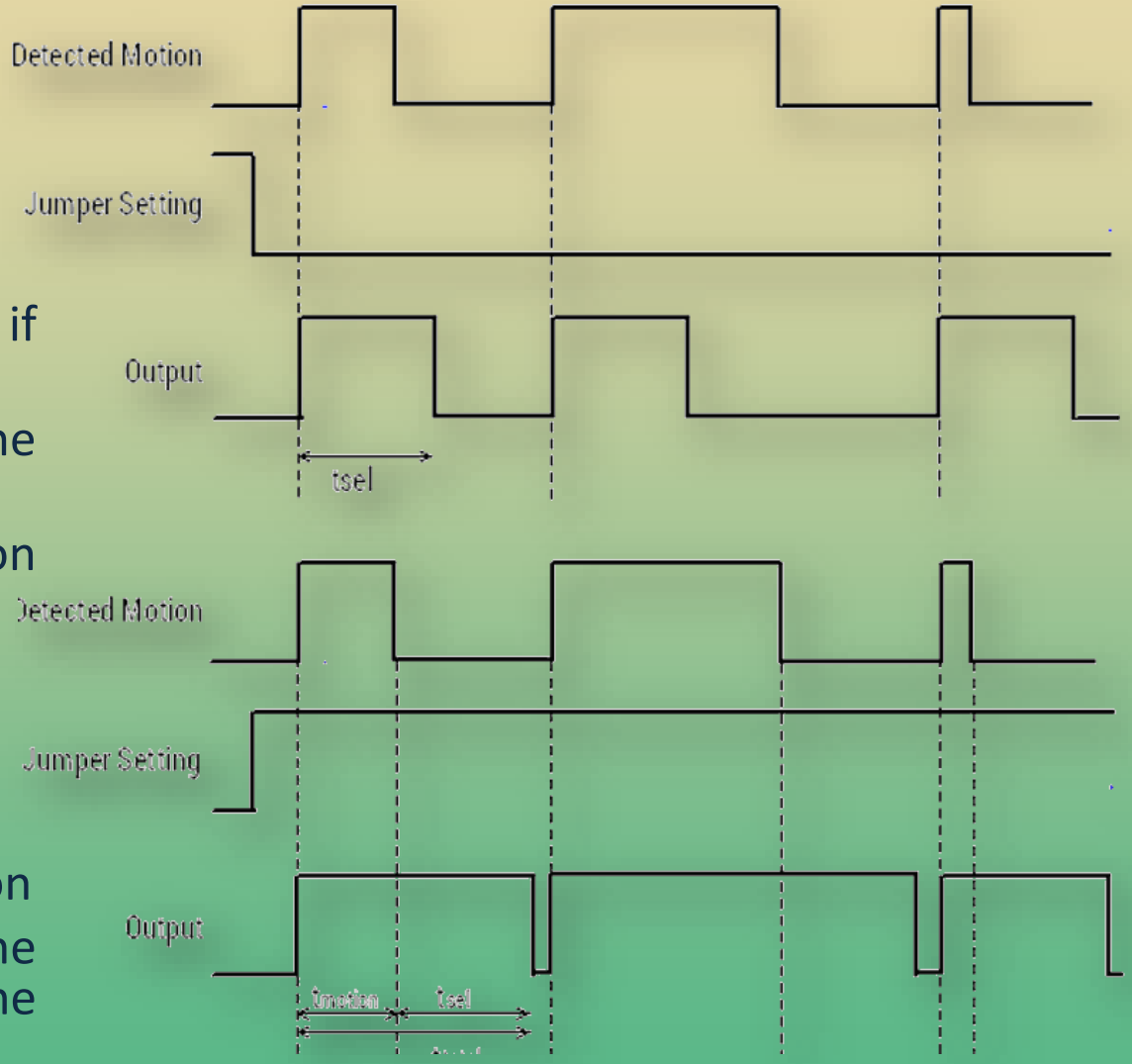
- The sensor is split in two slots, which are wired up so that they cancel each other out.
- If one half sees more or less IR radiation than the other, the output will swing high or low.
- Input signals from both terminals of PIR element are amplified using an amplifier circuit and compared using a comparator circuit.
- The PIR element is covered by the lens to increase the range of operation.



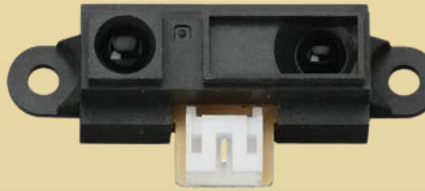


Sensors: PIR Motion Sensor

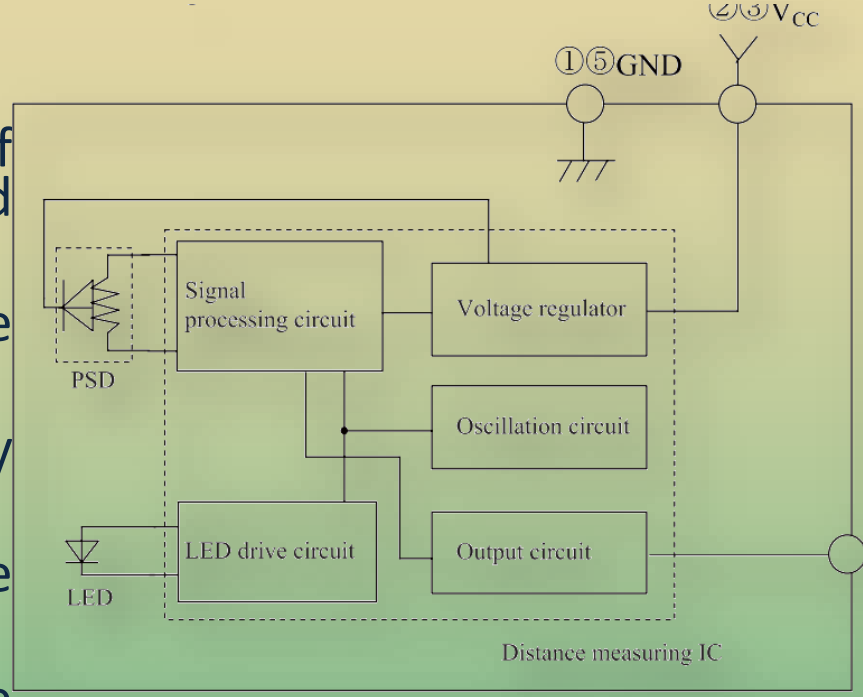
- PIR has 2 working modes:
- **Single Trigger Mode:**
  - jumper setting on PIR sensor set on LOW
  - Output goes HIGH when motion is detected
  - After specific delay (tsel) the output goes to LOW even if the object is in motion
  - output is LOW for some time and again goes HIGH if the object remains in motion
  - Delay (tsel) is provided by using the potentiometer on Sensor
- **Repeat Trigger Mode:**
  - Jumper setting on PIR sensor set on High
  - Output goes HIGH when motion is detected
  - Output of PIR sensor is HIGH until the object is in motion
  - When the object stops motion, or disappears from the sensor area, the PIR continues its HIGH state up to some specified delay (tsel)

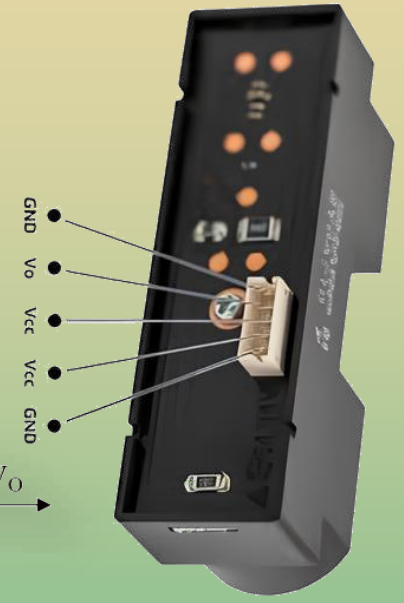


Sensors: Sharp IR Distance Sensor



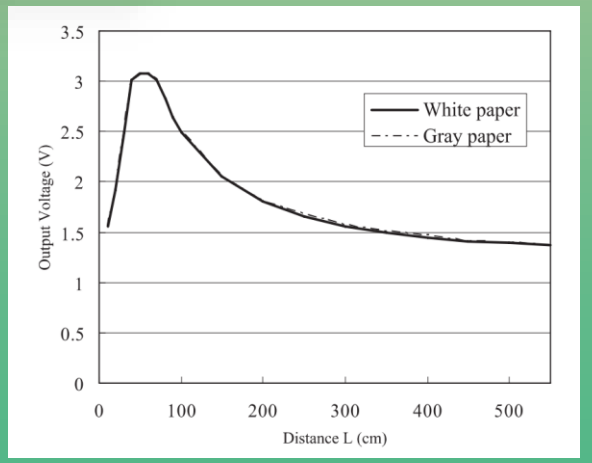
- Measures distance using infrared light
- Consists integrated combination of PSD(position sensitive detector), IRED(infrared emitting diode) and signal processing unit.
- Outputs voltage corresponding to the detection distance.
- Range varies according to model, generally between 4cm to 150cm
- Analog sensor, output can be read as voltage difference between V0 pin and Vcc
- 110° x 70° detection range, sensitivity can be adjusted by changing voltage
- Pins:
  - VCC (Power Input) : 5V
  - GND (Ground)
  - Vo (Analog Output - Distance Measurement)





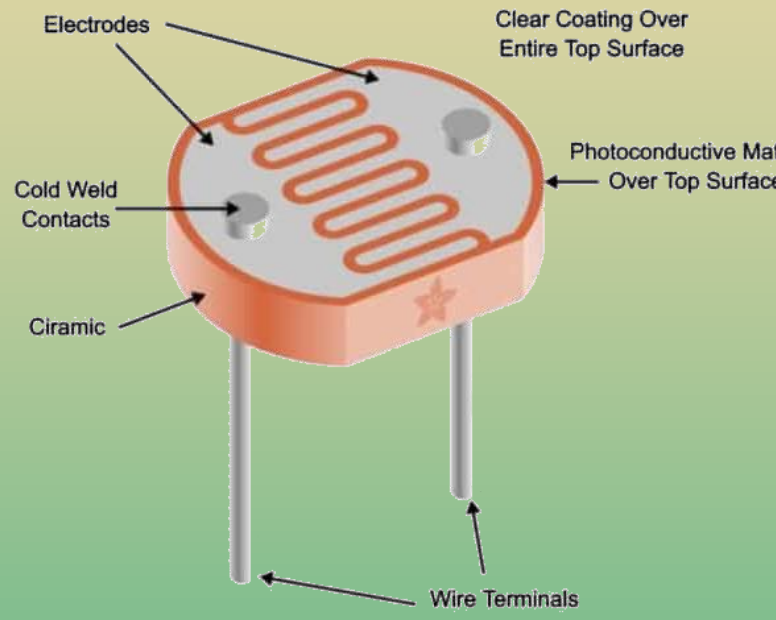
Application:

Projector(Auto-focus)
Robot cleaner
Auto-switch for illumination
Human detector
Game play etc.



Sensors: LDR Sensor

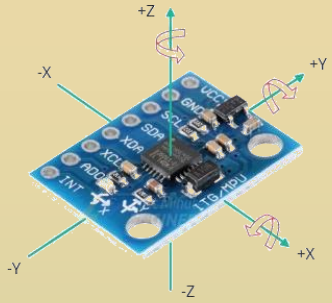
- An LDR or light-dependent resistor is also known as photoresistor, photocell, Photoconductor
- It is one type of resistor whose resistance varies depending on the amount of light falling on its surface
- It works on the principle of photoconductivity
- When the light falls on its surface, then the material conductivity reduces and also the electrons in the valence band of the device cross the conduction band
- Passive component, no external power required
- One terminal connects to VCC and another to GND
- Adjustable sensitivity (via blue digital potentiometer adjustment)
- Output Digital – 0V to 5V, Adjustable trigger level from preset.
- Operating Voltage: 3.3V to 5V DC.
- Operating Current: 15ma.



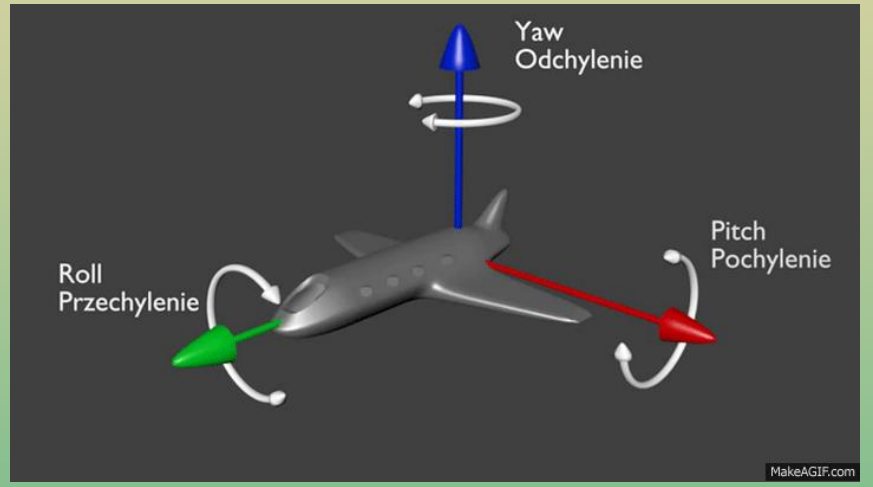
Application:

- Simple Smoke Detector Alarm, Clock with automatic light
- Laser-based security systems
- Solar Street Lamps, Camera light meters

Sensors: Gyro Sensor



- A Gyroscope measures the orientation and angular velocity of an object.
- These can measure the tilt and lateral orientation of the object
- There are three types of angular rate measurements:
  - **Yaw-** the horizontal rotation on a flat surface seeing the object from the Top
  - **Pitch-** Vertical rotation as seen in the object from the Front,
  - **Roll-** the horizontal rotation when seeing the object from Front.



- Specification:
  - Power Supply: DC3.3V-5V
  - Chip: MPU9250
  - Gyro range : ± 250 500 1000 2000 ° / sec
  - Acceleration range: ± 2 ± 4 ± 8 ± 16g

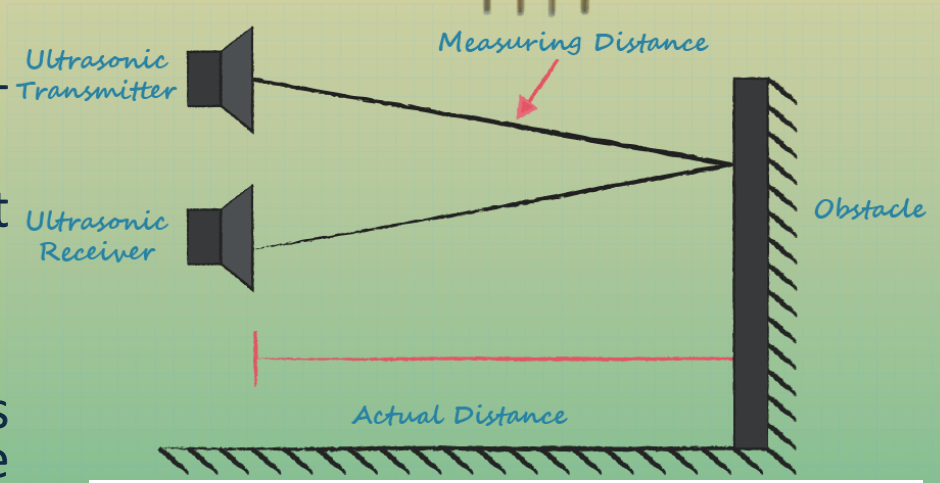
- **Applications:**
  - **C**ar navigation systems
  - Auto stability control systems of vehicles
  - Motion sensing for mobile games,
  - Camera-shake detection systems in digital cameras, etc.

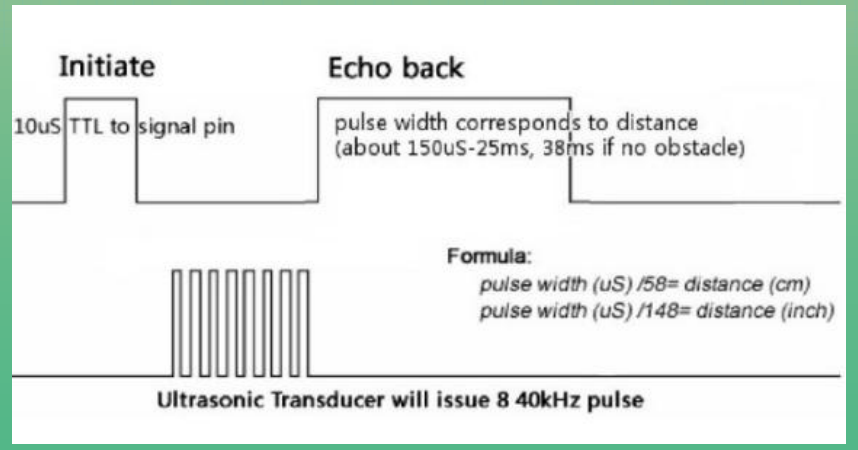
Sensors: Gyro Sensor

Pin	Function
VCC	Power supply
GND	Ground
SCL	Serial Clock Signal
SDA	Serial Data Input
EDA	External Data (master)
ECL	External Clock
ADO	Slave Address LSB, Serial Data Output
INT	Interrupt Digital output
NCS	Chip select
FSYNC	Frame synchronization digital input

Sensors: Ultrasonic Distance Sensor

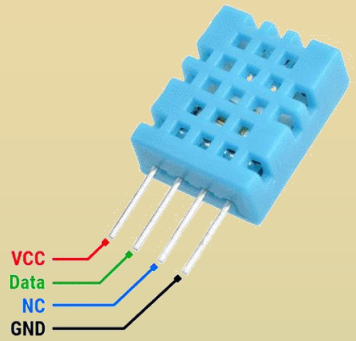
- Used to measure distance
- Works by reflecting ultrasonic sound waves (typically 40kHz)
- 2 eyes-like projects in the front, the Ultrasonic transmitter and Receiver
- It is a transmitter, a receiver, and a control circuit in one single-pack
- Excellent range accuracy and stable readings, operation is not affected by sunlight
- The Trigger and the Echo pins are the I/O pins of this module
- When the receiver detects the return wave the Echo pin goes high for a particular amount of time which will be equal to the time taken for the wave to return back to the sensor.
- Ultrasonic Ranging Module HC-SR04 specification:
  - Distance: 2cm - 400cm non-contact distance sensing capabilities
  - Ranging accuracy: up to 3mm.
  - Power Supply: +5V DC
  - Effectual Angle: <15°
  - Resolution: 0.3 cm





Sensors: DHT Sensor

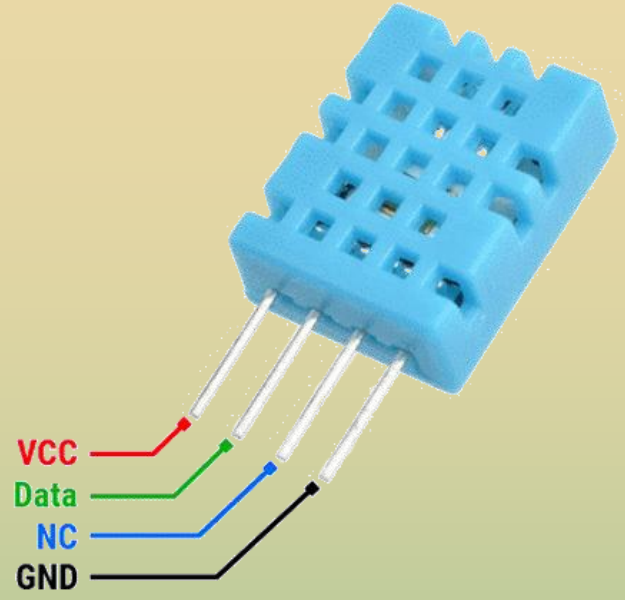
- The DHT-11 Digital Temperature And Humidity Sensor is a basic, ultra-low-cost digital temperature and humidity sensor.
- Includes a resistive sense of wet components and an NTC temperature measurement device, and is connected to a high-performance 8-bit microcontroller
- Digital sensor, data can be read digitally from data pin.
- Pins:
  - VCC (Power Input) : 3.3V – 5V
  - GND (Ground)
  - DATA (Bi-directional communication for temperature and humidity data)



- **Applications:**
  - Dehumidifier,
  - Testing and inspection equipment, consumer goods, automotive,
  - Automatic control
  - Data loggers
  - Weather stations
  - Humidity regulator

Specifications	
Humidity Measuring Range(%)	20 to 90
Temperature Measuring Range	0 to +50
Humidity Measurement Accuracy	Â±5.0
Temperature Measurement Accuracy	Â±2.0
Response Time(s)	<5

Sensors: DHT Sensor



- Data Format

8-bit humidity integer	8-bit Humidity decimal	8 bit temp integer	8 bit fractional temp	8 bit parity bit

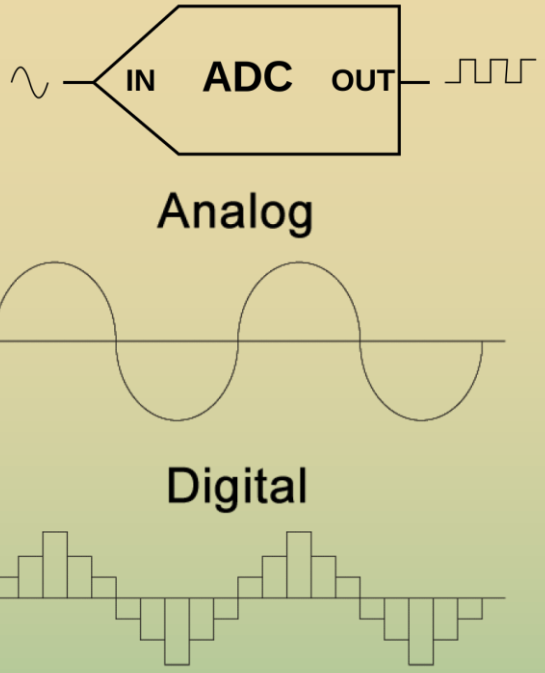
- Example:

0011 0101 0000 0000 0001 1000 0000 0000 0100 1101

Humidity: 0011 0101 = 35H = 53%

Temperature: 0001 1000 = 18H = 24 ℃

Need of ADC for Analog Sensors



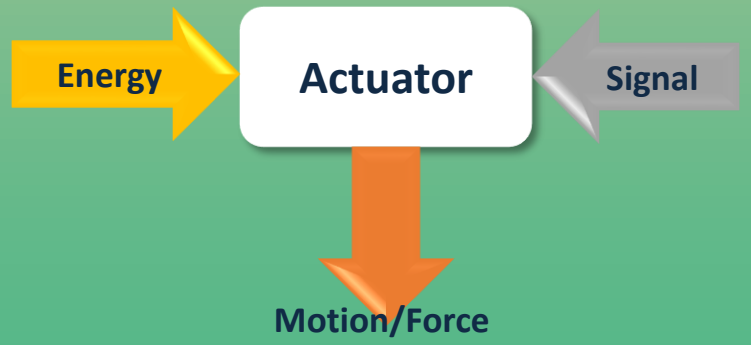
- Some sensors are analog sensors, which give the data in the form of an analog voltage, which is continuous, but Arduino like IoT devices can work on Digital signals
- So to bridge this gap, some conversion is needed.
- ADC can do that conversion.
- Analog signal is continuous but digital has set of finite steps, so accuracy of data depends upon the number of output bits in ADC
- 10-bit ADC pins are built-in, in Arduino Uno board

$$\boldsymbol{ADC\ reading} = \frac{2^{\boldsymbol{Resolution\ of\ ADC}}}{\boldsymbol{Max\ Voltage}} * \boldsymbol{Analog\ input\ Voltage}$$

- For Ex:
- Input voltage of 4V out of 5V for 10 bit resolution ADC,
- Reading = $(2^{10}/5)*4$ = 1024*0.8 = 819.2 = 11 0011 0011

Actuators

- An Actuator is a component of a machine that is responsible for moving or controlling a mechanism or system.
- An Actuator requires a control signal and a source of energy.
- The control signal is relatively low energy and may be electric voltage or current, pneumatic or hydraulic pressure or human power.
- Actuators are greatly valuable devices and have an assorted scope of use in fields, such as, building, electronic designing and can be found in numerous sorts of hardware, for example, printers, autos.
- Most actuators deliver either **direct (straight line), revolving (round) or oscillatory movement**.
- Three types of Actuators
  - Hydraulic Actuators
  - Pneumatic Actuators
  - Electric Actuators

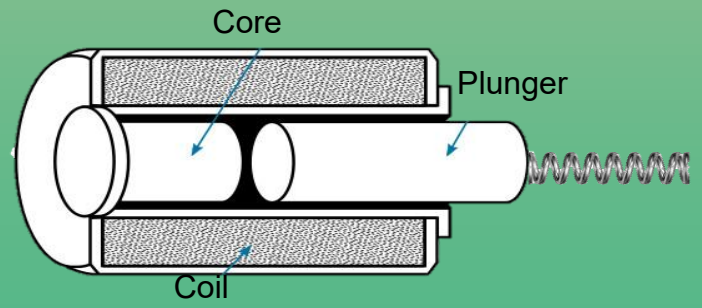


Actuators: Servo motor

- Servo motor-controlled actuators provide precise and repeatable movements for industrial machines, utilized across many industrial applications, including those requiring high-precision positioning and cycling.
- Servo actuators convert electrical energy into controlled mechanical motion.
  - **Linear Servo Motor:**
    - Move machine parts linearly, typically executing back-and-forth motions exert a mechanical force, facilitating straightforward linear movement
    - The core components include a rotary synchronous servo motor known for its high-speed rotational output.
    - This output is then amplified in terms of torque by gearboxes.
    - The rotary motion is converted into linear motion through mechanisms
    - like belts, leadscrews, or ball-screw assemblies
  - **Rotary Servo Motor:**
    - It excels in creating circular motion, either in fixed degrees or continuous rotation
    - The heart of these actuators is an electric motor, typically of the induction type, which effectively converts electrical energy into mechanical energy
    - This conversion results in rotational torque on the output shaft, a fundamental aspect for applications like mixers, fans, saws, and pumps.
- When integrated with a position sensor, these motors can accurately circularly position payloads.
- Voltage: Commonly 5V or 6V.
- Input: Pulse-width modulation (PWM) signal.
- Range: Typically 0 to 180 degrees
- Internal feedback mechanism for accuracy.

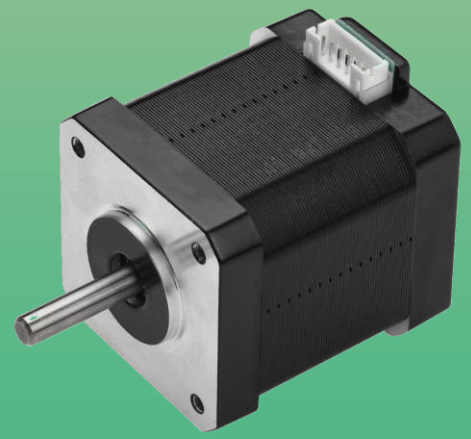
Actuators: Solenoid Lock

- A solenoid actuator is a control device that uses electromagnetism to convert electrical energy into mechanical motion.
- It is made of a movable coil and iron core. The strength of the Solenoid is determined by the number of turns on the coil.
- An important aspect of the solenoid is a jolt.
- A solenoid is an electromagnet formed by a conductor wound in a series of loops in the shape of a spiral
- soft-iron core is pinned or held in an immovable position
- A movable plunger (also soft iron) is held away from the core by a spring when the solenoid is de-energized, When current flows through the conductor, it produces a magnetic field.
- The magnetic flux produced by the coil establishes north and south poles in both the core and the plunger.
- The plunger is attracted along the lines of force to a position at the center of the coil.
- The de-energized position of the plunger is partially out of the coil due to the action of the spring.
- Binary control (on/off)
- Voltage: Varies, e.g., 6V, 12V
- Input: Electrical current for activation
- Magnetic fields move a plunger



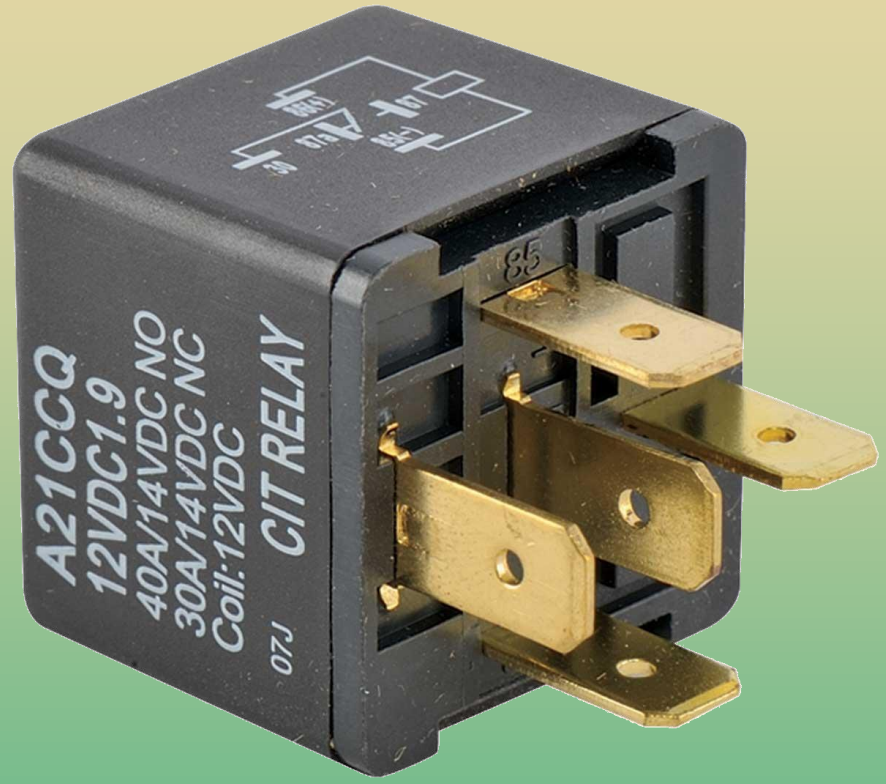
Actuators: Stepper Motor

- Stepper motor actuators are more complicated than standard DC actuators and require a stepper controller to drive the motor
- stepper motors are used in applications that require high-precision speed and position controls at the expense of a lower possible drive force
- It divides rotational motion into an equal number of steps with the help of actuators, depending on the application requirement
- Stepper motors offer consistent repetition of movement, speed control, and precision in positioning
- They have several industrial applications such as 3D printing, robotics, CNC machining, medical imaging, and so on
- Specification:
  - Rated voltage: 5V DC
  - Step Angle: 5.625° /64
  - Frequency: 100Hz
  - Self-positioning Torque: >34.3mN.m
- **Applications of Stepper motor:**
  - Automotive gauges
  - Surveillance equipment such as cameras
  - Zooming functions in digital cameras
  - Blood analysis machines
  - Fluid pumps
  - Hospital beds
  - Stretchers and incubators



Relay

- An electromechanical switch used to control high-power electrical devices using a low-power control signal
- Types:
  - **Electromagnetic Relay (EMR):** Uses an electromagnet to operate the contacts.
  - **Solid-State Relay (SSR):** Uses semiconductor devices for switching without mechanical parts.
- Voltage: Typically low voltage, e.g., 5V or 12V, depending on the relay type.
- It switches electrical contacts capable of handling higher voltages and currents.



Need of relay while working with Actuators

- **Handle Voltage Differences:** Actuators may require higher voltages incompatible with control circuits.
- **Provide Electrical Isolation:** Protect control electronics from high-power actuator circuits.
- **Switch High Currents:** Relays handle high currents, avoiding stress on control electronics.
- **Interface with Digital Systems:** Enable easy integration into digital control systems.
- **Protect Control Circuits:** Guard against back electromotive force and other potential issues.