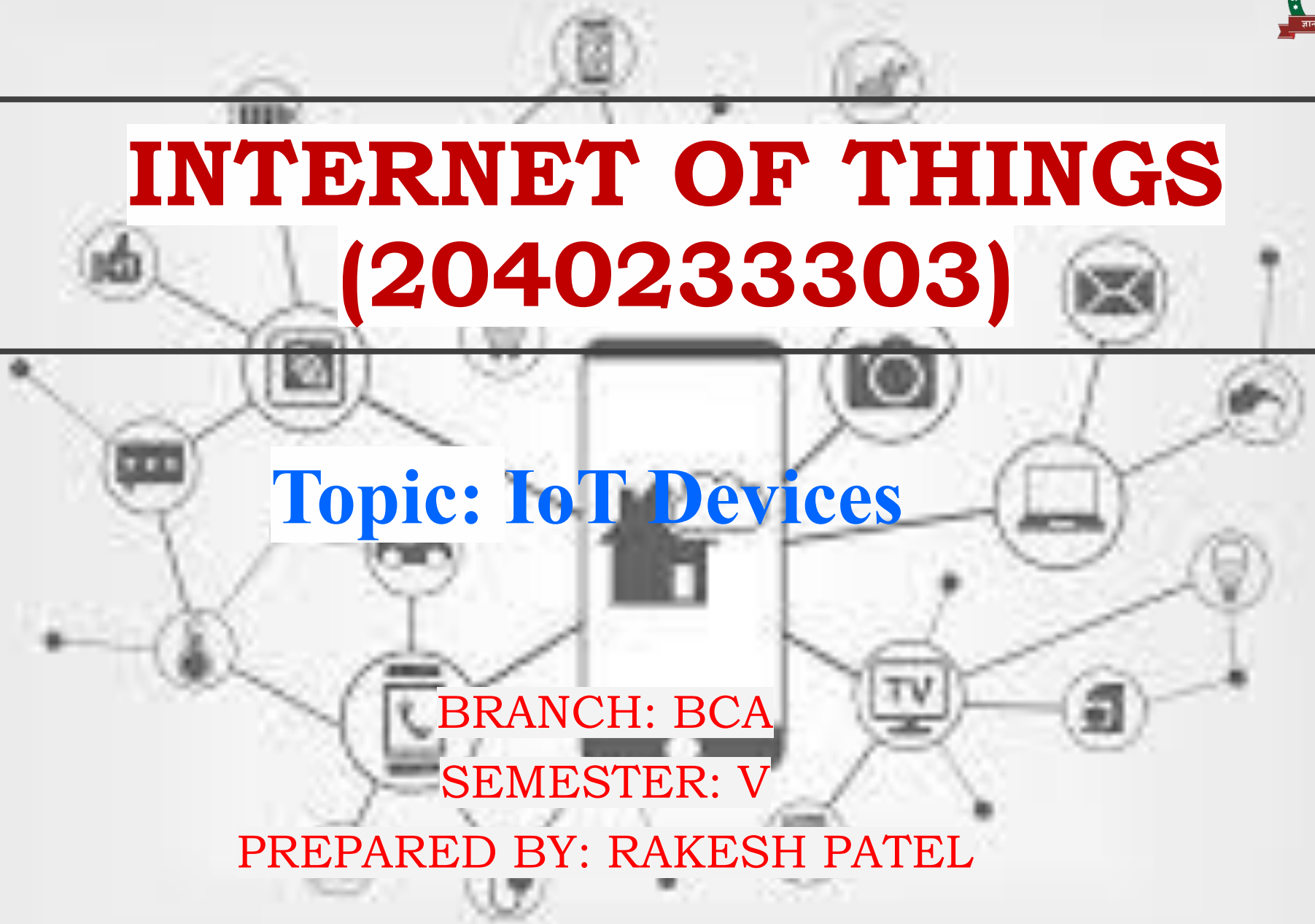
SILVER OAK UNIVERSITY
EDUCATION TO INNOVATION

INTERNET OF THINGS (2040233303)



Topic: IoT Devices

BRANCH: BCA

SEMESTER: V

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Bachelor of Computer Applications

Silver Oak College of Computer Application (SOCCA)

Expertise in Internet of Things

WHAT WILL WE BE COVERING IN THIS TOPIC?

Sensors And Actuators For IoT Applications

Programming Of Node-MCU, Arduino & Raspberry PI

Embedded IoT Systems With Edge Devices

Reading Sensor Data And Transmit To Cloud

Controlling Devices Through Cloud Using Mobile Application And Web Application

LEARNING OBJECTIVES

- Understanding the basic principles of sensors and actuators and Identify different types of sensors and actuators used in IoT applications.
- Implement complex IoT applications using Node-MCU, Arduino, and Raspberry Pi and Optimize code for performance and reliability in IoT applications.
- Define embedded systems and edge computing in the context of IoT.
- Interface sensors with microcontrollers and edge devices for data collection.
- Understanding data transmission from sensor to cloud.
- Understanding device control via cloud using mobile and web applications.

Sensors For IoT Applications

Sensors

A sensor detects (senses) changes in the ambient conditions or in the state of another device or a system, and forwards or processes this information in a certain manner [1].

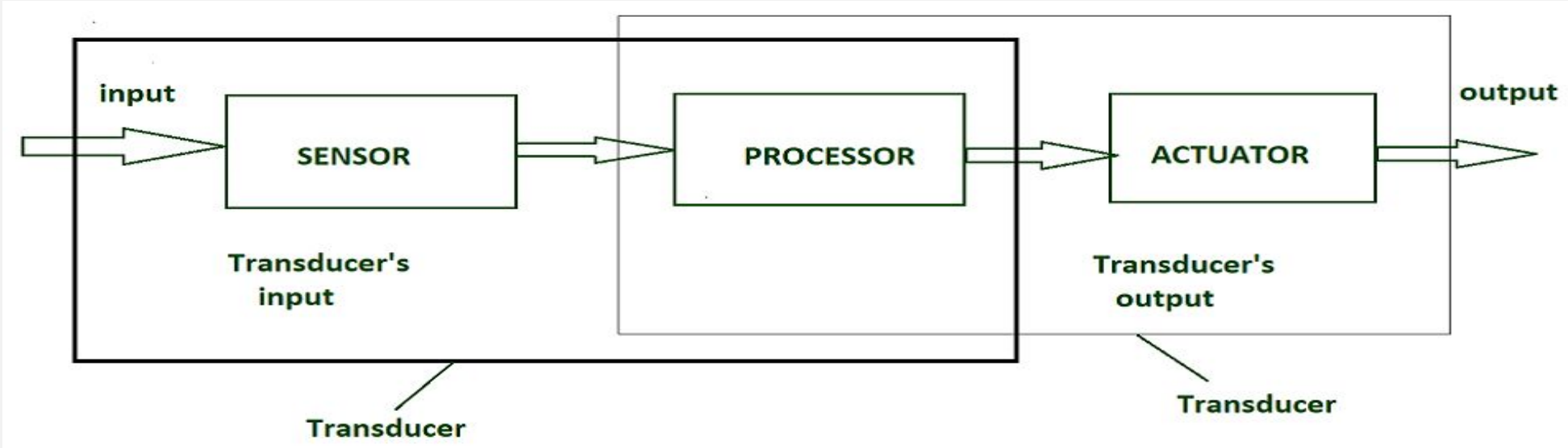
"A device which detects or measures a physical property and records, indicates, or otherwise responds to it" [2].

Sensors are devices that detect and respond to changes in an environment. They convert physical parameters (such as temperature, humidity, pressure, etc.) into signals that can be measured and interpreted.

References:
1. http://www.businessdictionary.com/definition/sensor.html
2. https://en.oxforddictionaries.com/definition/sensor

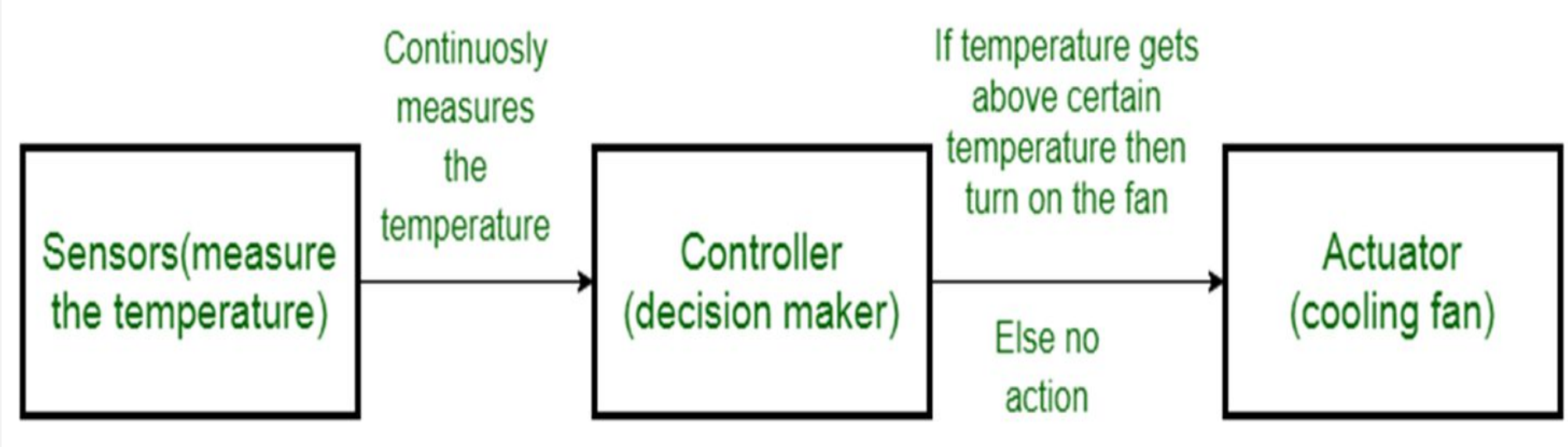
Sensors

1. They perform some input functions by sensing or feeling the physical changes in characteristics of a system in response to a stimuli.
2. For example heat is converted to electrical signals in a temperature sensor, or atmospheric pressure is converted to electrical signals in a barometer.



Actuators

- A device that turns electrical energy into mechanical energy is known as an actuator.



References:
1. https://www.tutorialspoint.com/actuators-in-iot

Actuators

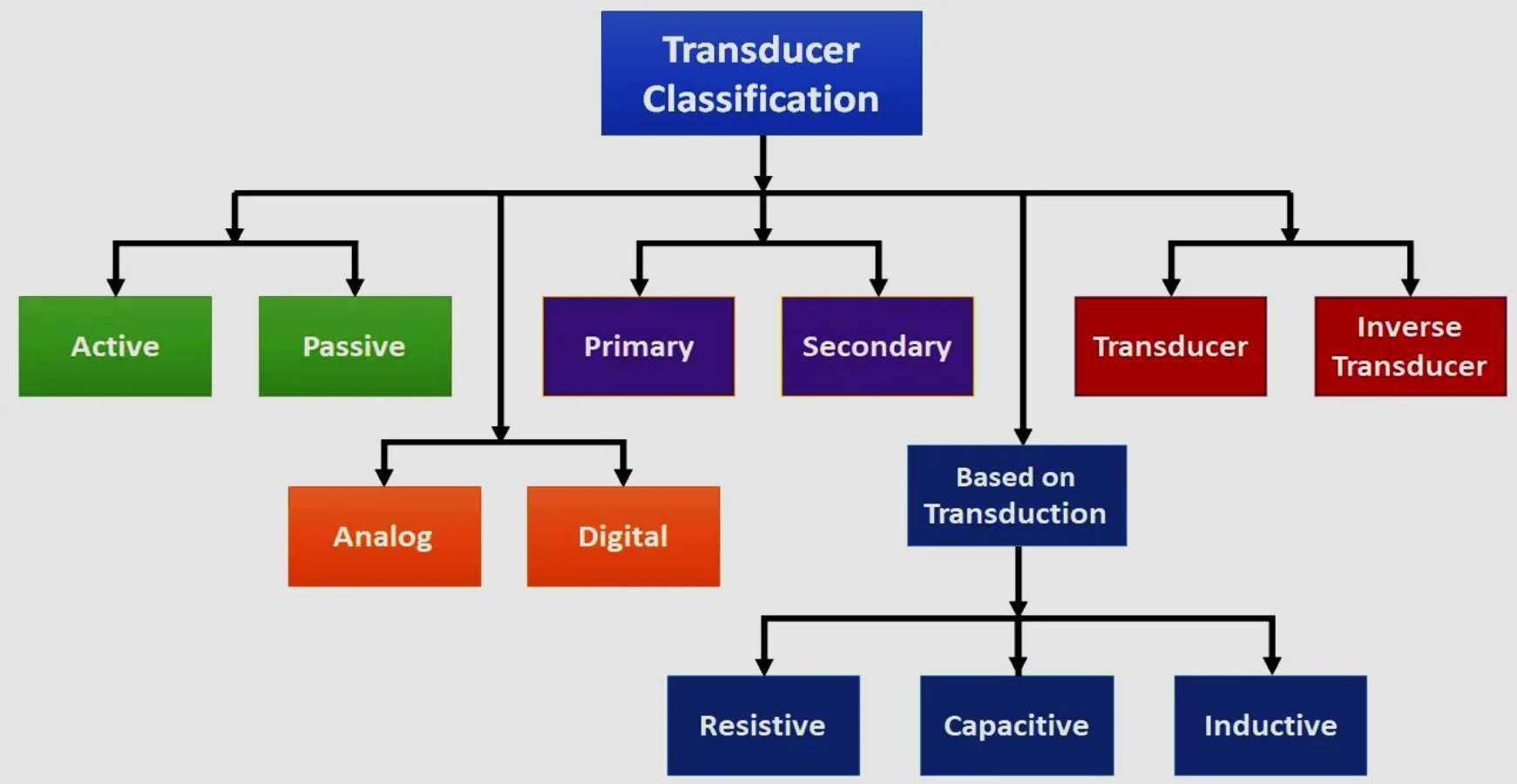
- An actuator, in other terms, is a component that can move or control a mechanism or system.
- Actuators are commonly employed in industrial automation, robotics, and other applications requiring precise mechanical system control.
- Actuators come in a variety of configurations, including electric, hydraulic, and pneumatic actuators.

References:
1. https://www.tutorialspoint.com/actuators-in-iot

Transducers

- Transducers convert or transduce energy of one kind into another.
- For example, in a sound system, a microphone (input device) converts sound waves into electrical signals for an amplifier to amplify (a process), and a loudspeaker (output device) converts these electrical signals back into sound waves.

Transducers classification



References:
1. https://instrumentationtools.com/sensors-and-transducers-classification/

Sensors vs. Transducer

The word “Transducer” is the collective term used for both Sensors which can be used to sense a wide range of different energy forms such as movement, electrical signals, radiant energy, thermal or magnetic energy etc., and Actuators which can be used to switch voltages or currents [1].

References:
1. https:// www.electronics-tutorials.ws/io/io_1.htm

Sensors Features

- It is only sensitive to the measured property (e.g., A temperature sensor senses the ambient temperature of a room.)
- It is insensitive to any other property likely to be encountered
- in its application (e.g., A temperature sensor does not bother about light or pressure while sensing the temperature.)
- It does not influence the measured property (e.g., measuring the temperature does not reduce or increase the temperature).

Sensor Resolution

- The resolution of a sensor is the smallest change it can detect in the quantity that it is measuring.
- The resolution of a sensor with a digital output is usually the smallest resolution the digital output it is capable of processing.
- The more is the resolution of a sensor, the more accurate is its precision.

➢ A sensor's accuracy does not depend upon its resolution.

Sensor classification

Based on Output

1. Analog
2. Digital

Based On Datatype

1. Scalar
2. Vector/ Multimedia

Analog Sensor

- **Analog Sensors** produce a continuous output signal or voltage which is generally proportional to the quantity being measured.
- Physical quantities such as Temperature, Speed, Pressure, Displacement, Strain etc. are all analog quantities as they tend to be continuous in nature.
- For example, the temperature of a liquid can be measured using a thermometer or thermocouple (e.g. in geysers) which continuously responds to temperature changes as the liquid is heated up or cooled down.

Digital Sensors

- **Digital Sensors** produce discrete digital output signals or voltages that are a digital representation of the quantity being measured.
- Digital sensors produce a binary output signal in the form of a logic “1” or a logic “0”, (“ON” or “OFF”).
- Digital signal only produces discrete (non-continuous) values, which may be output as a single “bit” (serial transmission), or by combining the bits to produce a single “byte” output (parallel transmission).

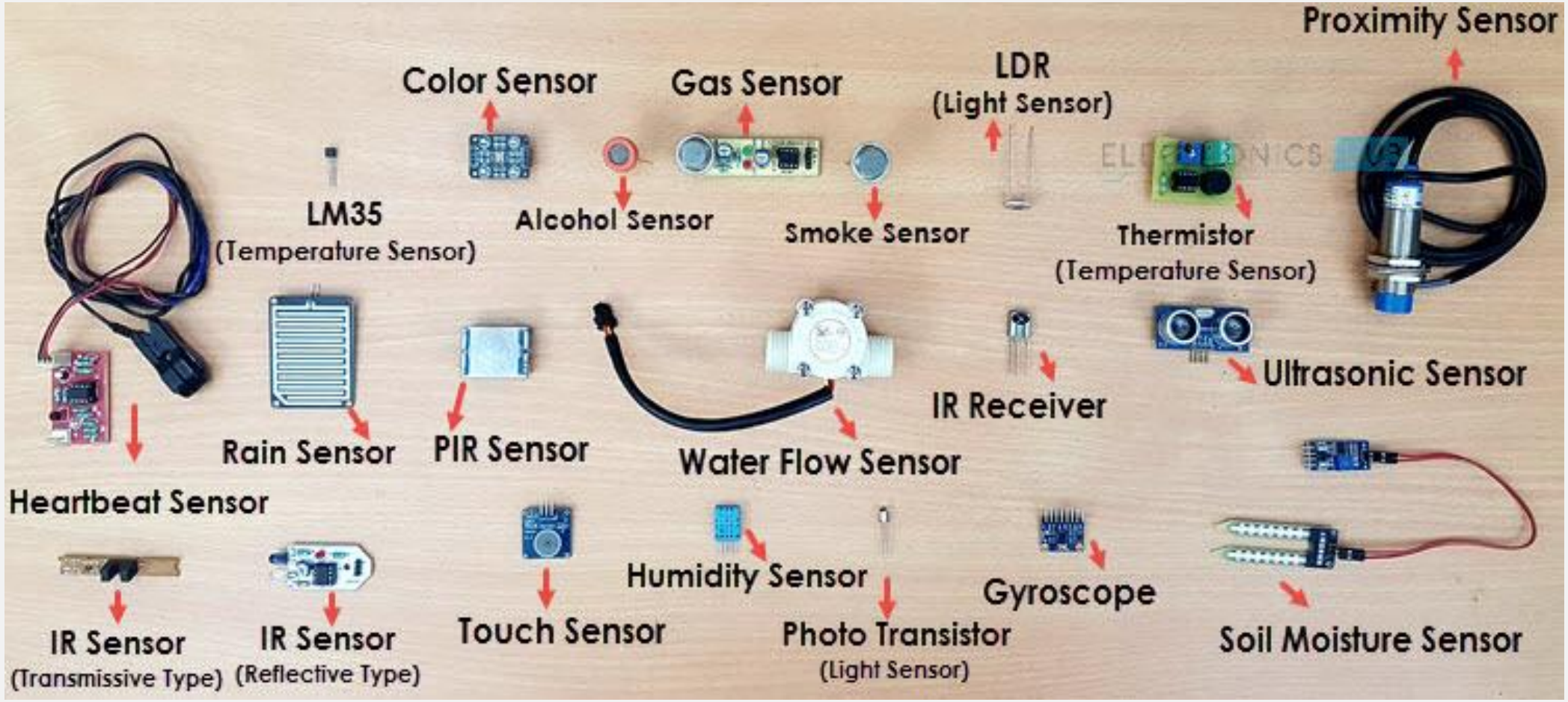
Scalar Sensors

- Scalar Sensors produce output signal or voltage which is generally proportional to the magnitude of the quantity being measured.
- Physical quantities such as temperature, color, pressure, strain, etc. are all scalar quantities as only their magnitude is sufficient to convey an information.
- For example, the temperature of a room can be measured using a thermometer or thermocouple, which responds to temperature changes irrespective of the orientation of the sensor or its direction.

Vector Sensors

- Vector Sensors produce output signal or voltage which is generally proportional to the magnitude, direction, as well as the orientation of the quantity being measured.
- Physical quantities such as sound, image, velocity, acceleration, orientation, etc. are all vector quantities, as only their magnitude is not sufficient to convey the complete information.
- For example, the acceleration of a body can be measured using an accelerometer, which gives the components of acceleration of the body with respect to the x,y,z coordinate axes.

Types of Sensors

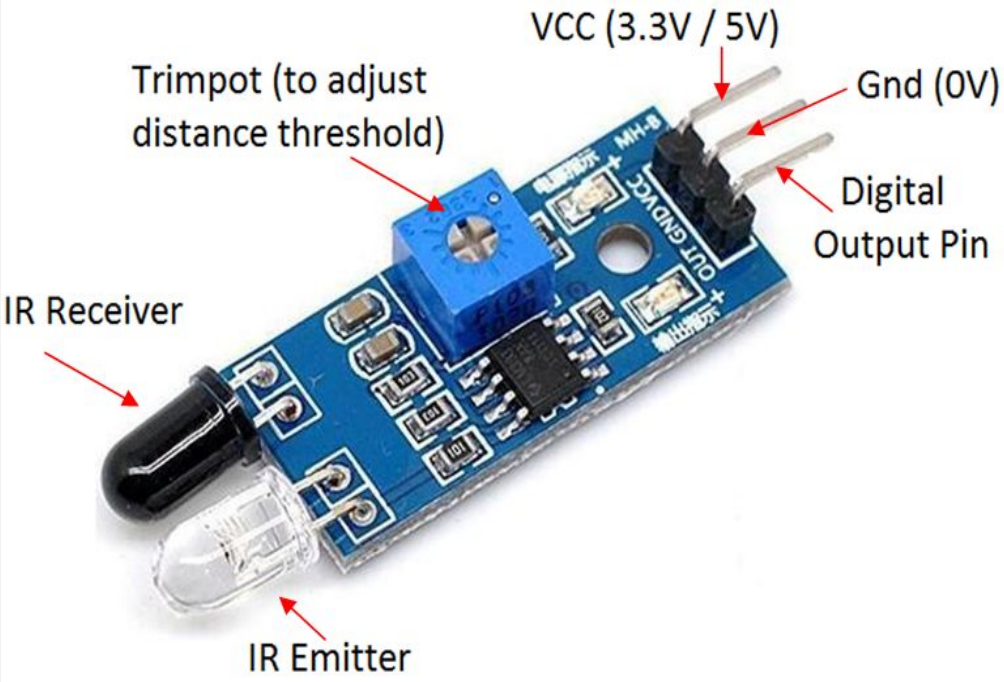


Types of Sensors

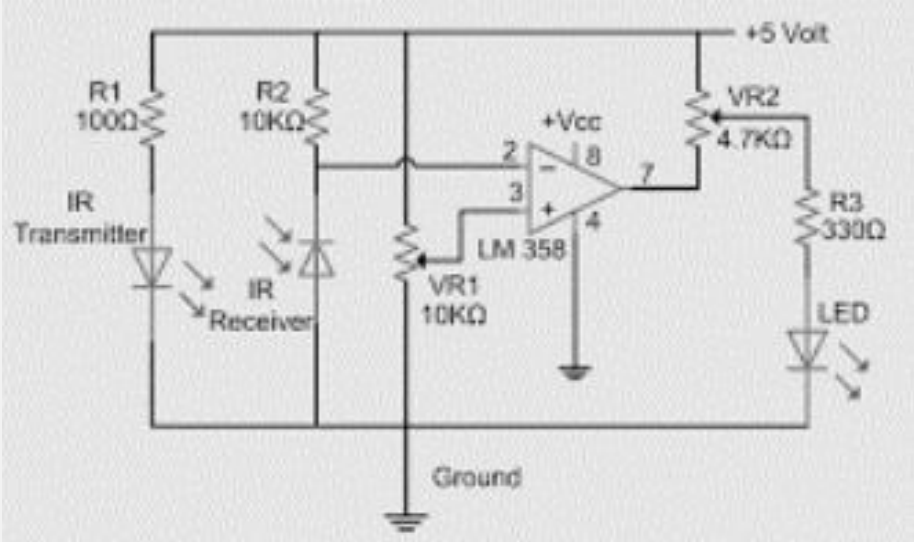
1. Infrared Sensor(IR Sensor)
2. Temperature & Thermocouple Sensors
3. Proximity Sensor
4. Ultrasonic sensor
5. Accelerometers & Gyroscope Sensor
6. Pressure Sensor
7. Hall Effect Sensor
8. Load cell
9. Light Sensor
10. Colour Sensor
11. Touch Sensor
12. Tilt Sensor
13. PIR Motion Detector & Vibration Sensor
14. Metal detector, Water Flow & Heartbeat Sensor
15. Flow and Level Sensor
16. Smoke, Fog, Gas, Ethanol & Alcohol Sensor
17. Humidity, Soil Moisture & Rain Sensor

Infrared Sensor (IR Sensor)

The IR sensor is an electronic device that measures and detects infrared radiation in its surrounding environment. Or in simple words, it is a light emitting diode that can detect the change in color, heat, and IR radiation.



- Operating Voltage: 3 to 5 VDC
- Measuring Range: 2 to 10 cm
- Detection Angle: 35°
- Current consumption: 20mA

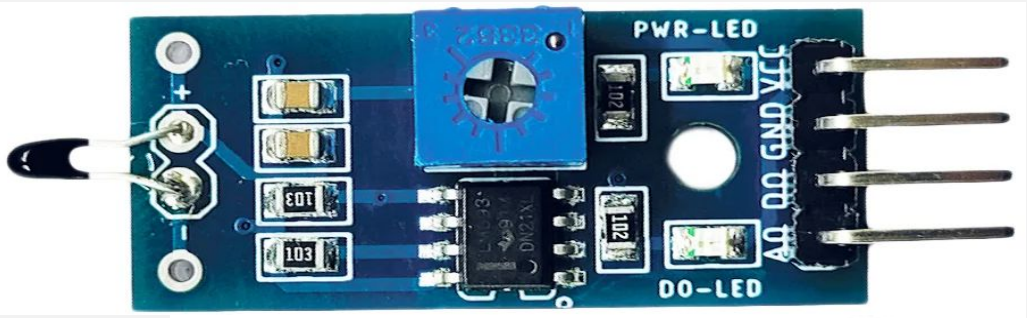


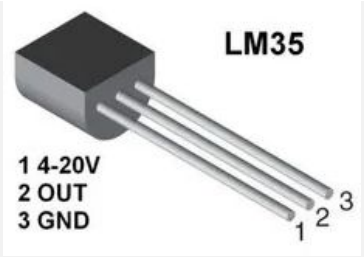
Price: Rs. 25 to 100

References:
1. https://circuitdigest.com/tutorial/different-types-of-sensors-and-their-working

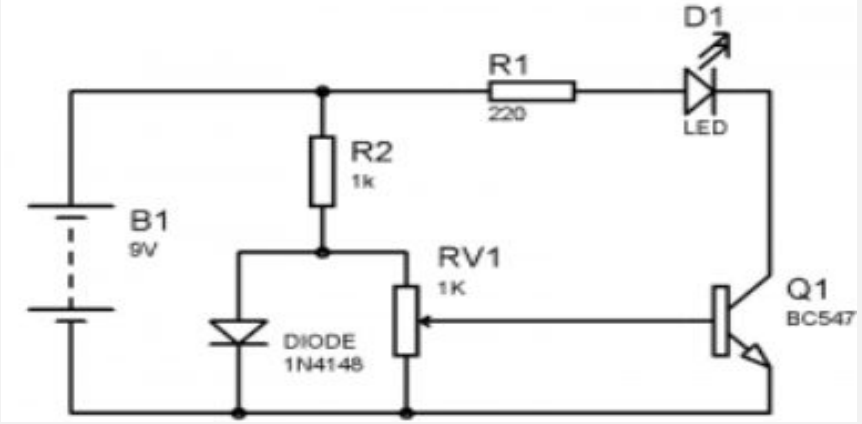
Temperature & Thermocouple Sensors

Temperature sensors measure the heat or cold produced by an object or system. They allow us to detect changes in temperature and can provide either an analog or digital output. Other types of temperature sensors are Thermocouples, Thermistors, Resistive Temperature Devices (RTD) and Temperature Sensor ICs (LM35) etc.





Operating voltage: 3V to 5V
Temperature Range: -55°C to +125°C
Accuracy: ±0.5°C
Price: Rs. 200 to 450

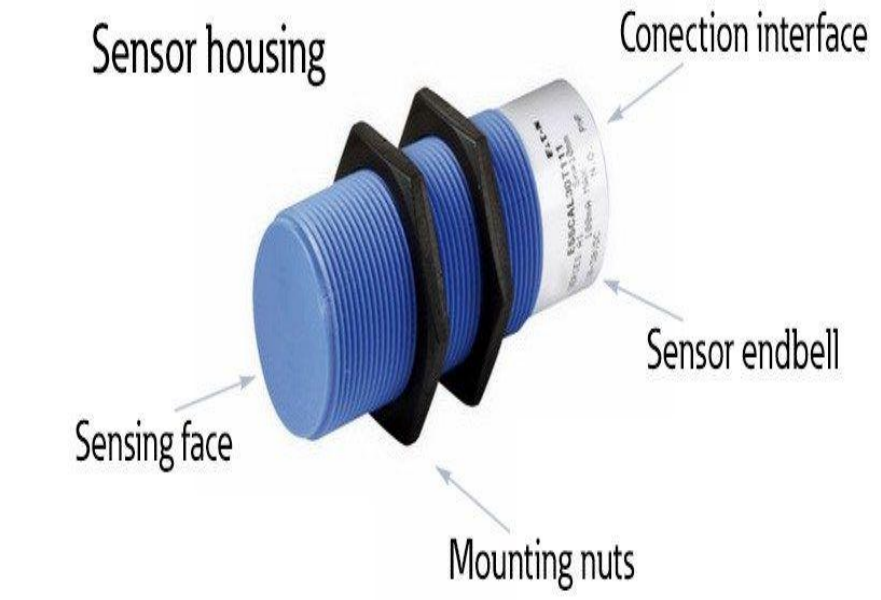


References:
1. https://circuitdigest.com/tutorial/different-types-of-sensors-and-their-working

Proximity Sensor

A proximity sensor can detect the presence of nearby objects without physical contact. It typically emits an electromagnetic field or beam of electromagnetic radiation (such as infrared) and monitors changes in the field or the return signal.

Sensing distance: 2 mm ± 10%, 4 mm ± 10%, 5 mm ± 10%, 8 mm ± 10%,12 mm ± 10%
Detectable Object: Ferrous metal
Operating Voltage Range: 12 to 24 VDC
Current Consumption: 15 mA max
Output:
– Load current: 200 mA max
– Residual voltage: 2V max. (load current: 200 mA, cable length: 2 m)
Indicators: Operation indicator (red)

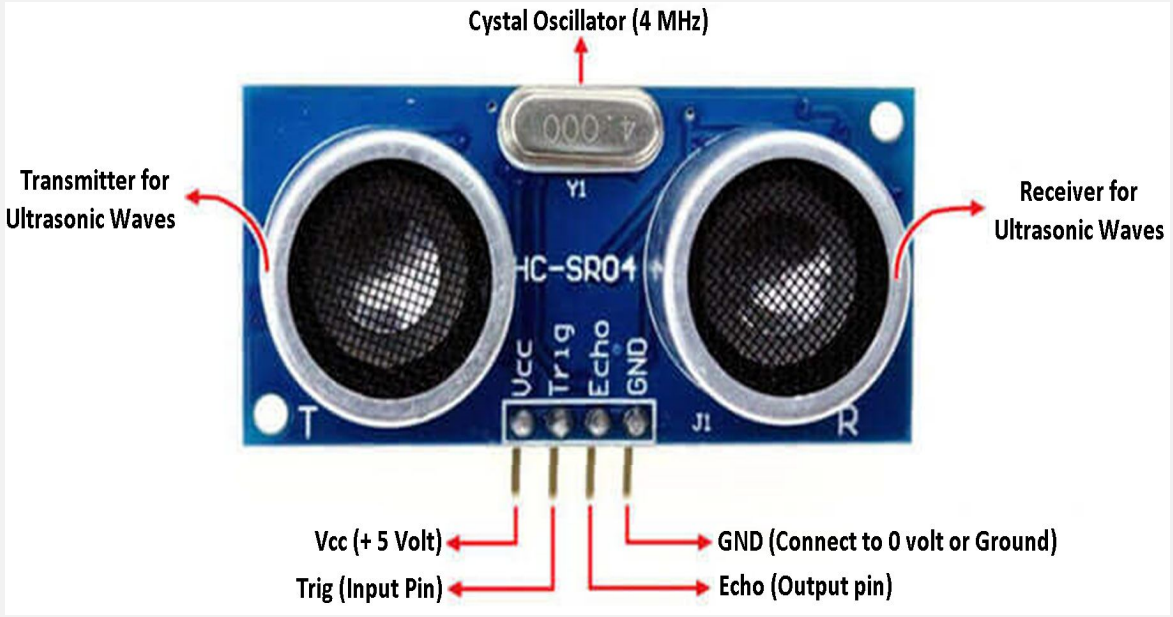


Price: Rs. 350 to 1200

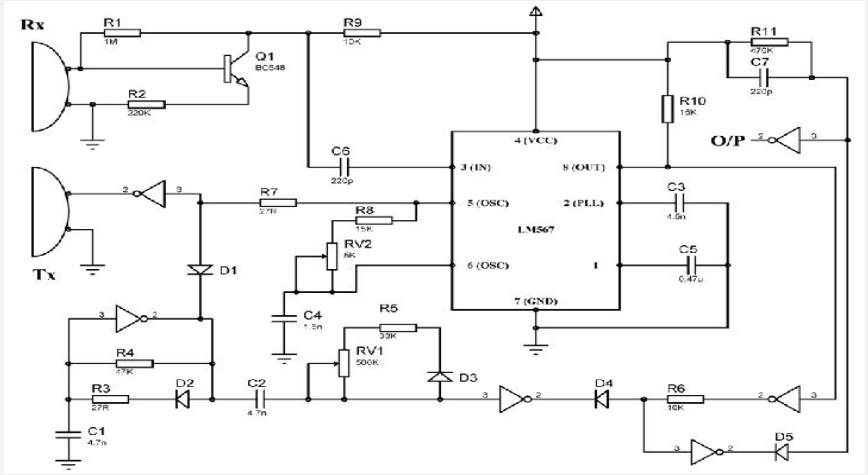
References:
1. https://circuitdigest.com/tutorial/different-types-of-sensors-and-their-working

Ultrasonic Sensor

An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves and converts the reflected sound into an electrical signal.



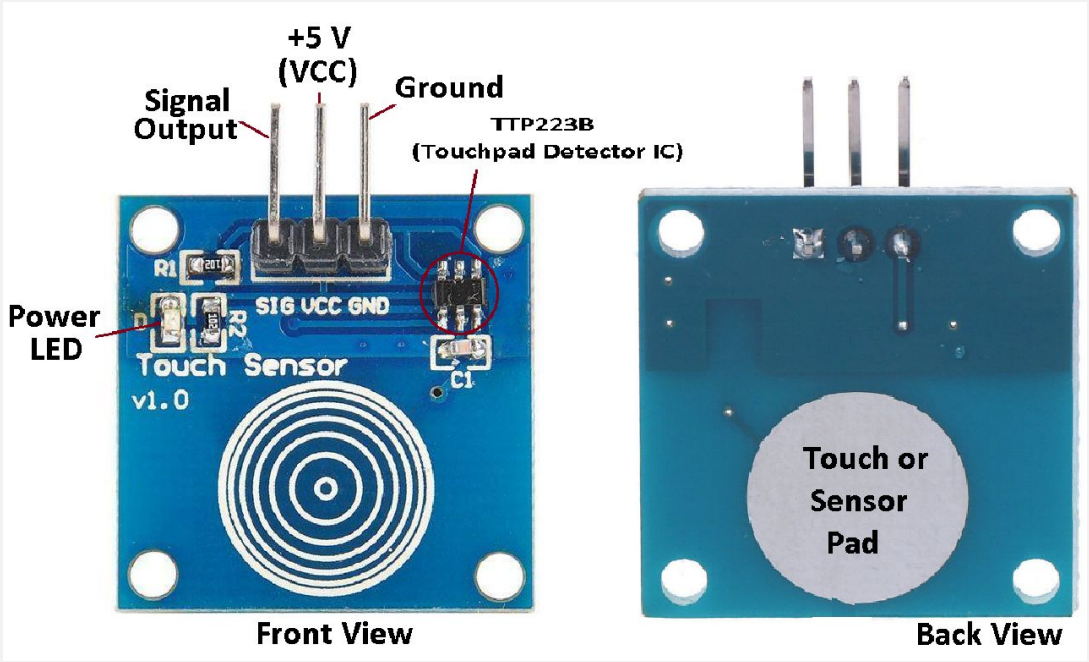
- Power Supply: DC 3.3 to 5V
- Working Current: 15mA
- Working Frequency: 40Hz
- Ranging Distance : 2cm – 400cm/4m or 13ft
- Resolution : 0.3 cm
- Measuring Angle: 15 degree
- Trigger Input Pulse width: 10uS



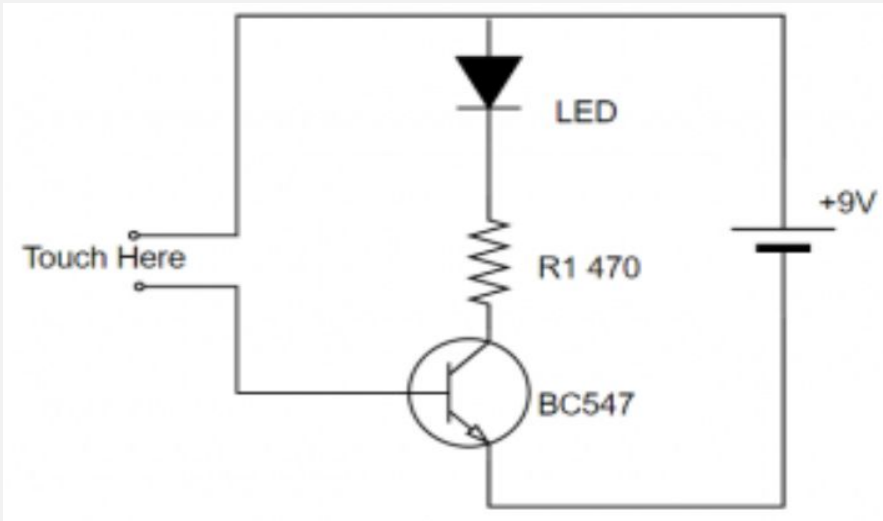
Price: Rs. 60 to 250

Touch Sensor

Touch Sensors are the electronic sensors that can detect touch. They operate as a switch when touched. These sensors are used in lamps, touch screens of the mobile, etc… Touch sensors offer an intuitive user interface.



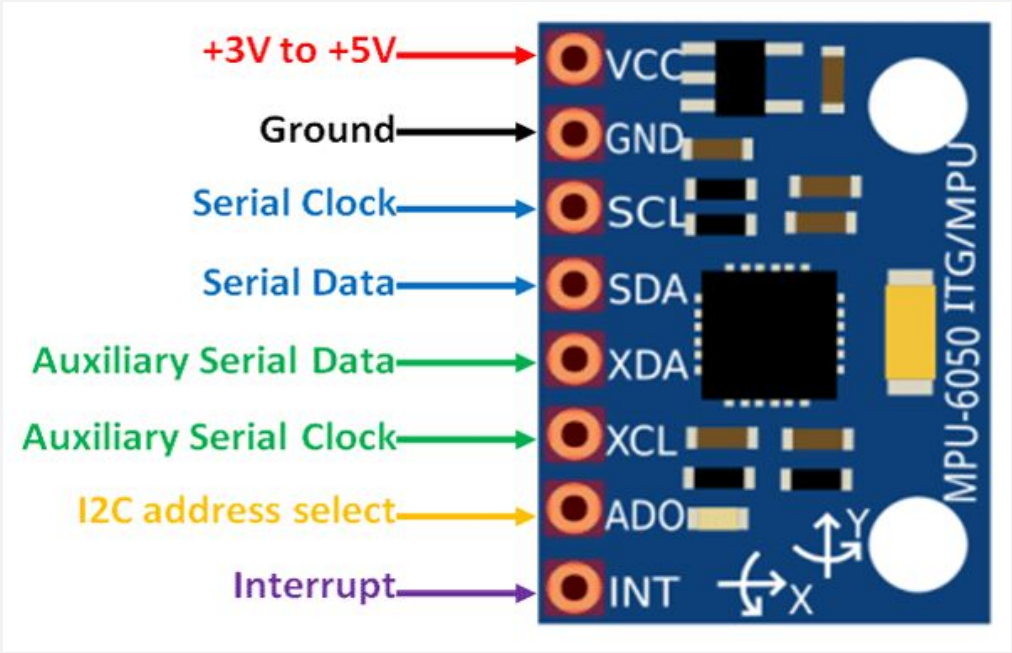
- Working Voltage Range: 2V to 5.5V
- Output high VOH: 0.8VCC
- Output low VOL: 0.3VCC
- On-board TTP223 capacitive touch sensor



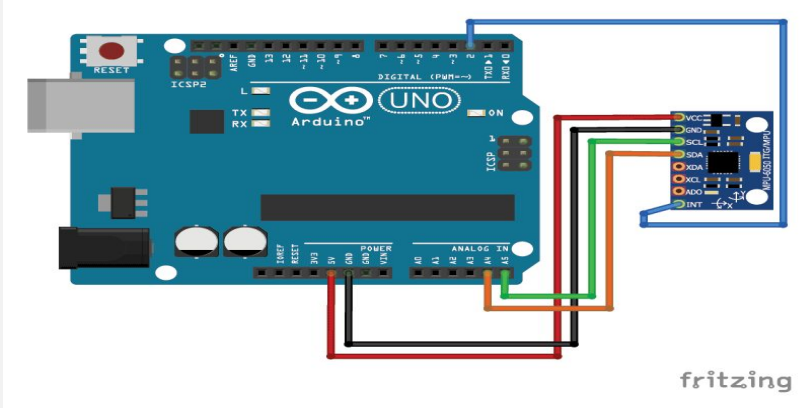
Price: Rs. 20 to 120

Accelerometer Sensor

Accelerometer is a type of sensor that is used to detect changes in position, velocity, and vibration by sensing motion. It can be either analog or digital type. In analog accelerometer, depending on volume of acceleration applied to accelerometer, continuous analog voltage signal is produced.



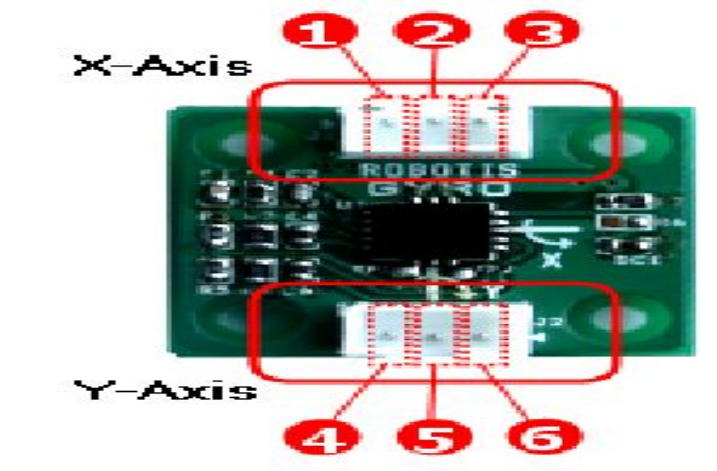
- Model: MPU6050
- Working Voltage Range: 3V to 5V
- Sensitivity at
  - XOUT =270 mV/g
  - YOUT = 300 mV/g
  - ZOUT = 330 mV/g



Price: Rs. 100 to 350

Gyroscope Sensor

A gyroscope sensor is a device that can measure and maintain the orientation and angular velocity of an object. These are more advanced than accelerometers. These can measure the tilt and lateral orientation of the object.



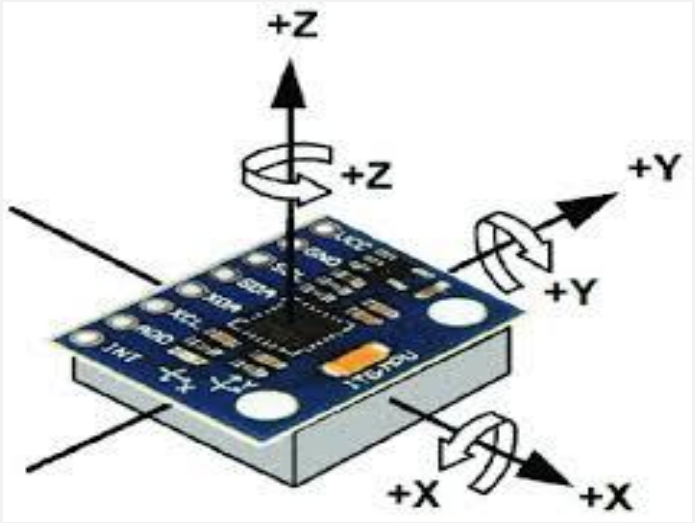
- Working Temperature : -40°C ~ 85°C
- Angular Velocity Calculation Range : -300°/s ~ 300°/s
- Bandwidth : 140Hz
- Sensitivity : 3.33mV/dps
- Recommended Voltage Supply : 4.5 ~ 5.5 V

•X & Y Axis Pin

1 & 6: ADC : Outputs the angular velocity into analog signals.

2 & %: Ground (GND)

3 &4: VCC (5 Volt)

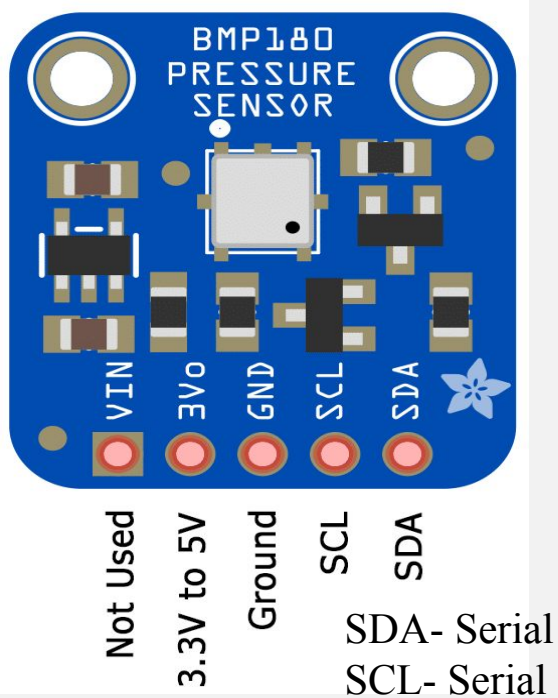


Price: Rs. 300 to 1850

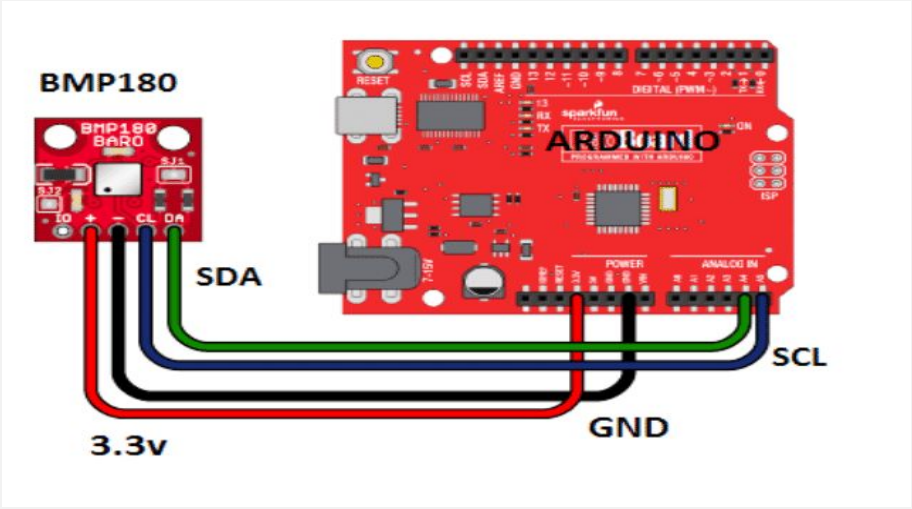
Pressure Sensor

A pressure sensor is a device for pressure measurement of gases or liquids. The pressure is an expression of the force required to stop a fluid from expanding and is usually stated in terms of force per unit area. A pressure sensor usually acts as a transducer; it generates a signal as a function of the pressure imposed.

- Operating voltage of BMP180: 1.3V – 3.6V
- Input voltage of BMP180MODULE: 3.3V to 5.5V
- Consumes 0.1uA standby
- Maximum voltage at SDA , SCL : VCC + 0.3V



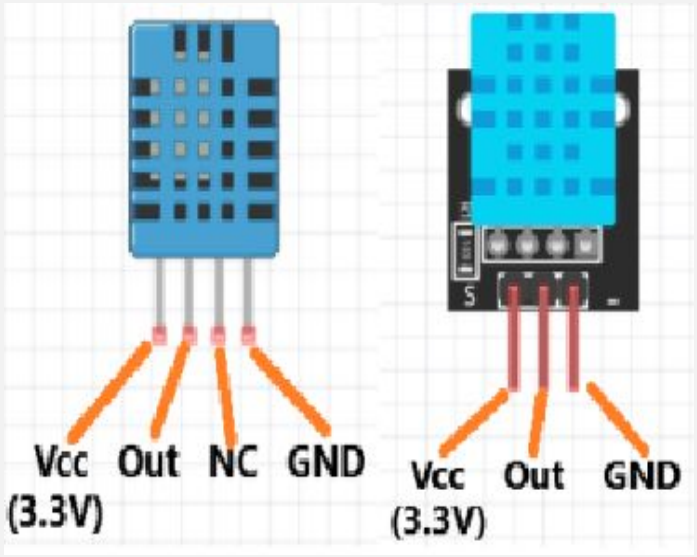
SDA- Serial data line
SCL- Serial clock line



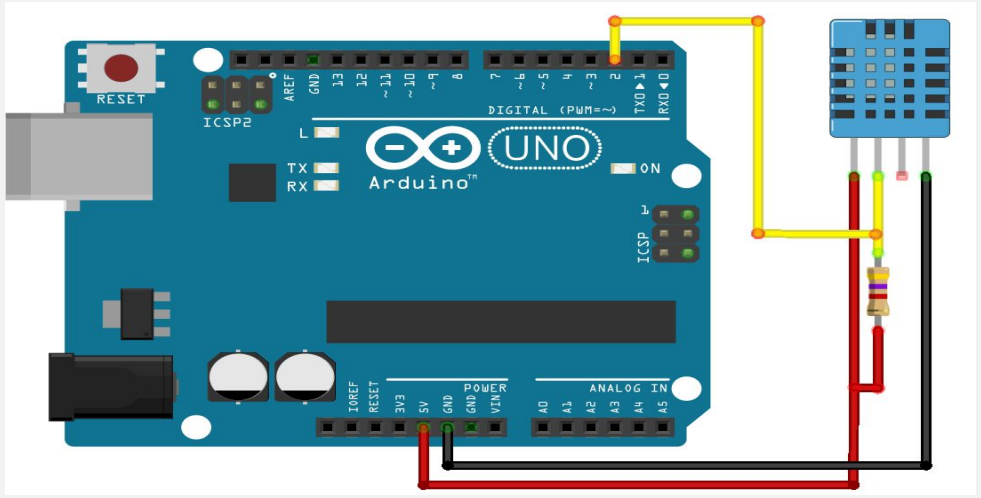
Price: Rs. 1200 to 3000

Humidity Sensor

Humidity sensors measure relative humidity (a ratio of water content in air to maximum potential of air to hold water). Since relative humidity is dependent on temperature of air, almost all Humidity Sensors can also measure Temperature.



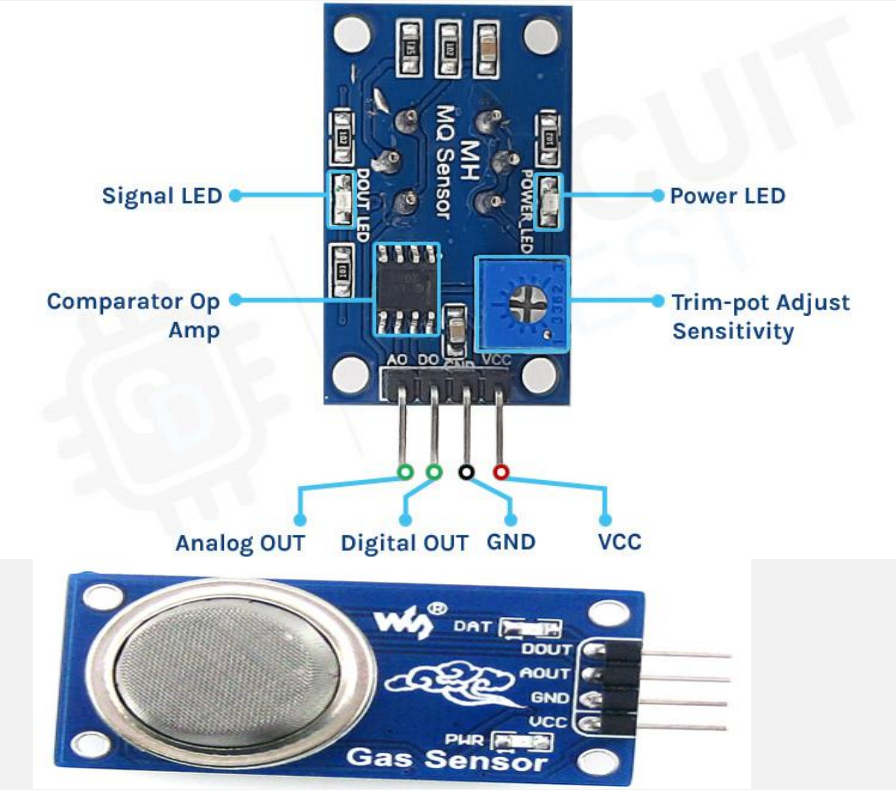
- Operating Voltage: 3.5V to 5.5V
- Operating current: 0.3mA (measuring) 60uA (standby)
- Output: Serial data
- Temperature Range: 0°C to 50°C
- Humidity Range: 20% to 90%
- Average Sending Period: 2 seconds



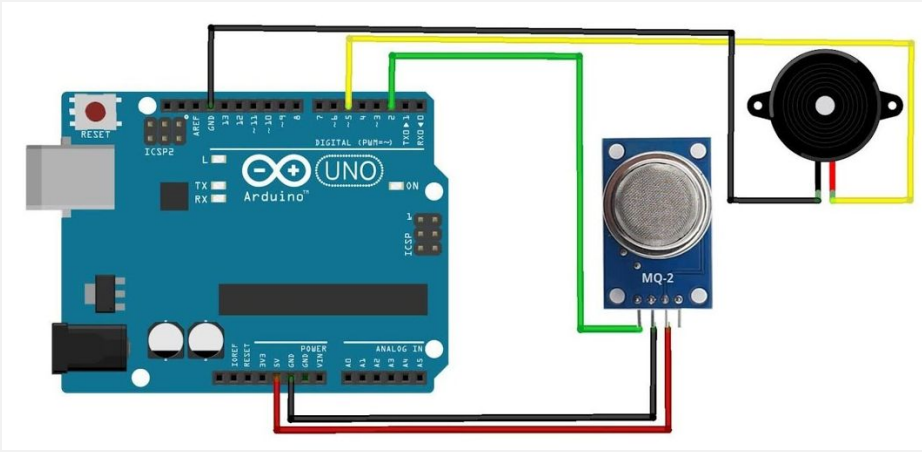
Price: Rs. 200 to 350

Smoke and Gas Sensor

Gas sensors (also known as gas detectors) are electronic devices that detect and identify different types of gasses. They are commonly used to detect toxic or explosive gasses and measure gas concentration.



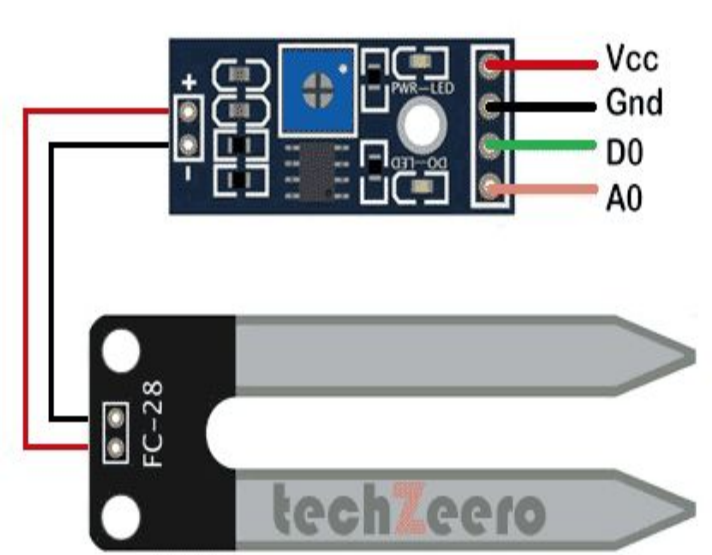
- Operating voltage 5V
- Load resistance 20 KΩ
- Heater resistance 33Ω ± 5%
- Heating consumption <800mw
- Sensing Resistance 10 KΩ – 60 KΩ
- Concentration Range 200 – 10000ppm



Price: Rs. 150 to 250

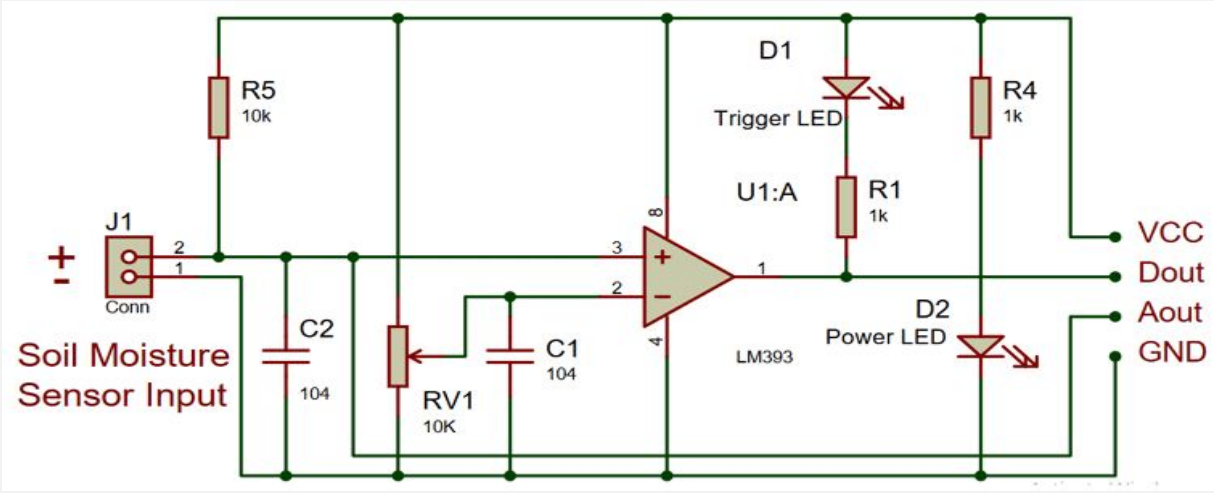
Soil Moisture Sensor

The soil moisture sensor is a kind of sensor used to measure the volumetric content of water within the soil.



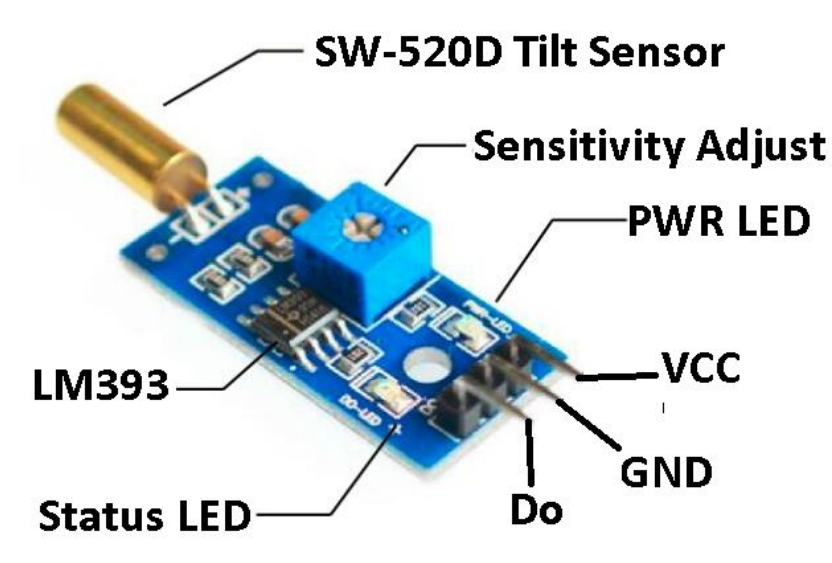
- Operating Voltage: 3.3V to 5V DC
- Operating Current: 15mA
- Output Digital - 0V to 5V, Adjustable trigger level from preset
- Output Analog - 0V to 5V based on infrared radiation from fire flame falling on the sensor

Price: Rs. 50 to 200

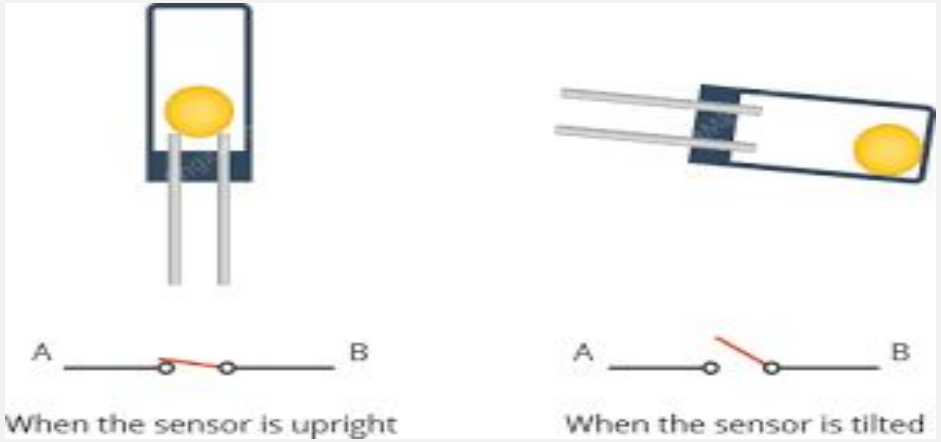


Tilt Sensor

A tilt sensor is an instrument that is used for measuring the change in tilt and monitoring of inclination and vertical rotation in vertical structures. The tilt sensor produces an electrical signal which is proportional to the degree of tilt in multiple axes. (Uniaxial & Biaxial)



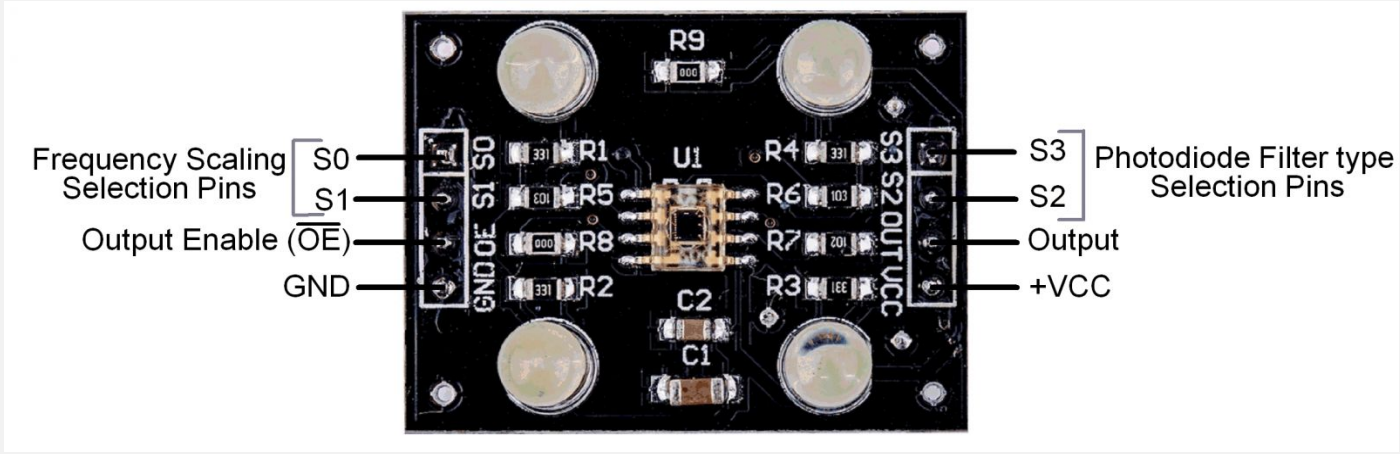
- Supply voltage: 3.3 V to 5V
- Output can directly connected to controller
- TTL level output
- Maximum output current : 15mA
- Maximum operating temperature: 0°C to + 80°C

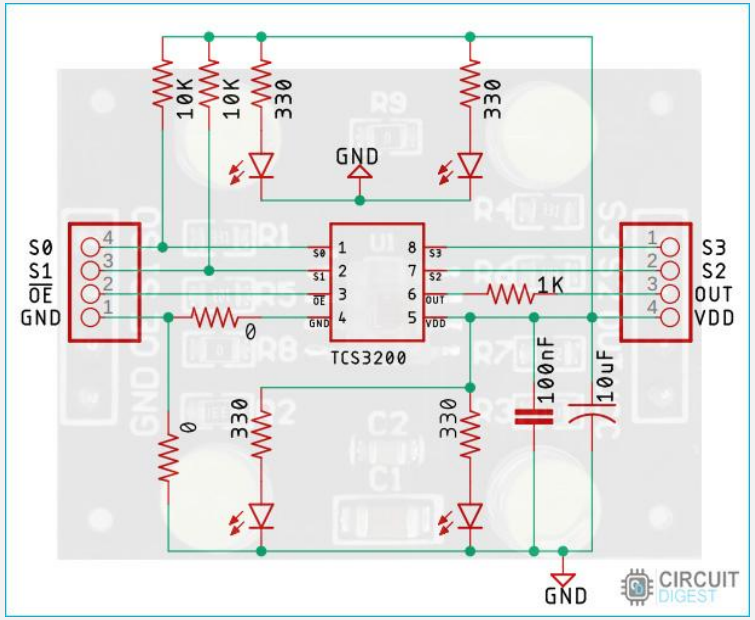


Price: Rs. 50 to 150

Color Sensor

A Color Sensor is an useful device in building color sensing applications in the field of image processing, color identification, industrial object tracking etc. The TCS3200 is a simple Color Sensor, which can detect any color and output a square wave proportional to the wavelength of the detected color.



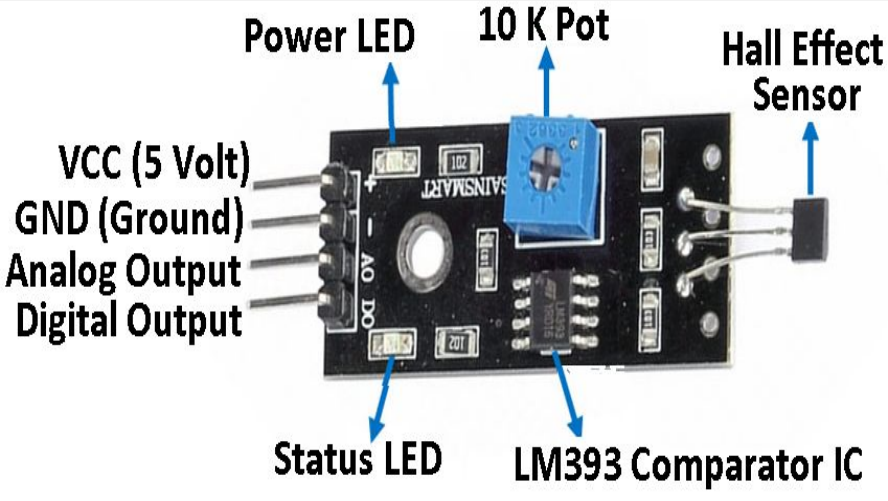


- Operating voltage range of 2.7V to 5.5V
- Operating temperature range of -40°C to 85°C
- Output frequency range of 0KHz to 2.7KHz
- High sensitivity to a wide range of colors

Price: Rs. 120 to 450

Hall Effect sensor

The sensor that works on principle of magnetic effect is called Hall Effect sensor. Magnetic field is the input and electrical signal is the output. Hall effect sensors are used for proximity sensing, positioning, speed detection, and current sensing applications.

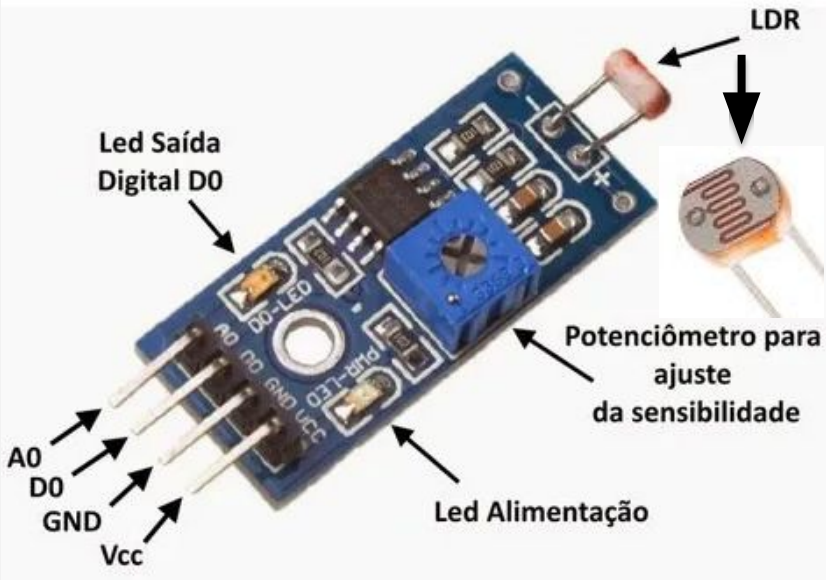


Price: Rs. 220 to 2450

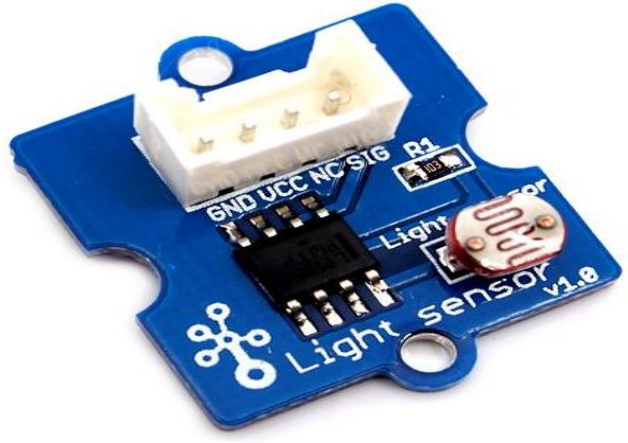
- Supply voltage (in V): 4.5 to 6 V
- Output type: linear or on/off
- Output resistance: 50 ohms
- Magnetic sensitivity (in Gs or T): at 5V – min: 0.75 mV/gauss – max 1.72 mV/gauss. Gauss being the sensitivity range for linear output sensors and T the tipping point for on/off sensors
- Polarity: unipolar or bipolar (sensitivity to the North or South Pole or both)
- Power supply current: 9 mA
- Operating temperature: – 20°C to + 85°C

Light Sensor

The sensor that works on principle of magnetic effect is called Hall Effect sensor. Magnetic field is the input and electrical signal is the output. Hall effect sensors are used for proximity sensing, positioning, speed detection, and current sensing applications.



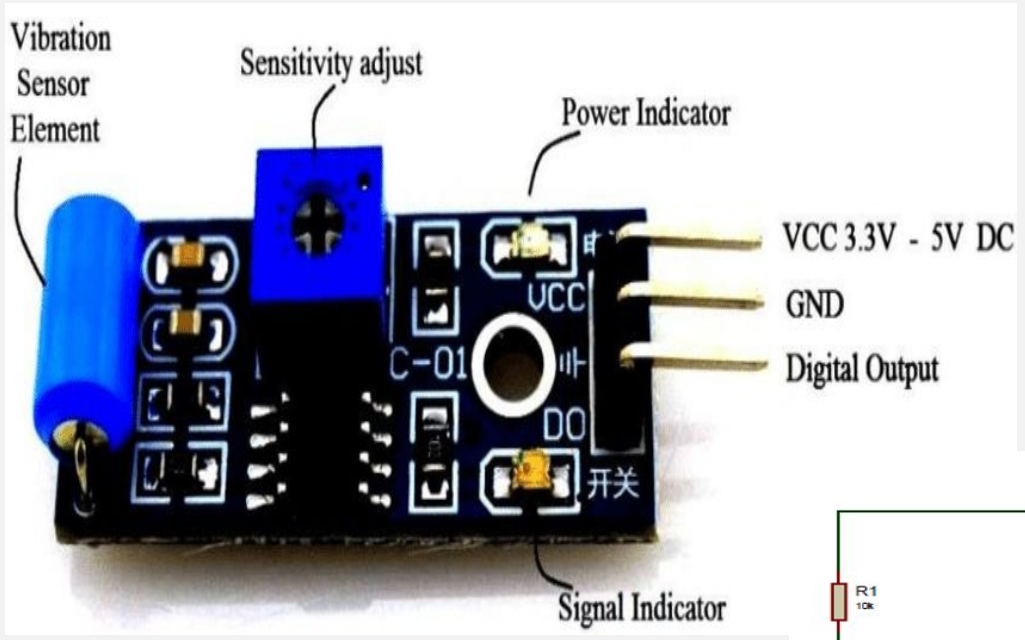
- Operating Voltage: 3.3V to 5V DC
- Operating Current: 15ma
- Output Digital - 0V to 5V, Adjustable trigger level from preset
- Output Analog - 0V to 5V based on light falling on the LDR



Price: Rs. 50 to 350

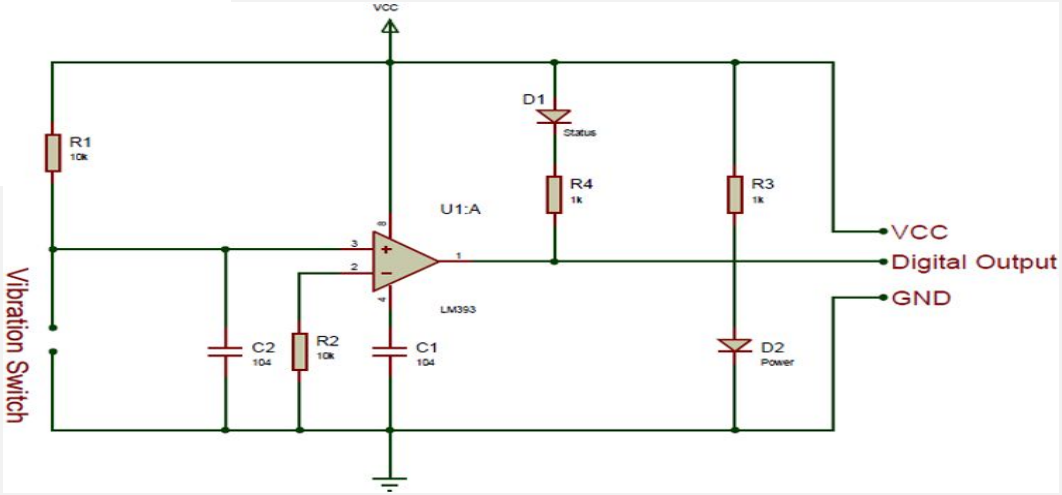
Vibration sensor

A vibration sensor is a device that detects and measures the vibration levels of objects or systems, converting these vibrations into electrical signals for monitoring and analysis.



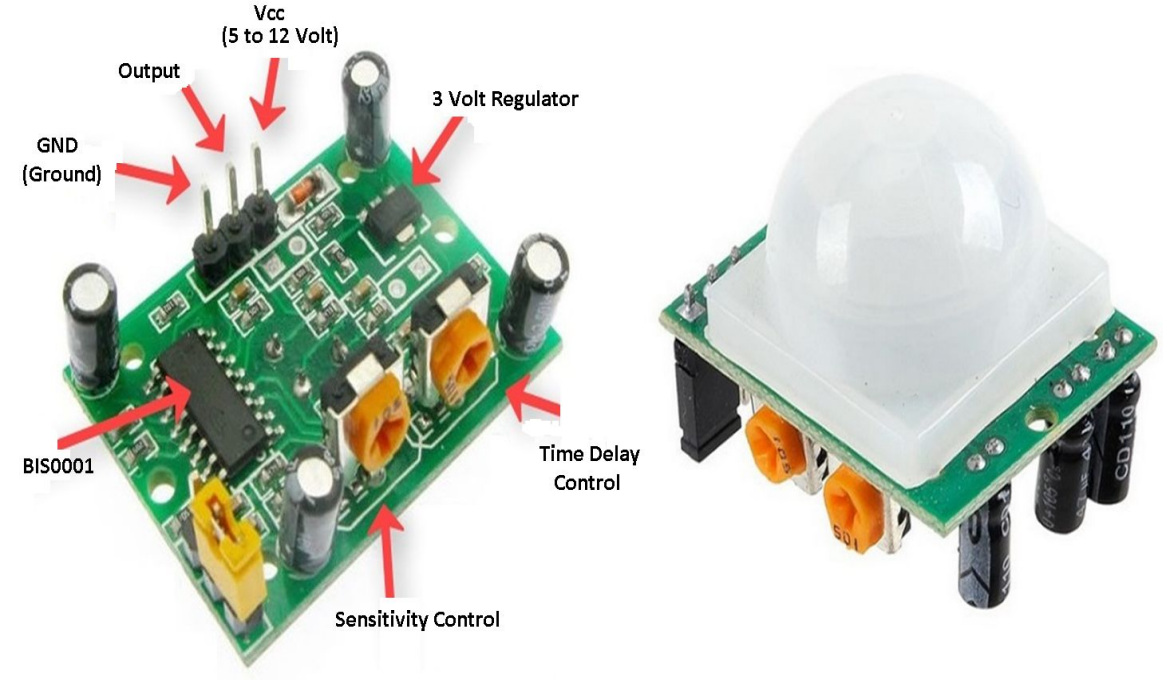
- Maximum working voltage (Vmax) : 12V
- Maximum current (Imax) : less than 5mA
- Open circuit resistance: more than 10 Ω
- On resistance: less than 5 Ω
- Ambient temperature: less than 100℃.
- Life expectancy: 5,00,000 times
- Response time: 2ms

Price: Rs. 50 to 300

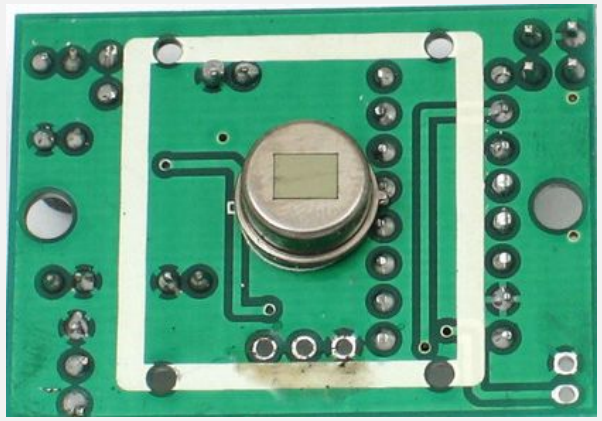


PIR motion detector sensor

A PIR (Passive Infrared) motion detector sensor is a device that detects motion by measuring the infrared (IR) radiation emitted by objects in its field of view. It is termed "passive" because it does not emit any radiation itself; instead, it only senses the infrared radiation.



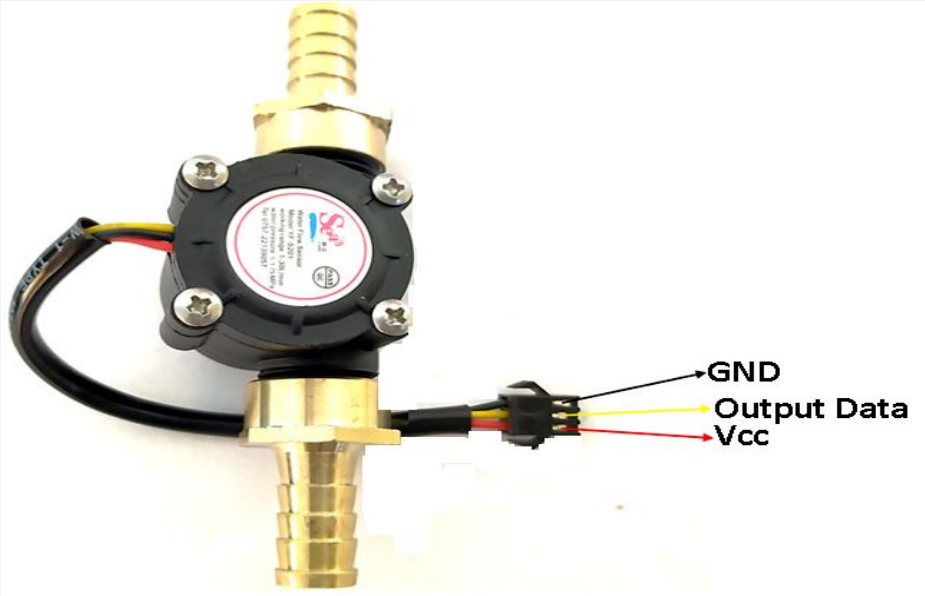
- Input Voltage: DC 4.5V to 20V
- Output Signal 0V / 3V (Output high when motion detected)
- Sensing Range: 7 meters (120 degree cone)
- Delay time: 8s to 200s (adjustable)
- Operating Temperature: -15℃ to +70℃



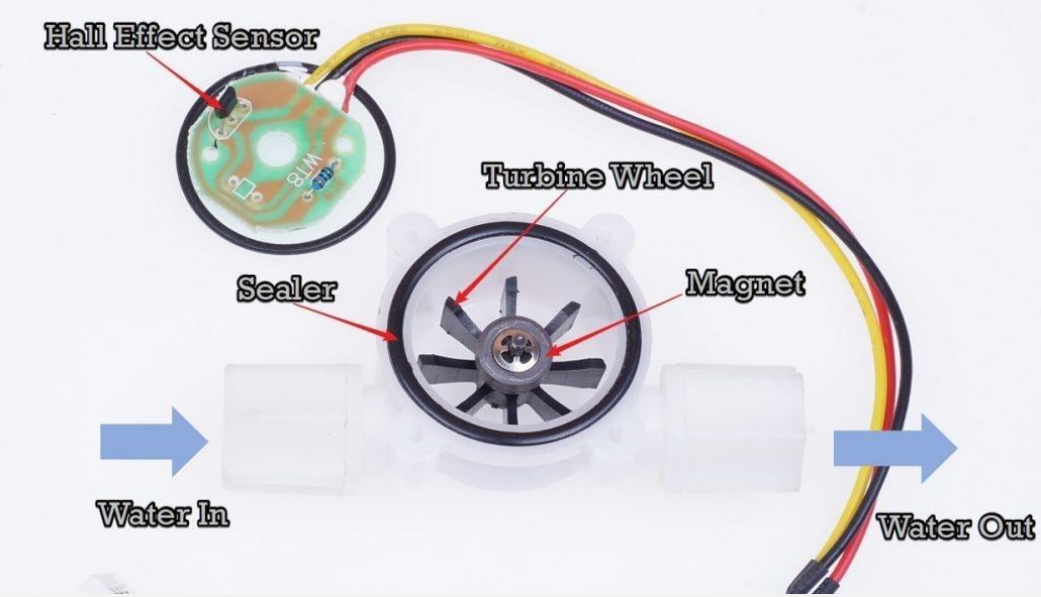
Price: Rs. 60 to 280

Flow Level Sensor

A flow sensor, also known as a flowmeter, is a device used to measure the flow rate or quantity of a fluid (liquid or gas) passing through a pipe or channel. It can provide various types of measurements, including the flow rate, total volume, and sometimes even the velocity of the fluid.



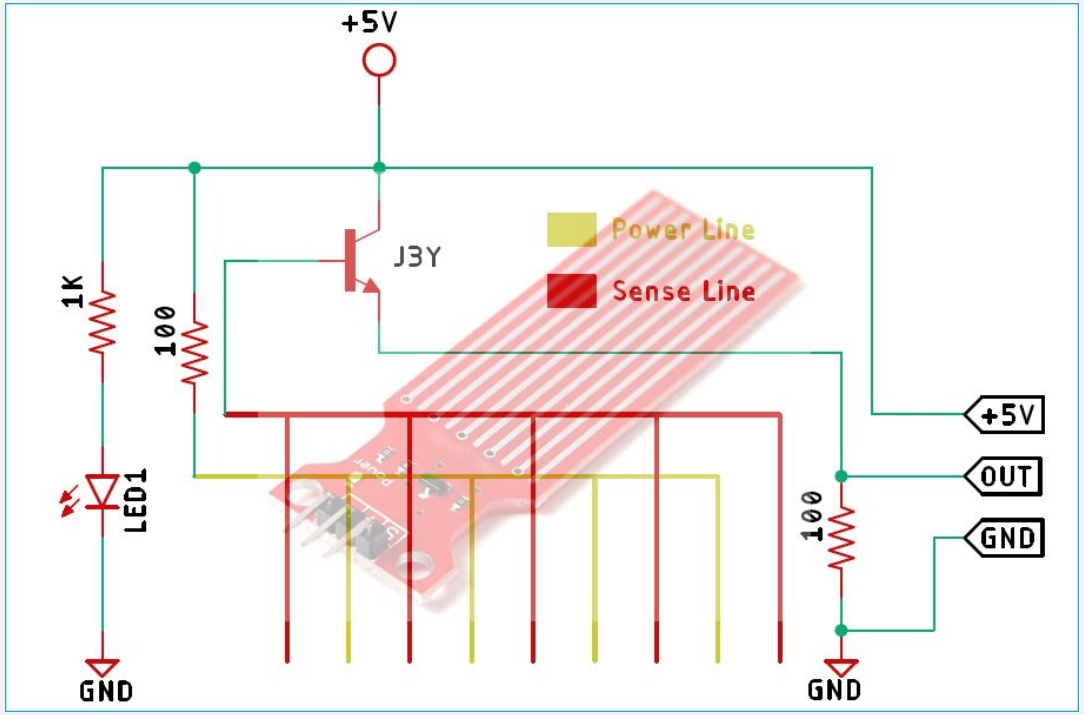
- Working Voltage: DC 5V to15V
- Interface Dimensions: G1/2Inch
- Flow Rate Range: 1 to 25L/min
- Water Pressure: ≤1.75MPa



Price: Rs. 3800 to 5000

Level Sensor

A level sensor is a device used to measure the level or height of a substance within a container or space. This substance can be a liquid, solid, or slurry. Level sensors are used to monitor and control the amount of material in tanks, silos, bins, and other storage vessels.



- Operating voltage: DC 3 to 5V
- Operating current: less than 20mA
- Sensor Type: Analog
- Detection Area: 40mmx16mm
- Operating temperature: 10℃ to 30℃
- Humidity: 10% to 90% non-condensing

Price: Rs. 20 to 80

Function of Actuators in IoT

- **Data Processing:** An IoT gateway or cloud–based platform processes the data acquired by sensors.
- **Decision Making:** Based on the desired consequence or action, the processed data is assessed and decisions are made.
- **Action:** Based on the decisions made in step 3, the IoT system sends signals to the actuators to conduct particular actions. An actuator, for example, may activate a motor to control the movement of a robotic arm or change the position of a valve to control the flow of water.
- **Feedback:** The actuators may provide feedback to the IoT system, such as confirmation that an operation was successfully done or an error message indicating that an action could not be completed.

References:
1. https://www.tutorialspoint.com/actuators-in-iot

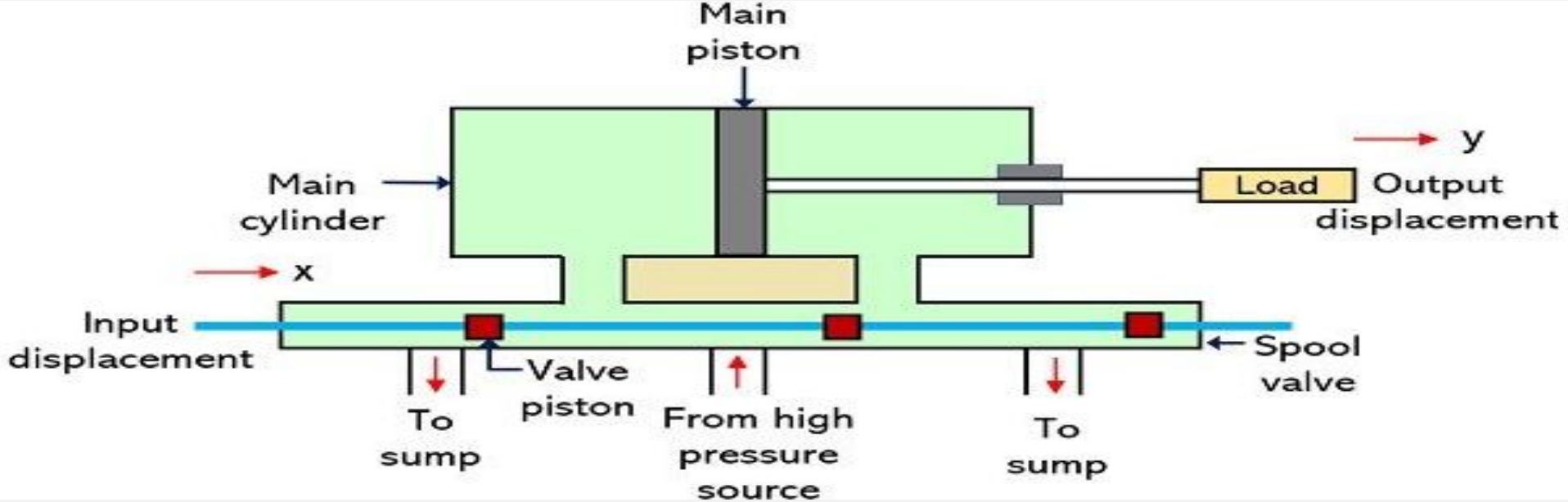
Types of Actuators

- Hydraulic Actuators
- Pneumatic Actuators
- Electrical Actuators
- Thermal Actuators
- Magnetic Actuators

References:
1. https://www.tutorialspoint.com/actuators-in-iot

Hydraulic Actuators

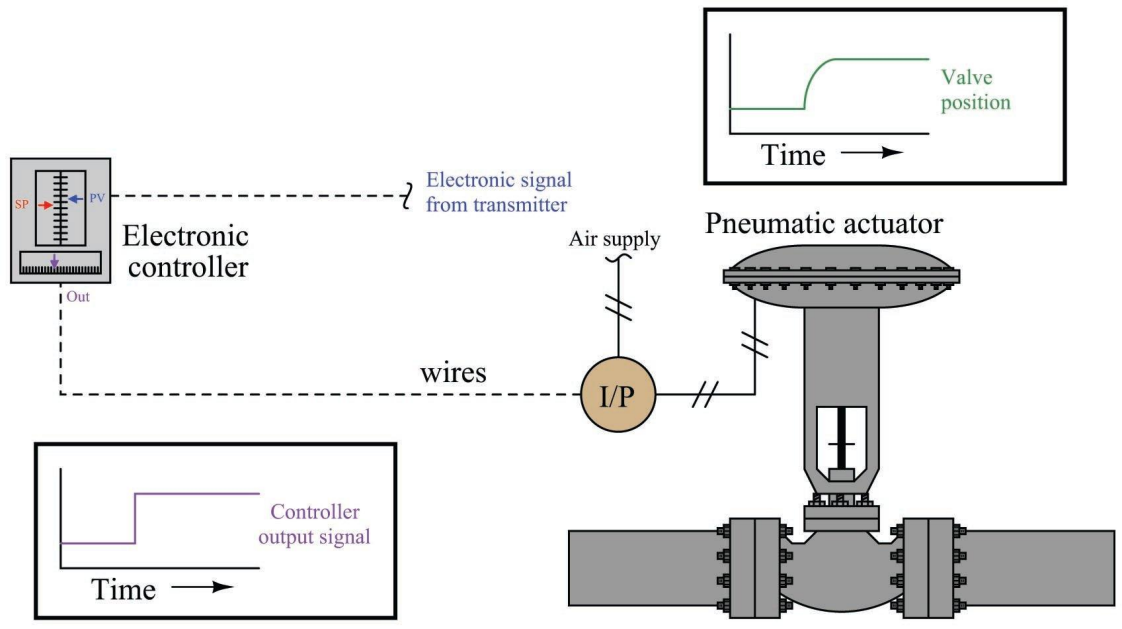
A hydraulic actuator is a mechanical device that converts hydraulic power into mechanical power. It typically includes a cylinder or fluid motor that operates through hydraulic pressure, resulting in rotary, linear, or oscillatory motion [1]. These actuators are commonly used in various applications, such as balers, cranes, excavators, loaders, and presses [2].

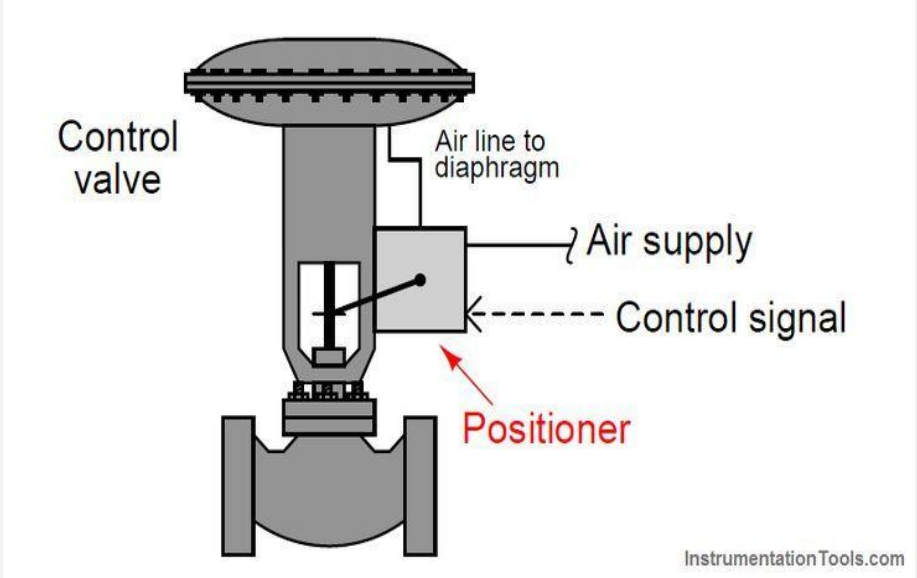


References:
1. https://www.elprocus.com/hydraulic-actuator/
2. https://www.maverickmachine.ca/news/hydraulic-actuators-101/

Pneumatic Actuators

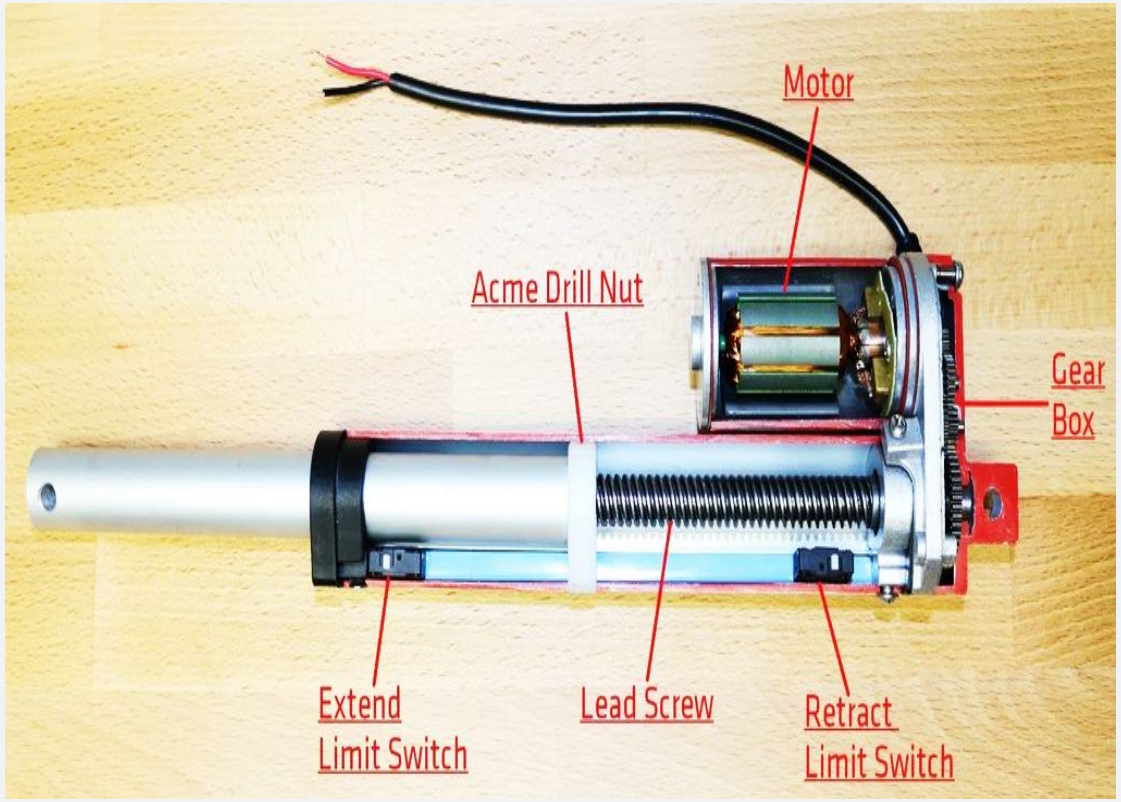
A pneumatic actuator is a device that converts energy, typically in the form of compressed air, into mechanical motion. This motion can be either linear or rotary, depending on the type of actuator used [1][2]. Pneumatic actuators are commonly known as pneumatic cylinders, air cylinders, or air actuators [1].





References:
1. https://www.processindustryforum.com/article/what-is-a-pneumatic-actuator
2. https://en.wikipedia.org/wiki/Pneumatic_actuator

Electric Actuators

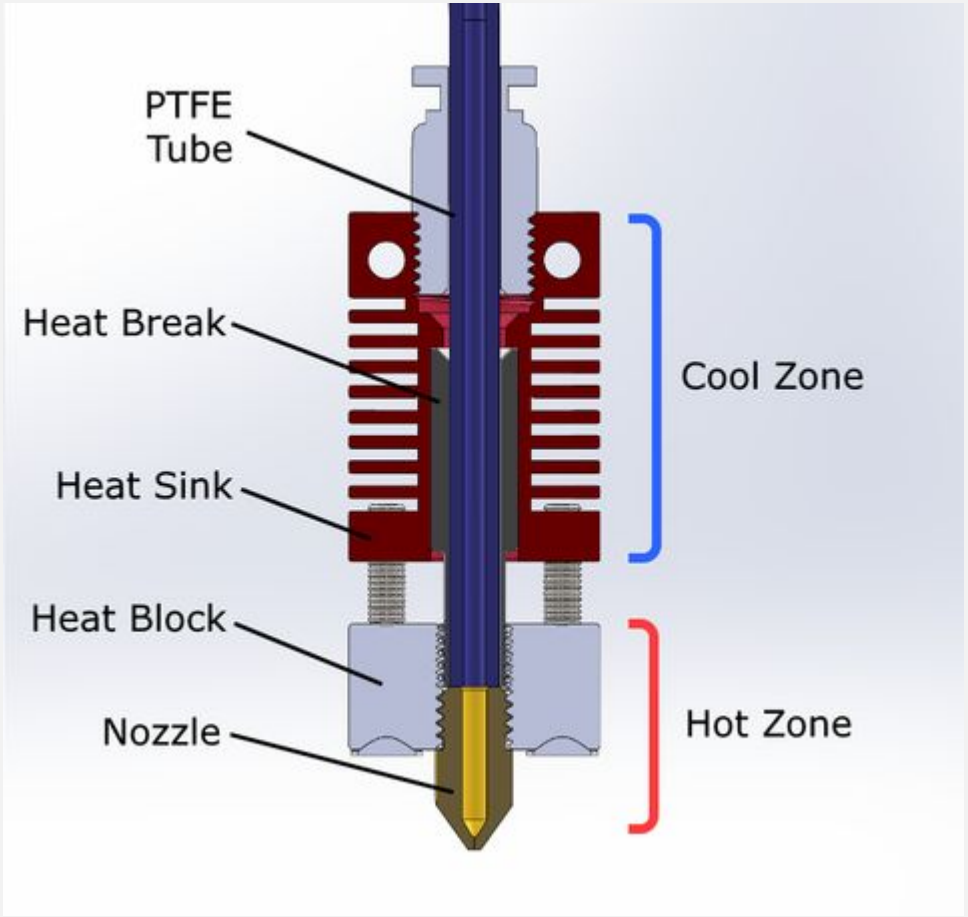


- An electric actuator is a device that converts electrical energy into mechanical motion. This motion can be either linear or rotary, depending on the design of the actuator.
- Electric actuators typically consist of an electric motor, a screw mechanism, and a feedback system.
- The electric motor generates rotary motion, which is then converted into linear motion through a screw mechanism. The feedback system ensures precise control of the actuator's position [1][2].

References:
1. https://www.norgren.com/en/support/blog/what-is-an-electric-actuator
2. https://en.wikipedia.org/wiki/Pneumatic_actuator

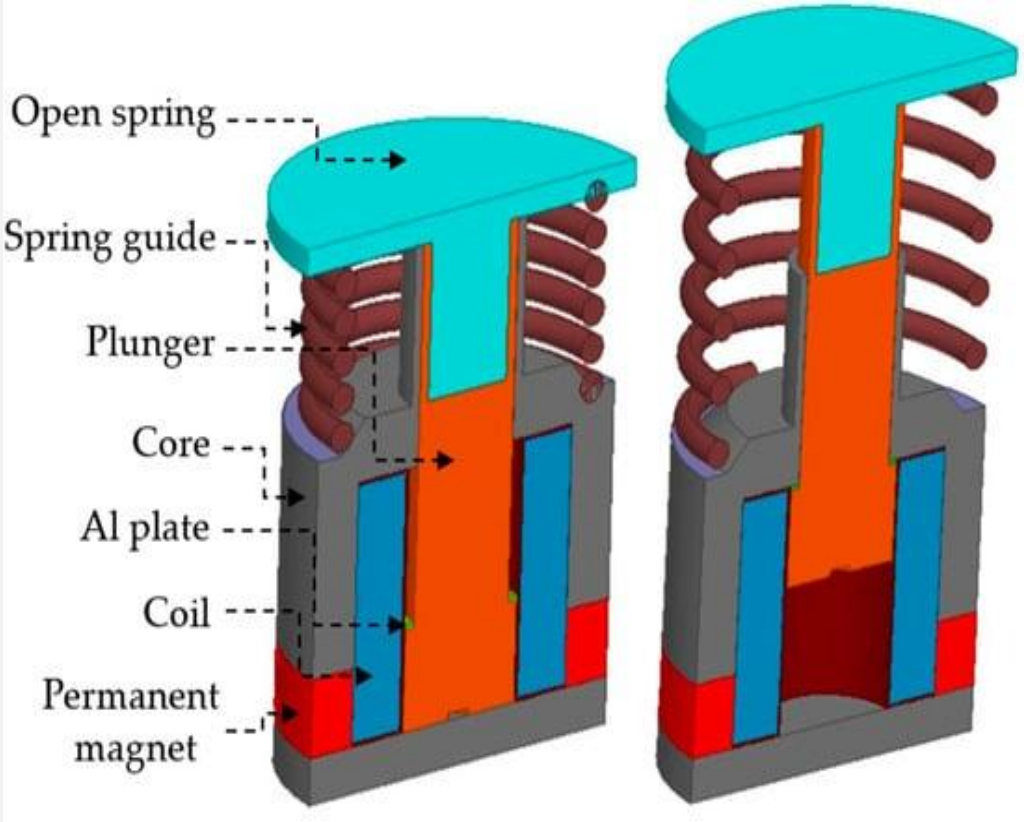
Thermal Actuators

- A thermal actuator is a mechanical system that converts thermal energy into kinetic motion.
- When the temperature rises, the temperature-sensitive material (such as wax) expands, pushing against the diaphragm.
- This pressure moves the piston within the guide.
- Conversely, when the temperature falls, the material contracts, allowing the piston to return to its original position.



References:
1. https://insights.globalspec.com/article/12034/how-do-thermal-actuators-work
2. https://link.springer.com/referenceworkentry/10.1007/978-94-017-9780-1_313

Magnetic Actuators



- Magnetic actuators are devices that utilize magnetic forces to generate motion.
- **Electromagnetic Actuators:** These common actuators rely on the interaction between electric currents and magnetic fields. When an electric current flows through a coil, it generates a magnetic field. This field interacts with a permanent magnet or another coil, resulting in a force that moves a mechanism.
- **Thermal Magnetic Actuators:** These work differently. A magnetic material is heated to its Curie temperature, causing a shift in its magnetic properties. This change generates a force.

References:
1. https://www.electricity-magnetism.org/electromagnetic-actuator/
2. https://www.mdpi.com/journal/actuators/special_issues/ATAMA

Arduino

- Arduino is an open-source electronics platform based on easy-to-use hardware and software.
- It's designed to make it accessible for anyone to create interactive projects.
- Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an ED, publishing something online.
- The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.

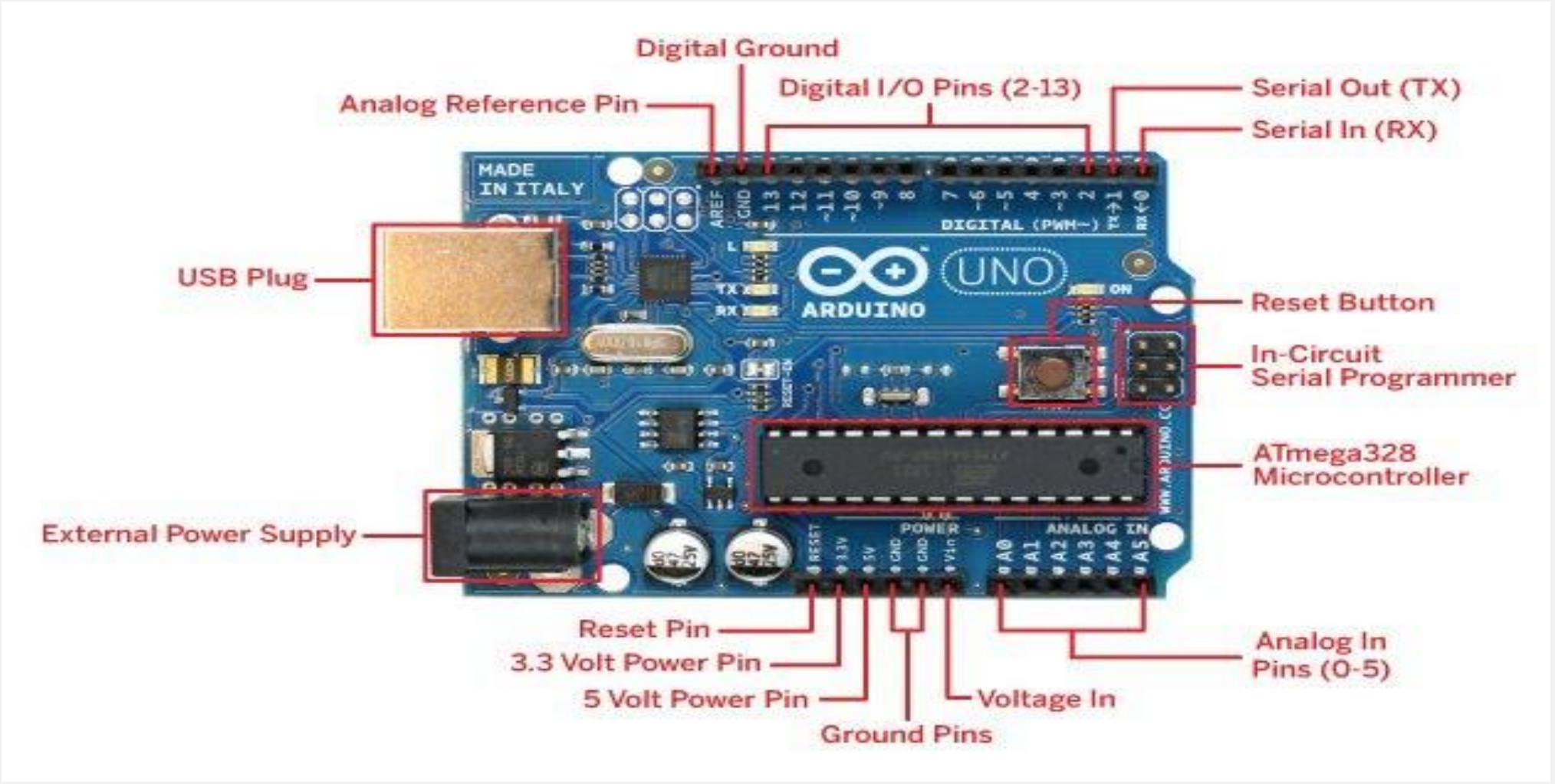
References:
1 https://docs.arduino.cc/learn/starting-guide/the-arduino-web-editor/

Key Components of Arduino

- Arduino Board: This is the physical hardware, a microcontroller board with various inputs and outputs.
- Arduino Software (IDE): This is the software used to write code for the Arduino board. It's user-friendly and doesn't require advanced programming knowledge.

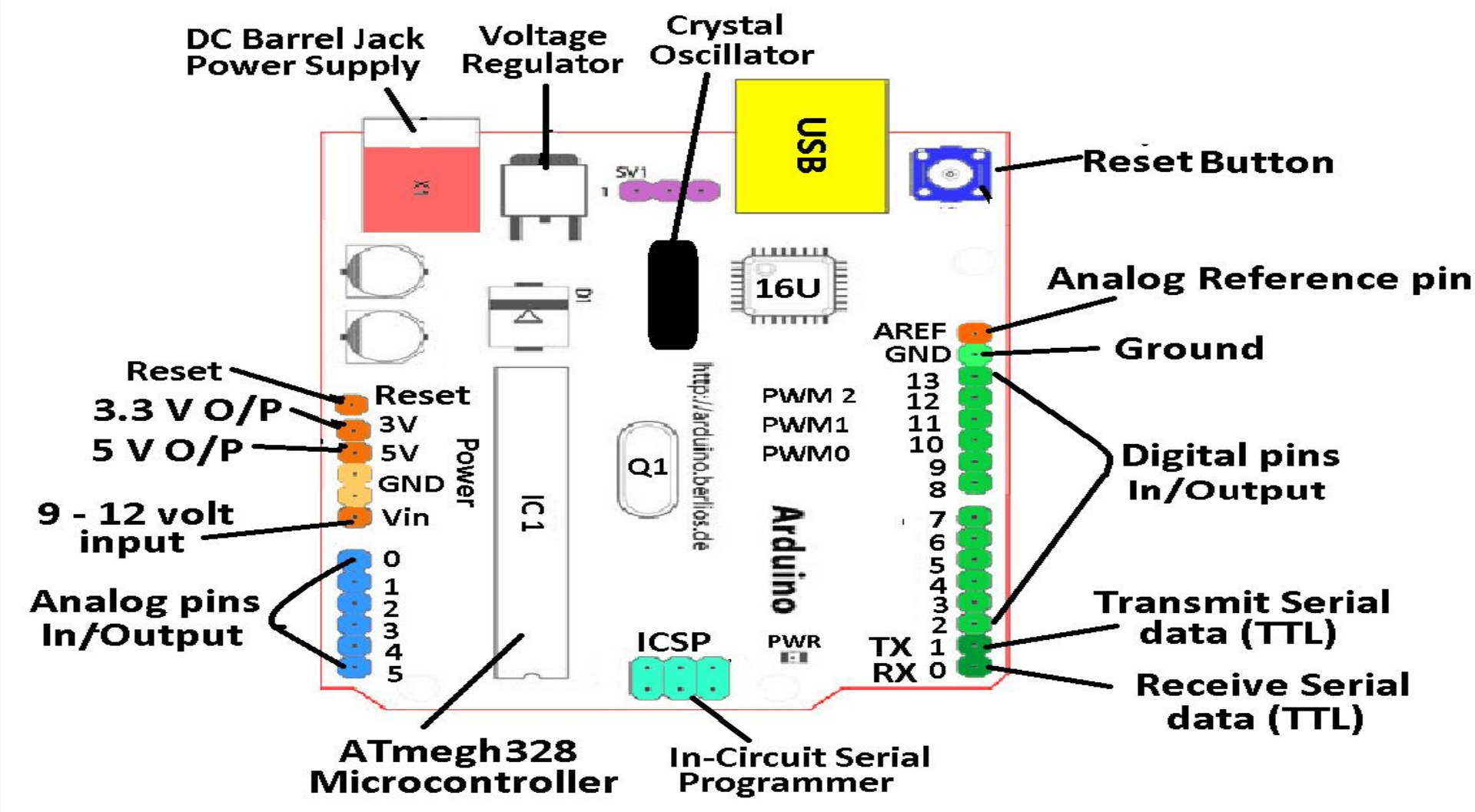
References:
1 https://docs.arduino.cc/learn/starting-guide/the-arduino-web-editor/

Arduino Board



References:
1 https://eeeproject.com/arduino-uno-board/

Arduino Pin Diagram



Arduino Digital Pins

- In addition to the specific functions listed below, the digital pins on an Arduino board can be used for general purpose input and output via the **pinMode(), digitalRead()**, and **digitalWrite()** commands.
- Each pin has an internal pull-up resistor which can be turned on and off using **digitalWrite()**, when the pin is configured as an input. The maximum current per pin is 40 mA.
- **Serial:** 0 (RX) and1 (TX). Used to receive (RX) and transmit (TX) TTL serial data.
  - On the Arduino Diecimila, these pins are connected to the corresponding pins of the FIDI USB-to-TTL Serial chip.
  - On the Arduino BT, they are connected to the corresponding pins of the WT11 Bluetooth module.
  - On the Arduino Mini and LilyPad Arduino, they are intended for use with an external TTL serial module (eg. the Mini-USB Adapter).

Continue…

- **Eternal Interrupts:** 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the **attachInterrupt()** function for details.
- **PWM:** 3,5, 6, 9, 10, and 11. Provide 8-bit PWM output with the **analogWrite()** function. On boards with an **ATmega8**, PWM output is available only on pins 9, 10, and 11.
- **BT Reset:** 7. (Arduino BT-only) Connected to the reset line of the Bluetooth module.
- **SPI:** 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language.
- **LED:** 13. hi On the Diecimua and LilyPad, there the is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it is off.

Arduino Analog Pins

- The analog input pins support 10-bit analog-to-digital conversion (ADC) using the **analogRead()** function.
- Most of the analog inputs can also be used as digital pins: analog input 0 as digital pin 14 through analog input 5 as digital pin 19. Analog inputs 6 and 7 (present on the Mini and BT) cannot be used as digital pins.
- **I2C (Inter-Integrated Circuit)**: 4 (SDA, Serial Data access) and 5 (SCL, Serial Clock Layer). Support 12C (TWI, Two-Wire Interface) communication.

Arduino Power Pins

- VIN (sometimes labelled "9 V"). The input voltage to the Arduino board when it is using an external power source.
  - You can supply voltage through this pin, Or, if supplying voltage via the power jack, access it through this pin.
  - Note that different boards accept different input voltages ranges, please see the documentation for your board. Also note that the LilyPad has no VIN pin and accepts only a regulated input.
- **5 V:** The regulated power supply used to power the microcontroller and other components on the board.
  - This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated5 V supply.
- **3V3:** (Diecimila-only) A 3.3 volt supply generated by the on-board FTDI (Future Technology Devices International Limited) chip.
- **GND:** Ground pins.

Arduino Other Pins

- **AREF:** Reference voltage for the analog inputs. Not currently supported by the Arduino software.
- **Reset:** Bring this line **LOW** to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.
- It has **14 digital** input/output pins (of which **6** can be used as **PWM** outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an **ICSP (in-circuit serial programming)** header, and a reset button.
- The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7 V, however, the 5 V pin may supply less than five volts and the board may be unstable.
- If using more than 12 V, the voltage regulator may overheat and damage the board.
- The recommended range is 7 to 12 volts.

Arduino Uno R3 Programming

- The programming of an Arduino Uno R3 can be done using IDE (**Integrated Development Environment**) software. The microcontroller on the board will come with pre-burned by a boot loader that permits to upload fresh code without using an exterior hardware programmer.
- The communication of this can be done using a protocol like STK500.
- We can also upload the program in the microcontroller by avoiding the boot loader using the header like the In-Circuit Serial Programming.

How Arduino works

- **Sense:** Arduino boards can read data from various sensors like light, temperature, or button presses.
- **Process:** The data is processed by the microcontroller based on the code you've written.
- **Act:** Arduino can control outputs like motors, LEDs, or displays based on the processed data.

References:
1 https://docs.arduino.cc/learn/starting-guide/the-arduino-web-editor/

Why Arduino is Popular

- **Easy to learn:** The simplified programming language and user-friendly IDE make it accessible for beginners.
- **Versatile:** Arduino can be used for a wide range of projects, from simple blinking LEDs to complex robots.
- **Open-source:** The hardware and software are freely available, encouraging creativity and innovation.
- **Large community:** There's a vast online community sharing projects, tutorials, and support.

References:
1 https://docs.arduino.cc/learn/starting-guide/the-arduino-web-editor/

Features of Arduino

Hardware Features

- **Microcontroller**: The heart of the Arduino board, responsible for processing data and controlling outputs.
- **Input/Output Pins:** Both digital and analog pins allow interaction with various sensors and actuators.
- **Power Supply:** Options for external power supply or USB connection.
- **USB Interface:** For programming and communication with a computer.
- **Reset Button:** To restart the board.
- **Expandable:** Additional components can be connected using headers and shields.

References:
1 https://docs.arduino.cc/learn/starting-guide/the-arduino-web-editor/

Features of Arduino

Software Features

- **Open-source:** Both hardware and software are freely available.
- **Easy-to-use IDE:** The Arduino Integrated Development Environment (IDE) provides a user-friendly interface for writing and uploading code.
- **Easy to learn**: The simplified programming language (Based on C++) and user-friendly IDE make it accessible for beginners.
- **Large Community:** A vast online community offers support, tutorials, and project ideas.
- **Cross-platform Compatibility:** Works on Windows, macOS, and Linux.
- **Libraries:** A rich collection of pre-written code for various functions.

References:
1 https://docs.arduino.cc/learn/starting-guide/the-arduino-web-editor/

Features of Arduino

General Features

- **Versatility:** Can be used for a wide range of projects, from simple electronics to robotics and IoT applications.
- **Low Cost:** Affordable boards and components.
- **Rapid Prototyping:** Quickly test and iterate on project ideas.
- **Educational:** Excellent platform for learning electronics and programming.
- **Large community:** There's a vast online community sharing projects, tutorials, and support.

References:
1 https://docs.arduino.cc/learn/starting-guide/the-arduino-web-editor/

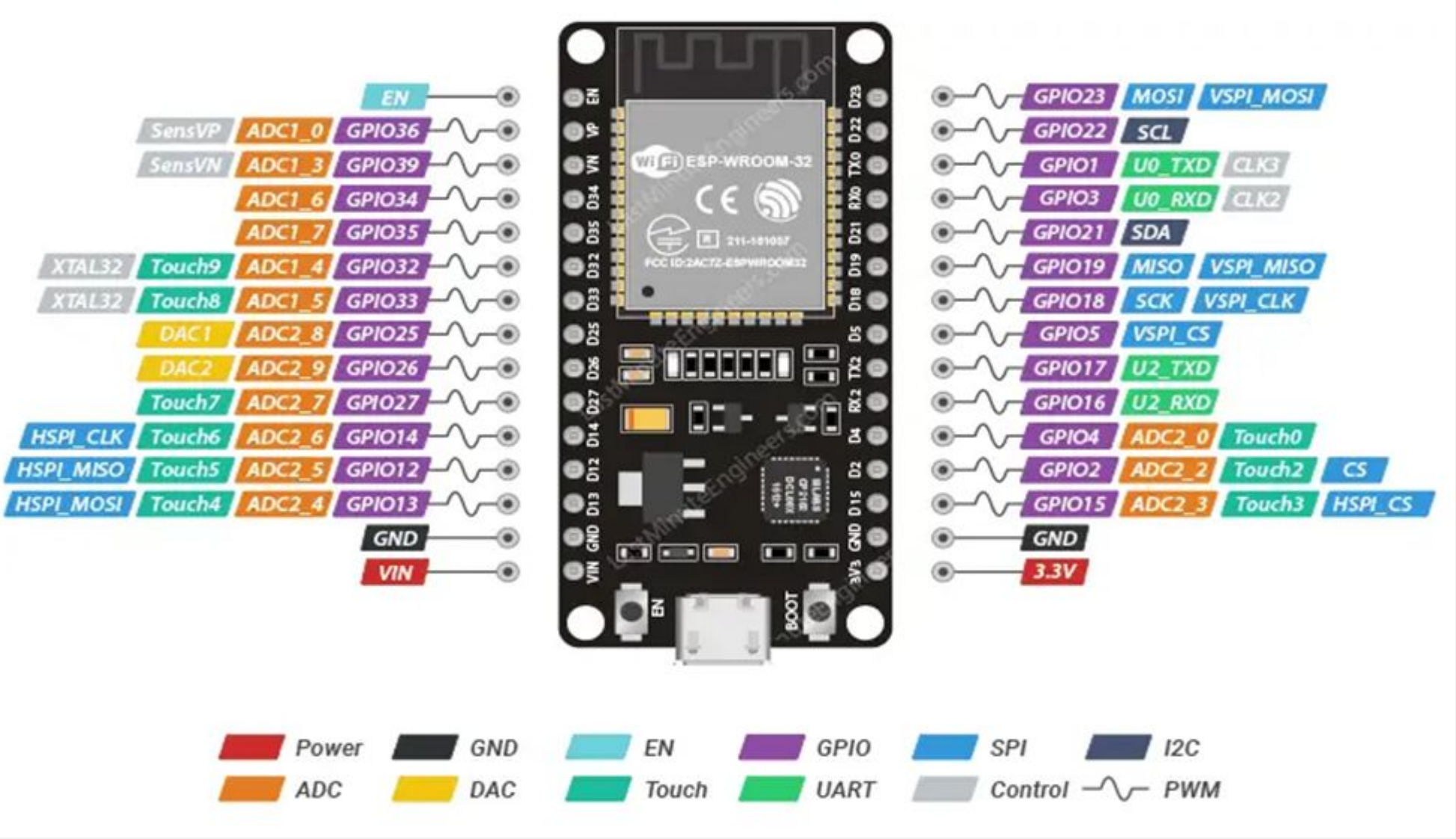
NodeMCU-ESP32

- The ESP32 is a low-cost, low-power system-on-chip (SoC) microcontroller with integrated Wi-Fi and Bluetooth capabilities.
- Developed by Espressif Systems, the ESP32 is designed for use in a wide range of applications, including IoT (Internet of Things), home automation, wearable electronics, and more.
- It features dual-core or single-core variants, a high level of integration, and multiple GPIO pins, making it a versatile choice for developers and hobbyists alike.

Features of NodeMCU-ESP32

- **Wireless Connectivity**: Integrated 2.4 GHz Wi-Fi and Bluetooth (classic and BLE) for seamless communication in IoT and wireless projects.
- **Processing Power**: Equipped with a dual-core 32-bit Xtensa LX6 CPU, running at up to 240 MHz, with up to 520 KB SRAM and 4 MB Flash memory.
- **Versatility**: Supports a wide range of peripherals, including UART, SPI, I2C, and ADC, allowing for diverse applications and easy integration with sensors and other components.
- **Power Efficiency**: Designed with multiple power-saving modes, making it suitable for battery-powered devices and energy-sensitive applications.
- **Development Support**: Extensive software support, including the ESP-IDF (Espressif IoT Development Framework) and compatibility with the Arduino IDE, ensuring a broad developer community and abundant resources.

NodeMCU-ESP32 Pin Diagram



Working of NodeMCU-ESP32

1. **Data Collection**: The ESP32 collects data from connected sensors (e.g., temperature, humidity, motion) through its GPIO pins and various communication interfaces like SPI, I2C, or ADC.
2. **Processing**: The dual-core processor of the ESP32 processes the collected data, allowing for real-time decision-making or preprocessing before transmission. It can also run algorithms to filter, analyze, or compress the data.
3. **Wireless Communication**: The ESP32 uses its integrated Wi-Fi or Bluetooth modules to connect to the internet or other devices, transmitting data to cloud servers, mobile apps, or other networked devices.

Continue…

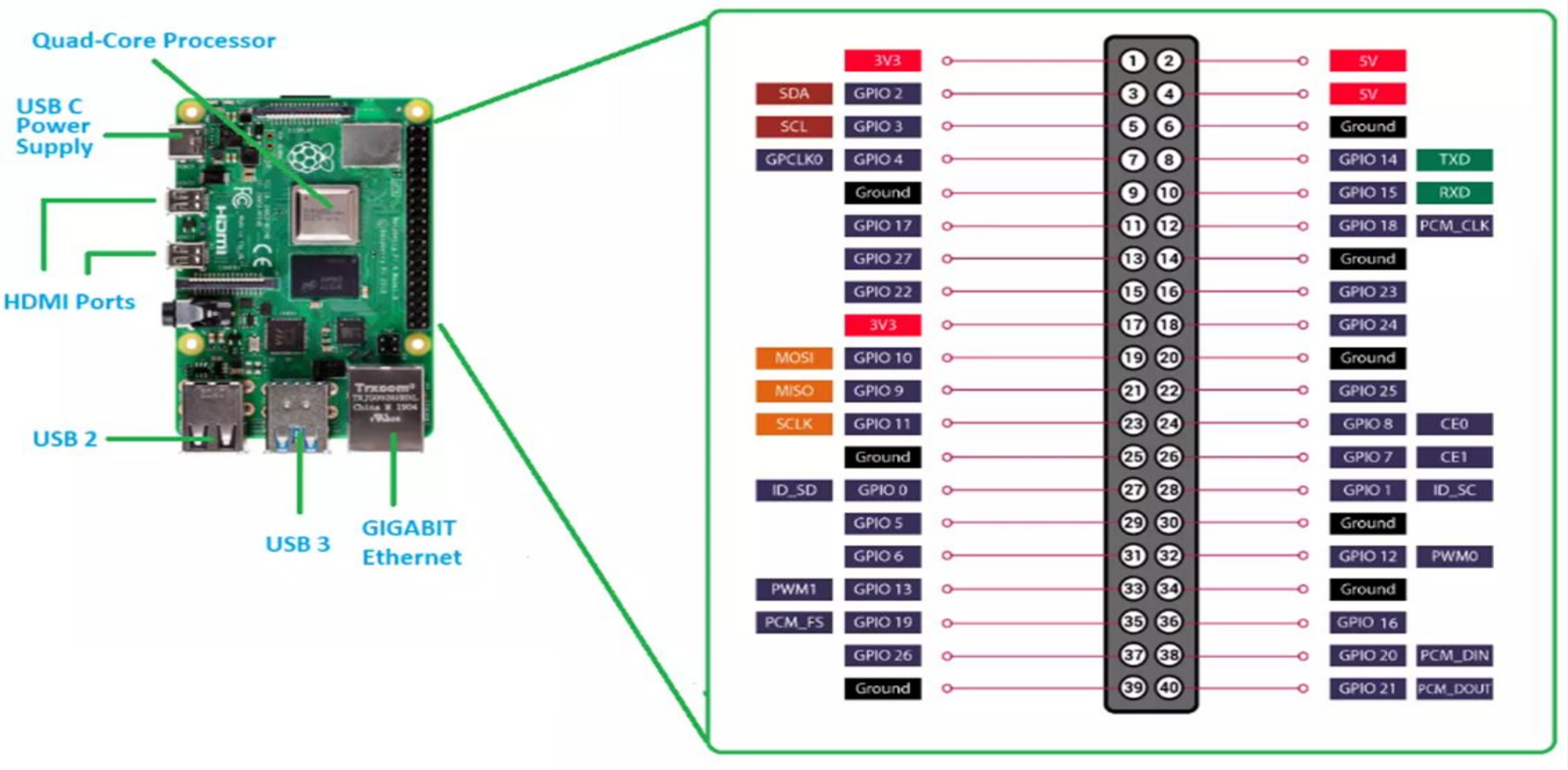
4. **Remote Control and Monitoring**: Through the internet, users can remotely monitor the data collected by the ESP32 and send control commands back to the device, enabling real-time interaction with the IoT system.
5. **Power Management**: The ESP32 optimizes power consumption using its various sleep modes, which is crucial for battery-powered IoT devices. This extends the device's operational life in the field.
6. **Integration with IoT Platforms**: The ESP32 can interface with popular IoT platforms (e.g., AWS IoT, Google Cloud IoT) to store, analyze, and visualize data, enabling complex IoT solutions with cloud-based services.

Raspberry Pi

- The Raspberry Pi 4 Model B is a powerful single-board computer renowned for its versatility and compact size, offering significant advancements over microcontrollers like Arduino and ESP32.
- Boasting a quad-core ARM Cortex-A72 processor running at up to 1.5GHz, it provides ample computing power for a range of applications.
- Raspberry Pi 4 supports a full-fledged operating system like Raspberry Pi OS (formerly Raspbian), facilitating a wide array of programming languages including Python, C/C++, and more.
- Its rich hardware interface includes multiple USB ports, HDMI output for displays, GPIO pins for hardware interfacing, and Ethernet connectivity, making it ideal for both standalone projects and IoT applications requiring network connectivity and multimedia capabilities.

References:
1 https://www.raspberrypi.com/documentation/computers/getting-started.html

Raspberry Pi 4B Pin Diagram



Features of Raspberry Pi

- **Processor**: It features a 1.5 GHz 64-bit quad-core ARM Cortex-A72 CPU, offering significant performance improvements over previous models.
- **Memory Options**: Available in 2GB, 4GB, and 8GB LPDDR4 RAM variants, allowing for various use cases from simple tasks to more demanding applications.
- **USB Ports**: Equipped with two USB 3.0 ports and two USB 2.0 ports, providing faster data transfer and connection to a wide range of peripherals.
- **Networking**: Includes Gigabit Ethernet, dual-band 802.11ac Wi-Fi, and Bluetooth 5.0, ensuring robust and versatile connectivity options.
- **Storage**: Uses a microSD card for storage, but also supports booting from USB 3.0-connected SSDs for faster performance.
- **GPIO Pins**: It has a 40-pin GPIO header, making it ideal for hardware projects, prototyping, and IoT applications.
- **Power**: Powered via a USB-C connector, with a requirement of 5V/3A for stable operation, especially with peripherals connected.
- **Software**: Supports various operating systems, including Raspberry Pi OS, Ubuntu, and other Linux distributions, making it versatile for different projects.

References:
1 https://www.raspberrypi.com/documentation/computers/getting-started.html

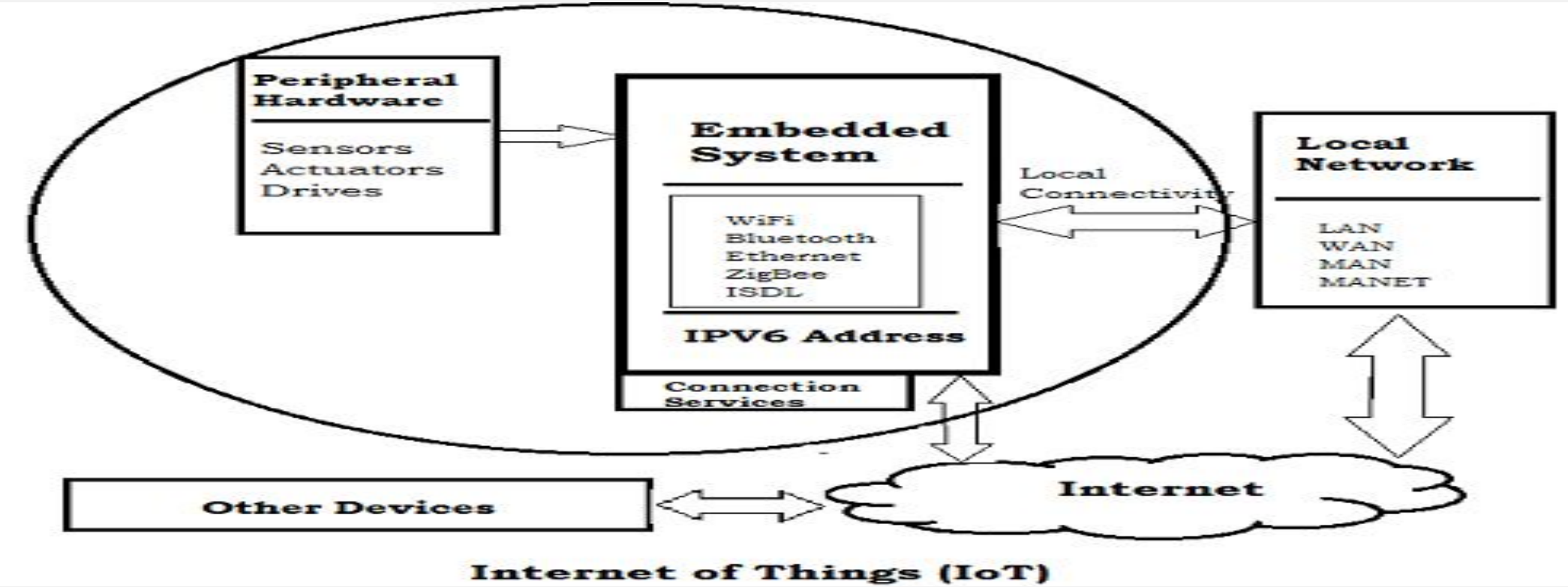
Working of Raspberry Pi

- The Raspberry Pi is a compact, affordable computer that runs on an ARM-based microprocessor and typically uses a Linux-based operating system like Raspberry Pi OS. It functions like a regular computer, with storage provided by an SD card and memory through built-in RAM.
- It offers various connectivity options, including USB ports, HDMI for display, and both wired and wireless networking. These features allow users to connect peripherals like keyboards, mice, and monitors, making it versatile for different tasks.
- A standout feature is its GPIO pins, which enable the Raspberry Pi to interact with external hardware, making it ideal for DIY projects and IoT applications. Its low cost and simple power requirements make it popular for education and hobbyist use.

References:
1 https://www.raspberrypi.com/documentation/computers/getting-started.html

Embedded IoT System

- The embedded devices are the objects that build the unique computing system. These systems may or may not connect to the Internet.
- An embedded device system generally runs as a single application. However, these devices can connect through the internet connection, and able communicate through other network devices.



References:
1. https://www.javatpoint.com/iot-embedded-devices

An embedded IoT system consists of the following key components:

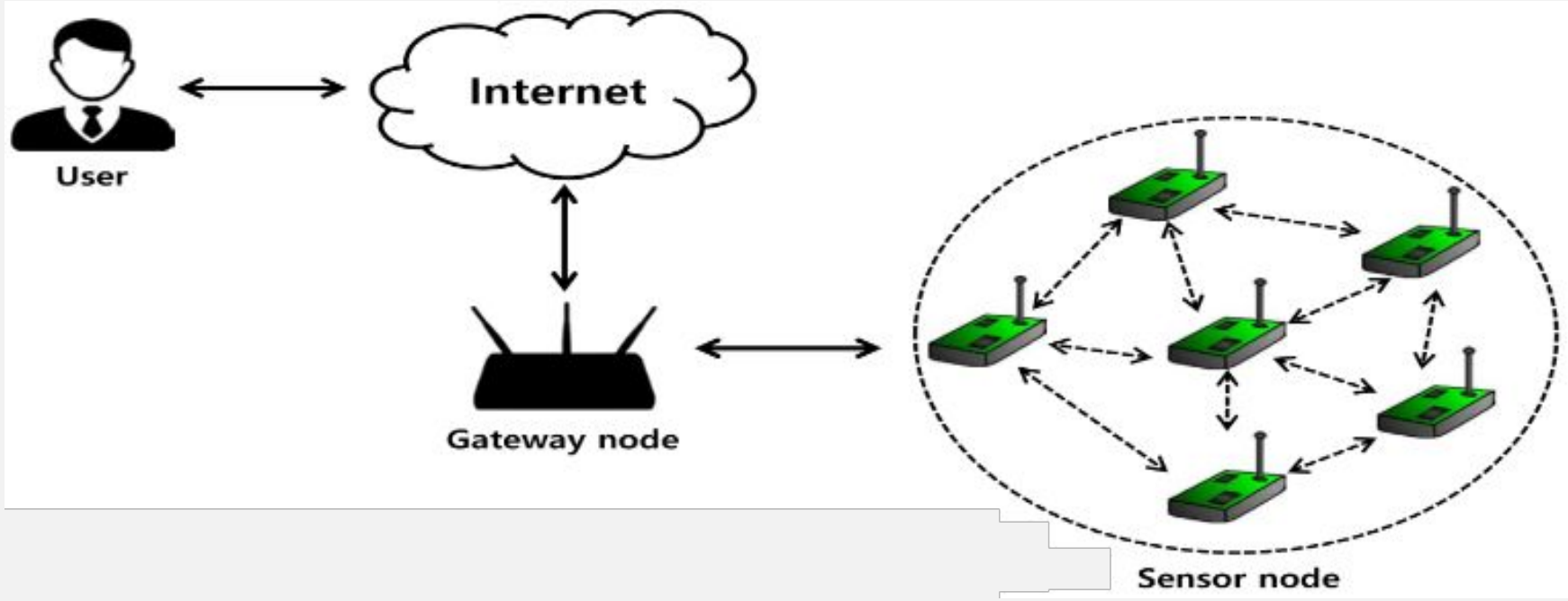
1. **Microcontroller/Microprocessor**: Acts as the brain, processing data and controlling other components.
2. **Sensors**: Gather data from the environment, such as temperature, humidity, or motion.
3. **Actuators**: Perform actions in response to data, like turning on a light or opening a valve.
4. **Embedded Software/Firmware**: Specialized code that runs on the microcontroller, managing tasks and operations.
5. **Connectivity Module**: Enables communication with other devices and networks, typically through Wi-Fi, Bluetooth, or cellular networks.
6. **Power Supply**: Provides the necessary power for the system, often through batteries or direct electrical connections.
7. **Memory**: Stores data and instructions for the system, including both volatile (RAM) and non-volatile memory (Flash).
8. **Communication Interface**: Manages the interaction between the device and external systems, including protocols like MQTT, HTTP, or CoAP.

Real World Examples:

1. **Smart Thermostats (e.g., Nest)**: These devices adjust home heating and cooling based on user preferences and environmental conditions, controlled remotely via a smartphone app
2. **Wearable Fitness Trackers (e.g., Fitbit)**: Devices that monitor physical activity, heart rate, and sleep patterns, sending data to an app for real-time health insights.
3. **Industrial IoT Sensors**: Sensors in factories monitor equipment performance, predict maintenance needs, and optimize production processes, improving efficiency and reducing downtime.
4. **Smart Agriculture Systems (e.g., soil moisture sensors)**: Devices that monitor soil conditions, weather, and crop health, helping farmers optimize water usage and increase yield.
5. **Smart Refrigerators (e.g., Samsung Family Hub)**: Refrigerators with touchscreens and internet connectivity that track food inventory, suggest recipes, and allow remote monitoring of contents.
6. **Healthcare Monitoring Devices (e.g., continuous glucose monitors)**: Wearable devices that continuously monitor health metrics like blood sugar levels and send alerts or data to healthcare providers.
7. **Smart City Infrastructure (e.g., smart streetlights)**: Streetlights that adjust brightness based on ambient light or motion, improving energy efficiency and safety in urban areas.

Reading Sensor Data And Transmit To Cloud

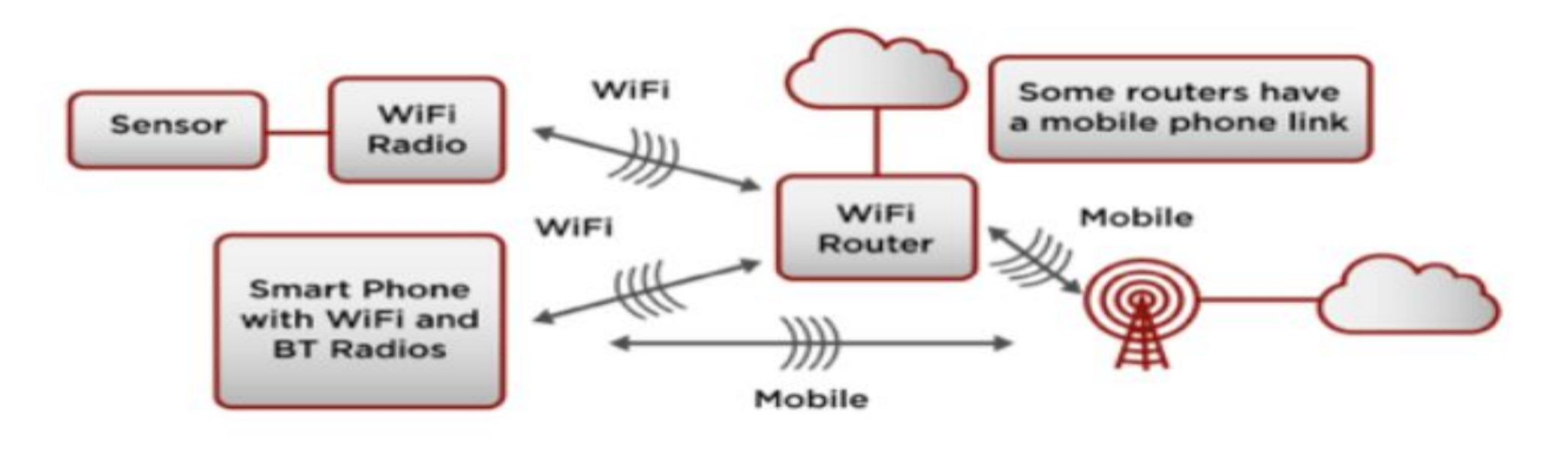
1. **Sensor Data Collection**: The sensor detects and measures specific environmental parameters (e.g., temperature, humidity, motion) and converts them into electrical signals.
2. **Analog-to-Digital Conversion (ADC)**: If the sensor output is analog, an ADC converts the analog signal into a digital format that the microcontroller can process.
3. **Data Processing**: The microcontroller or microprocessor reads the digital data from the sensor, possibly processing or filtering it for noise reduction or data validation.
4. **Data Packaging**: The processed data is formatted into a specific protocol (e.g., JSON, XML) for transmission.



5. **Data Transmission**: The data is sent to the cloud via a communication module, such as Wi-Fi, Bluetooth, or cellular network, using protocols like MQTT, HTTP, or CoAP.
6. **Cloud Reception**: The cloud server receives the transmitted data, where it can be stored, analyzed, or displayed in real-time dashboards.
7. **Data Utilization**: The data is used for further analysis, decision-making, or triggering actions, which may include sending alerts, controlling devices, or updating logs.

Controlling Devices Through Cloud Using Mobile Application And Web Application

- Controlling devices through cloud-based mobile and web applications allows users to manage and operate various devices remotely using the internet.
- This technology is commonly used in smart homes, industrial automation, and various IoT (Internet of Things) applications.



Sensor To Wi-Fi Router To Cloud

Working :

- **Devices**: Smart devices (like lights, thermostats, cameras, etc.) are connected to the internet through Wi-Fi or other networks.
- **Cloud**: These devices send and receive data to and from a cloud server, which stores and processes the information.
- **Mobile/Web Applications**: Users interact with the cloud server through a mobile app or web browser, sending commands and receiving feedback from the devices.

Steps to control device:

- **Set Up Devices**: Connect the smart devices to your home or office network.
- **Install Application**: Download the corresponding mobile app on your smartphone or access the web application through a browser.
- **Connect to Cloud**: Log in to the application, which connects to the cloud server where your devices are registered.
- **Control Devices**: Use the app to turn devices on/off, adjust settings, monitor status, and receive alerts.

Thus, Controlling devices through cloud-based mobile and web applications offers convenience and flexibility in managing your devices from anywhere.

While it brings many benefits, it's essential to address security and compatibility to ensure a smooth and safe experience.

SUMMARY

- Sensors and actuators are crucial for IoT applications, enabling environmental monitoring and physical actions, while programming NodeMCU and Arduino microcontrollers facilitates these applications through platforms like the Arduino IDE. NodeMCU, with built-in Wi-Fi, and Arduino, with its versatile hardware, are key for creating IoT projects.
- Controlling devices through the cloud using mobile and web applications allows remote monitoring and control, leveraging cloud platforms for data processing and command execution, providing benefits like automation and scalability but also requiring robust security and reliability measures.

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Thank You