Components in IoT System Design : IoT Devices

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IoT Devices

Sensors – Types, Use and Calibration

Actuators – Types and Use

Embedded Devices - Hardware

Arduino Prototype Development Platform

Raspberry Pi Prototype Development Platform

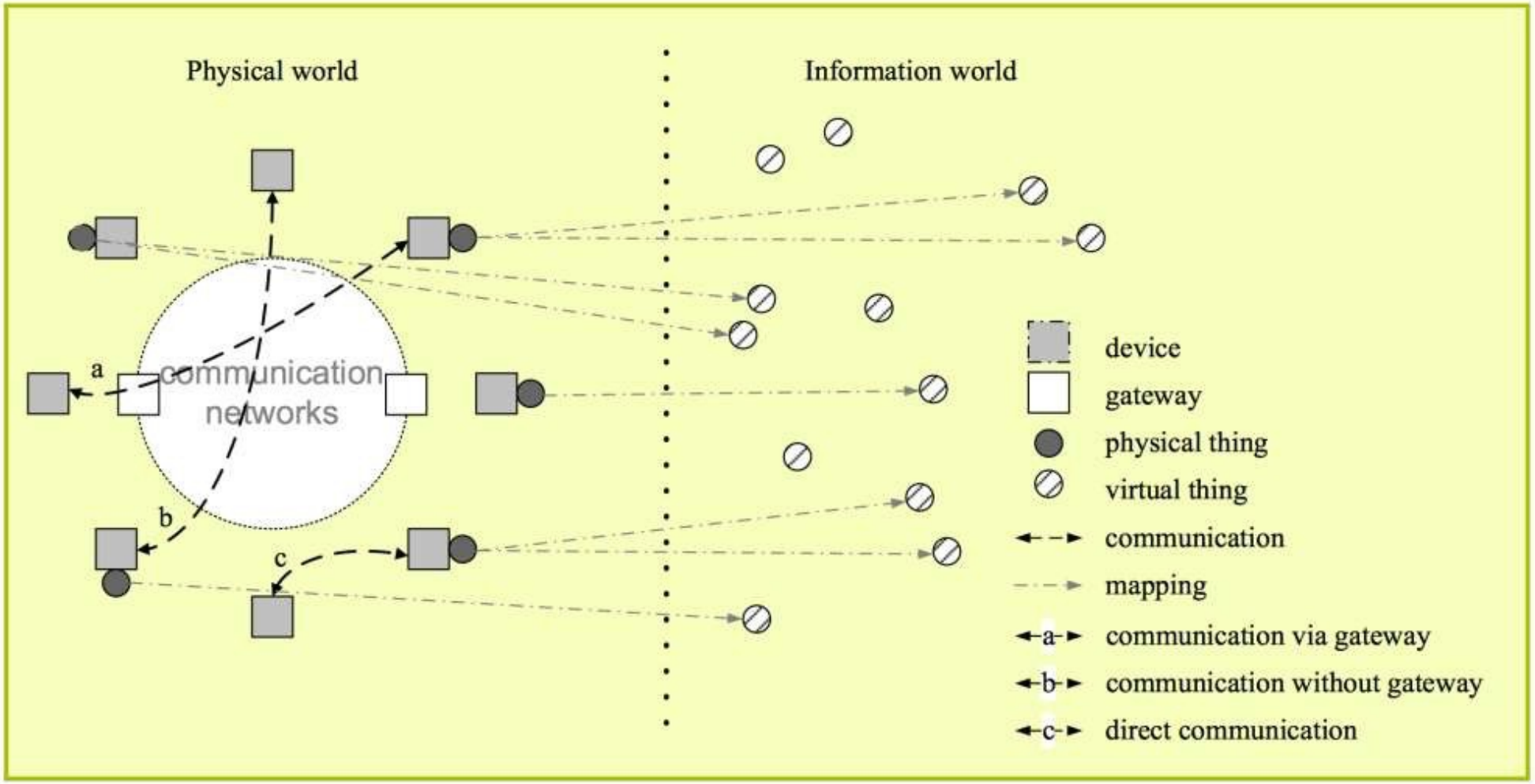
Things

Physical things exist in the physical world and are capable of being sensed, actuated and connected. Examples of physical things include the surrounding environment, industrial robots, goods and electrical equipment.

Virtual things exist in the information world and are capable of being stored, processed and accessed. Examples of virtual things include multimedia content and application software.

Source: Recommendation **ITU-T Y.2060**

Physical and Virtual World



IoT Device – ITU Definition

IoT device is a piece of equipment with the capabilities of communication and optional capabilities of sensing, actuation, data capture, data storage and data processing. The devices collect various kinds of information and provide it to the information and communication networks for further processing.

Some devices also execute operations based on information received from the information and communication networks.

Source: Recommendation **ITU-T Y.2060**

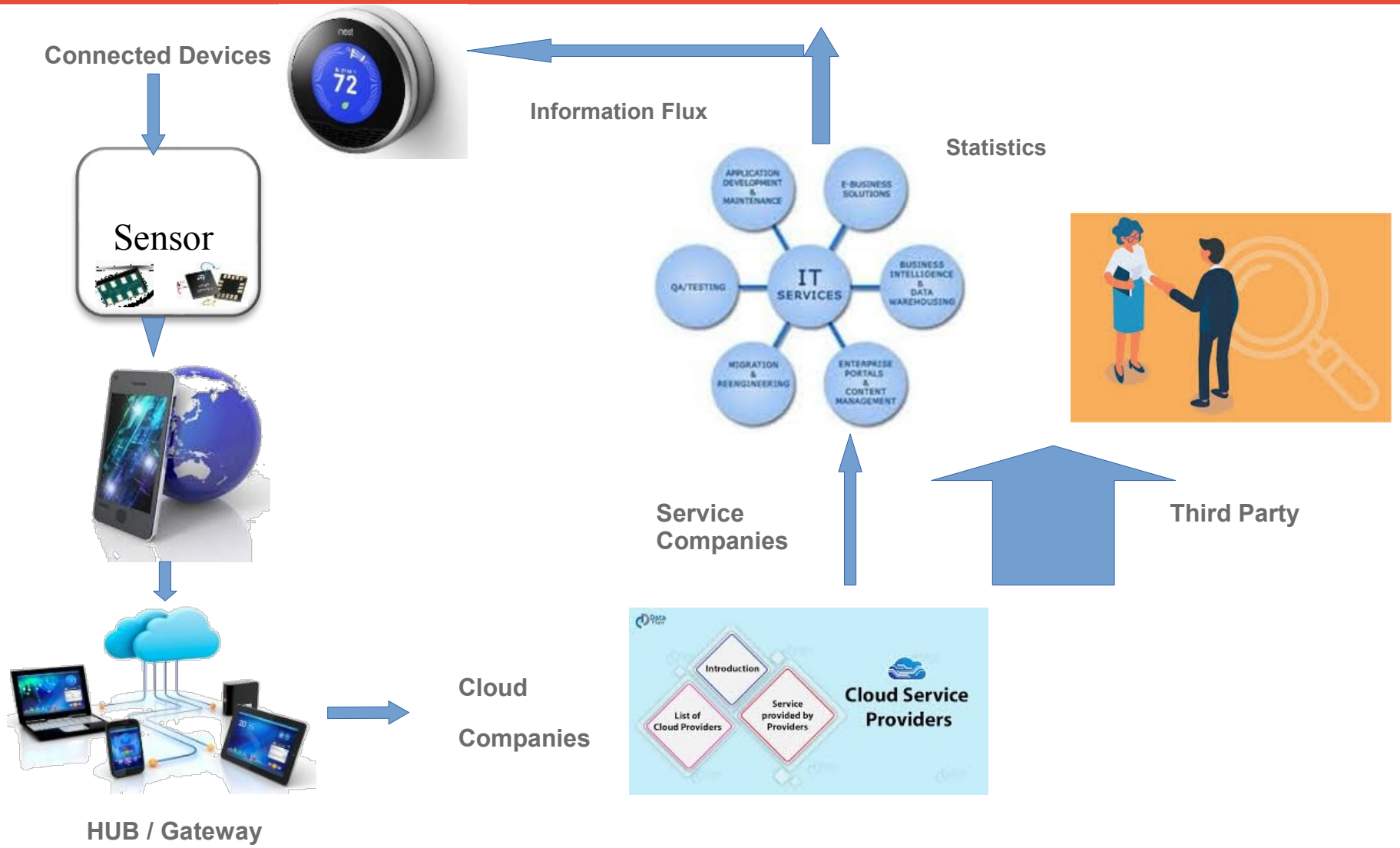
Fundamental characteristics

- **Interconnectivity**: With regard to the IoT, anything can be interconnected with the global information and communication Infrastructure.
- **Heterogeneity**: The devices in the IoT are heterogeneous as based on different hardware platforms and networks. They can interact with other devices or service platforms through different networks.

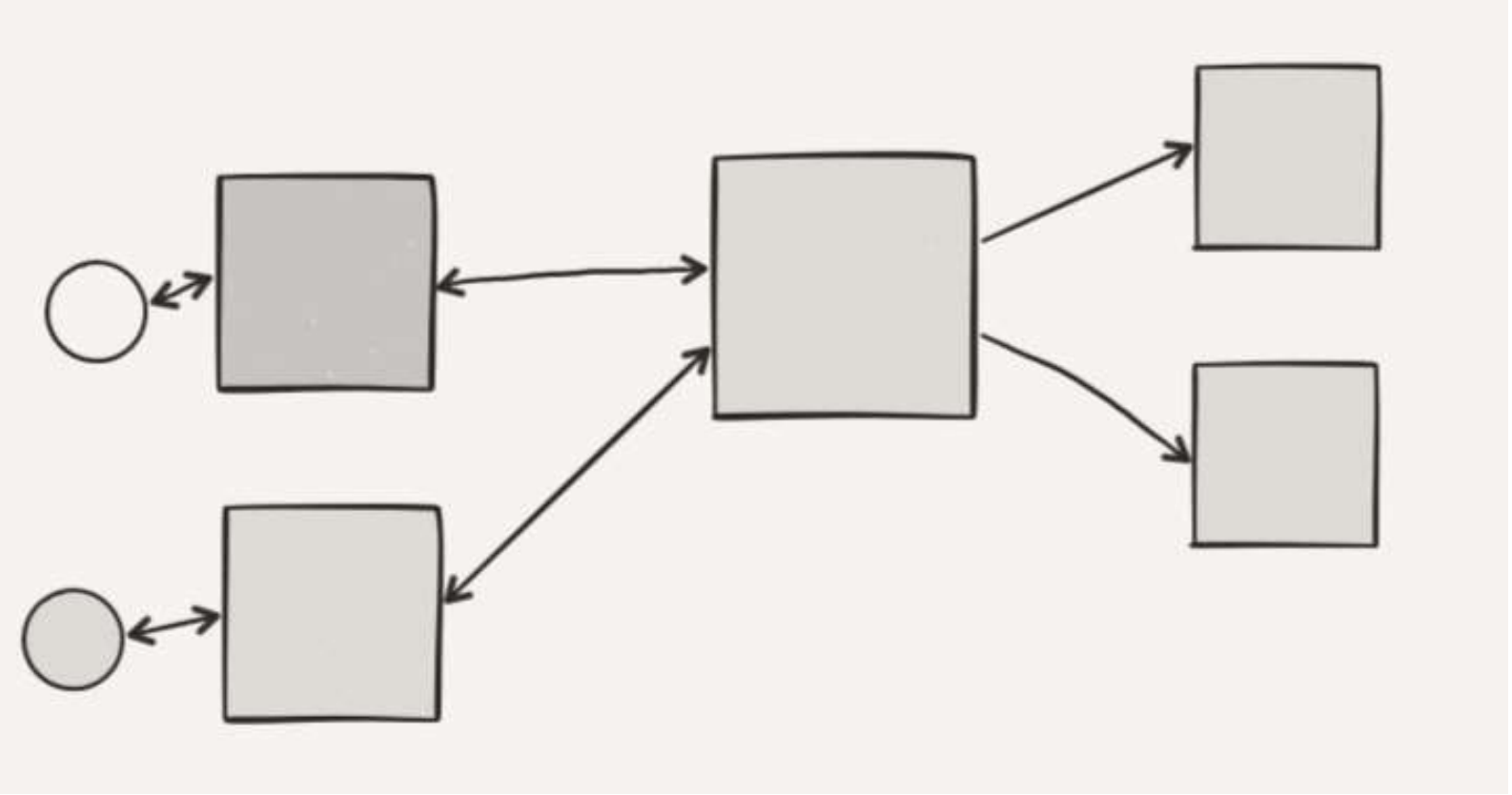
- **Dynamic changes**: The state of devices change dynamically, e.g., sleeping and waking up, connected and/or disconnected as well as the context of devices including location and speed. Moreover, the number of devices can change dynamically.

Source: Recommendation **ITU-T Y.2060**

IoT System Design Cycle

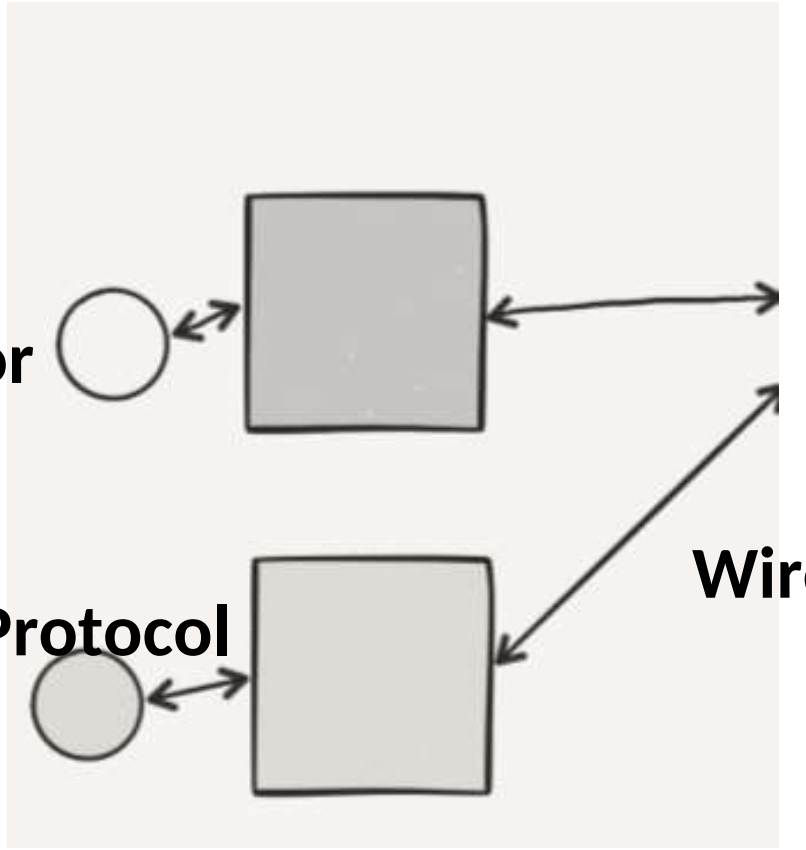


IoT Architecture

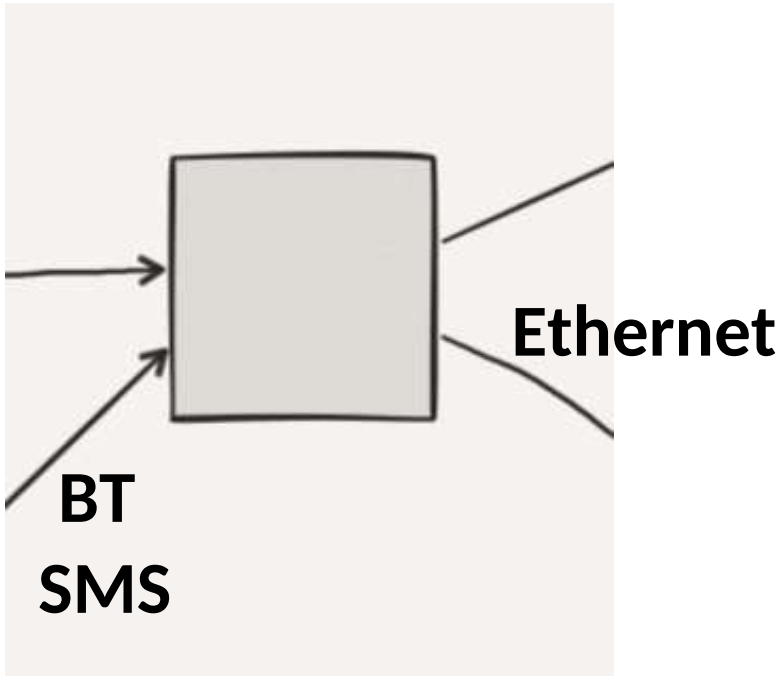


Node Gateway Services

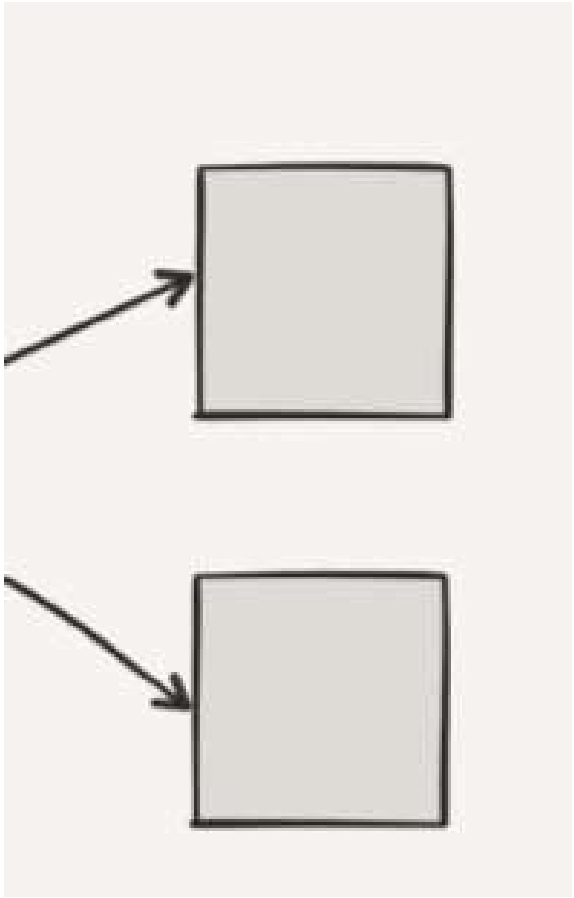
IoT Architecture : Node



IoT Architecture : Gateway



IoT Architecture : Services

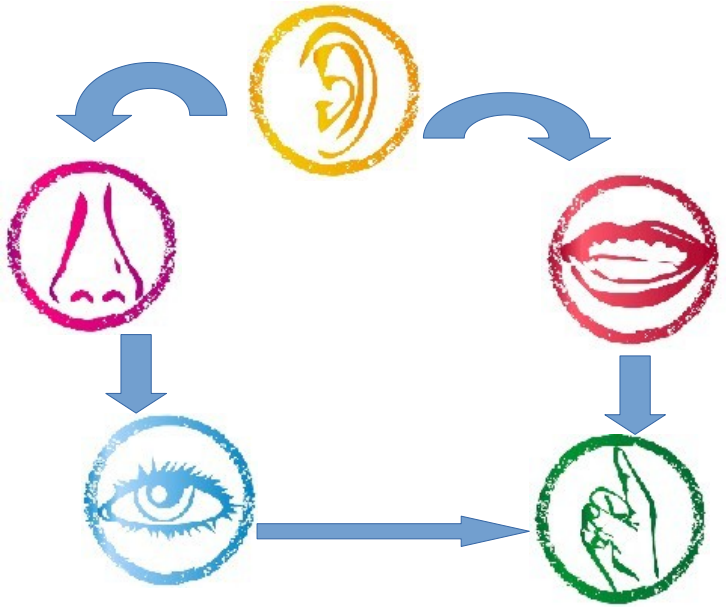


Graphing
Machine Learning
Alerting

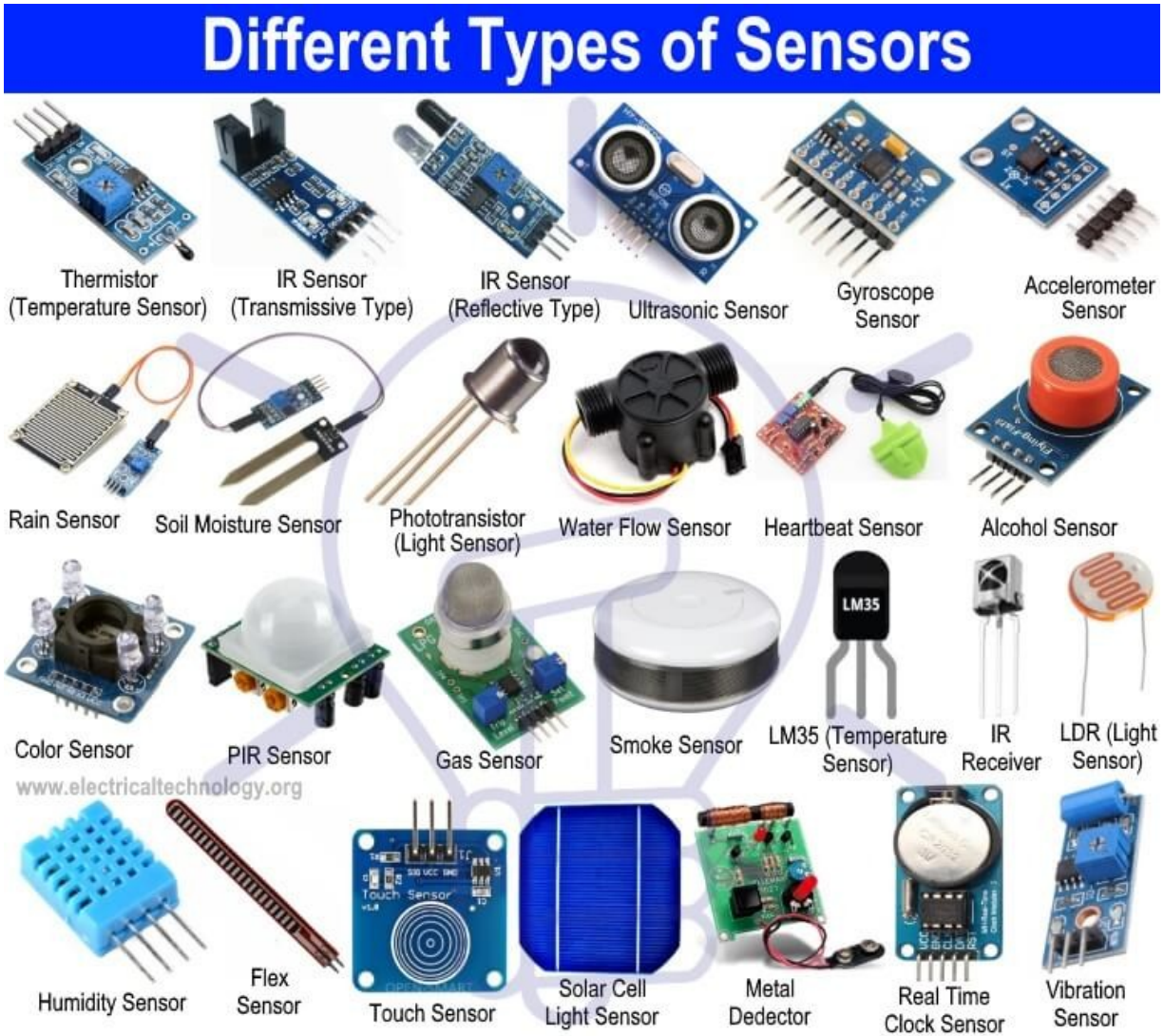
Sensors

- **Sensors measure or identify a particular quantity**

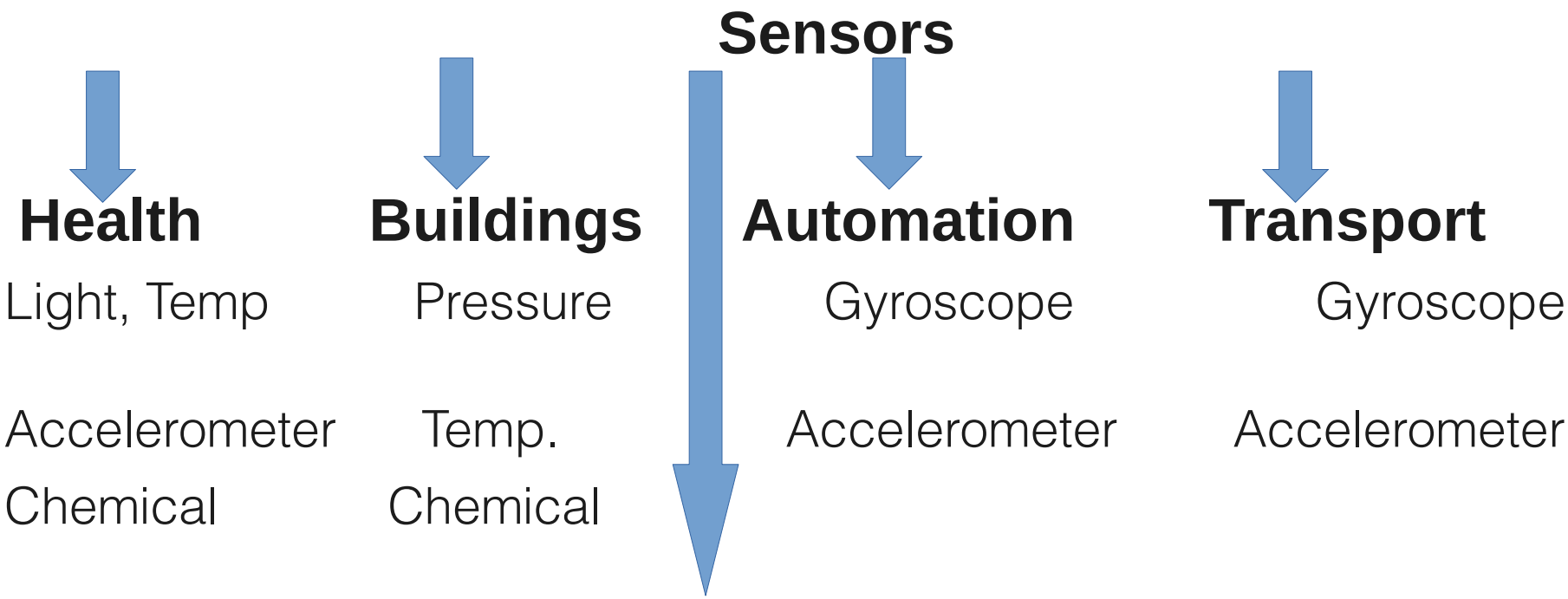
- Convert physical quantities to electrical signals understood by machines



Type of Sensors

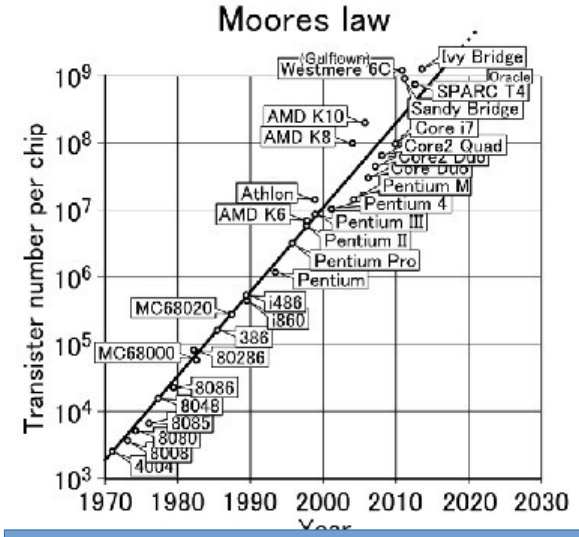


Sensors in IoT

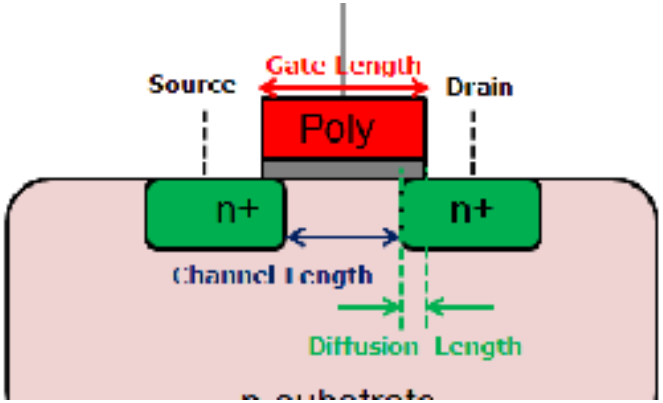


Mobile Phone : A Sensor Hub

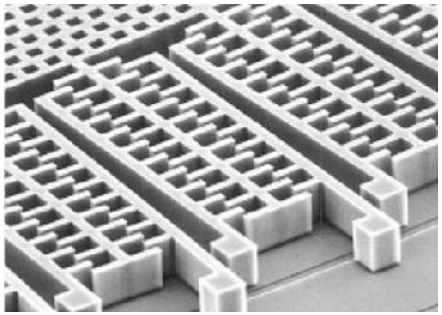
Sensing Technology : Role of VLSI Design



Technology node ≡ Min Feature Size



Micro Electro Mechanical Systems (MEMS)



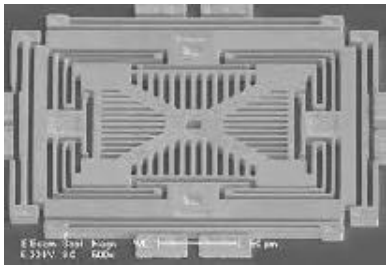
VLSI Technology applied for Sensing

Micro Electro Mechanical Systems (MEMS)

- Miniaturized mechanical and electro-mechanical elements
- Moving structures fabricated on a Silicon substrate
- Made using techniques of micro-fabrication

Micro motor

Gyroscope



Accelerometer

MEMS fabrication is same as IC (CMOS) fabrication, except

- Mechanical Properties
- Feature Size
- Unconventional Materials

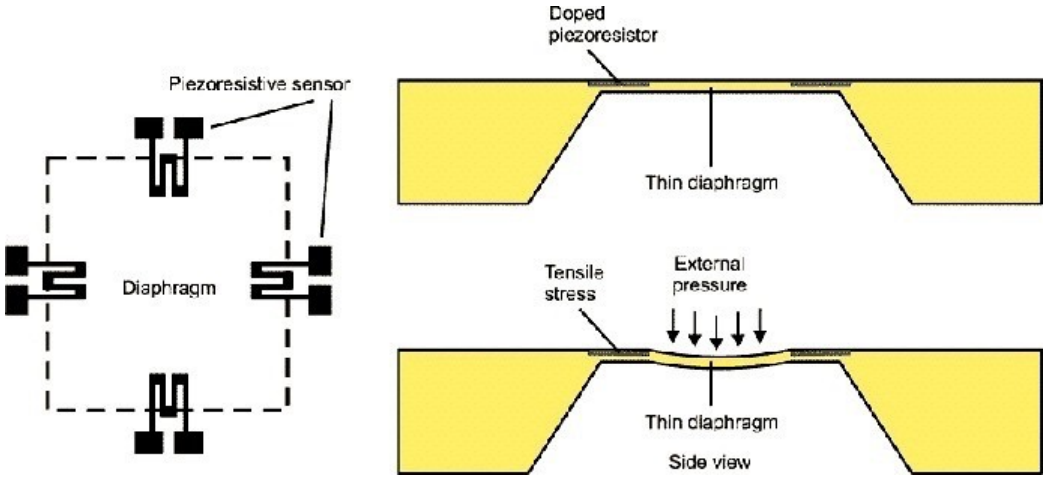
Sensors - Physical parameter Sensing

Senses change in physical parameters :

Temp, Pressure, Light Intensity, Smoke in proximity

Acceleration, orientation, vibration, gases, organic vapour

Transducer - Converts physical quantities such as heat , sound, strain, pressure into electrical energy



Calibration of Sensors

Randomness in mother nature gets manifested in the sensors during fabrication and packaging which lead to random errors in sensors

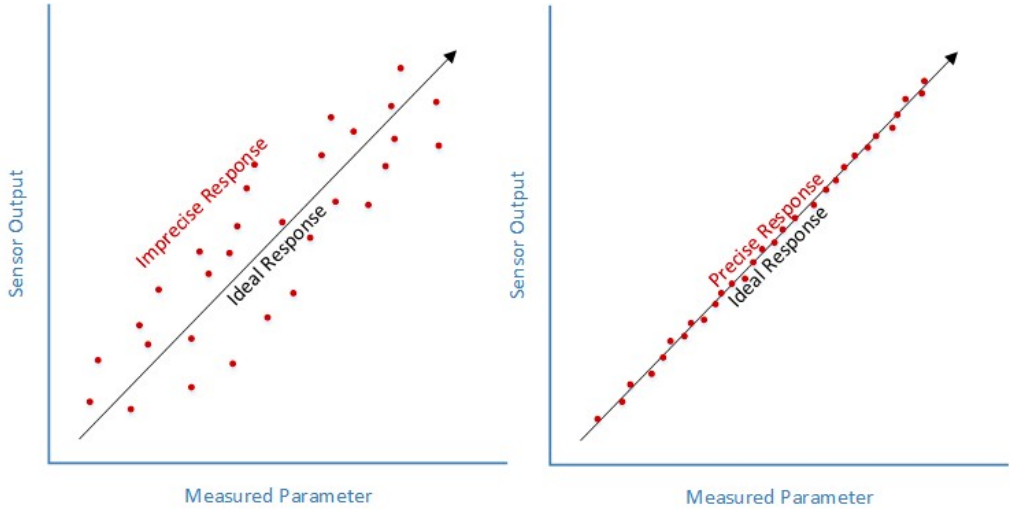
Some errors may come after prolonged use. Further, there are some errors that occur based on the environment/operating conditions.

These errors are corrected by calibrating the sensors.

Sensor parameters are compared with any standard reference to find the error.

Pcalibrated = Pmeasured * k + b ; k = Gain and b = Bias

The process of correcting sensors output with gain and bias known as calibration compensation.

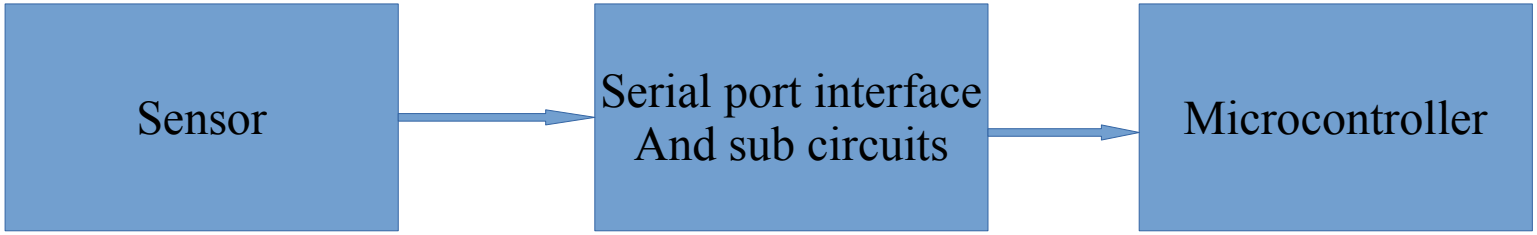


Sensing Circuit

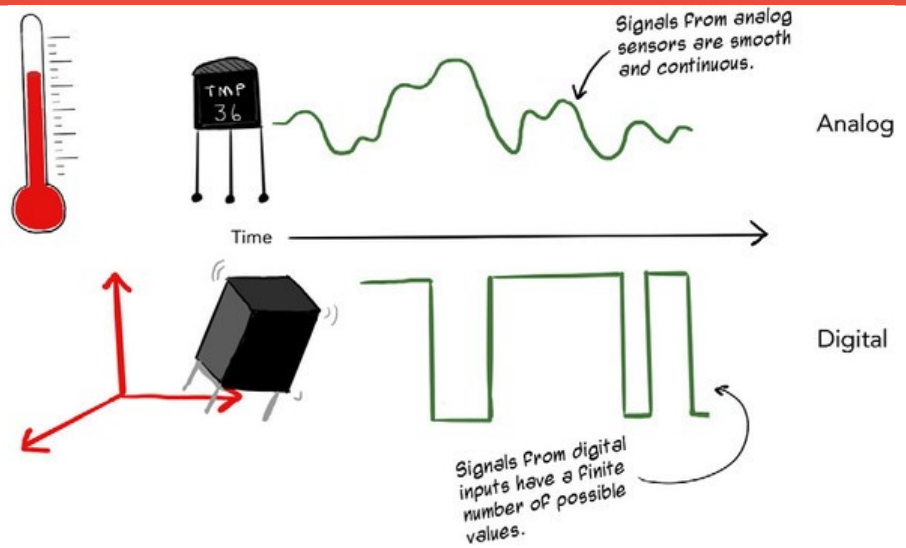
Circuit input receives output of sensor/transducer

Circuit output variation is according to the variation in physical condition

The circuit receives energy in the form of variation in currents, voltages, their phase angle or frequencies.



Type of Sensors : Analog and Digital



Digital

DHT-22

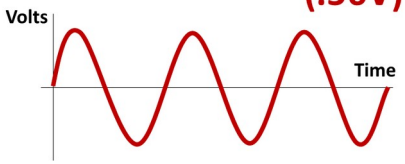
25.2°C → 25.2

10110100010101110010101101110101110101010111010100

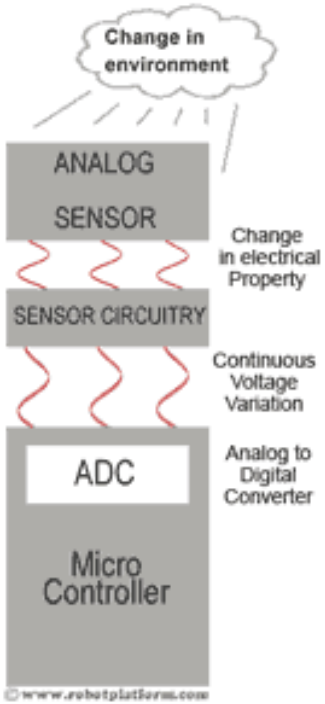
Analog

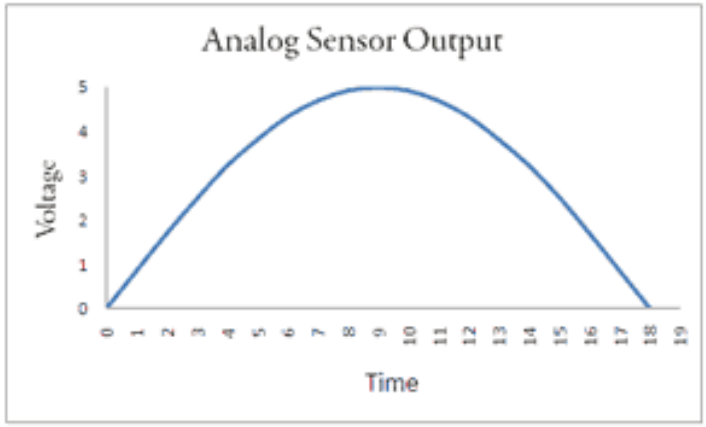
SEN-AP006G

25.2°C → 49kΩ (.56V)



Analog Sensors





Uses the sensor and associated electronic analog circuit

Generate analog output as per environment conditions

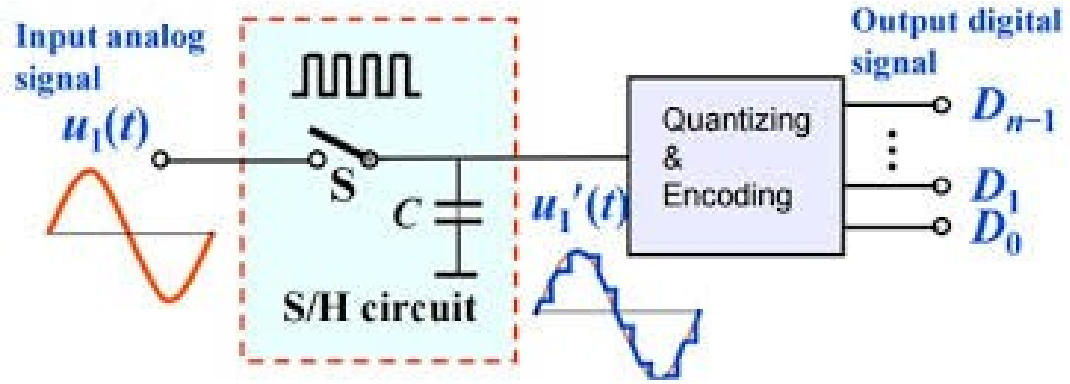
Temperature, strain, pressure, force, flex,vapours,magnetic field or proximity changes

Resistance of sensing component changes with pressure, strain, magnetic field or humidity causing strain on the sensor

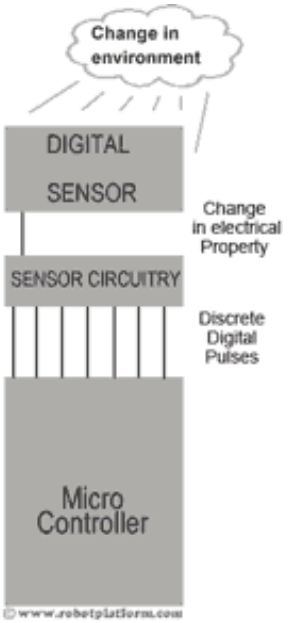
Analog Sensor Circuit – Conditioning, Sampling, ADC

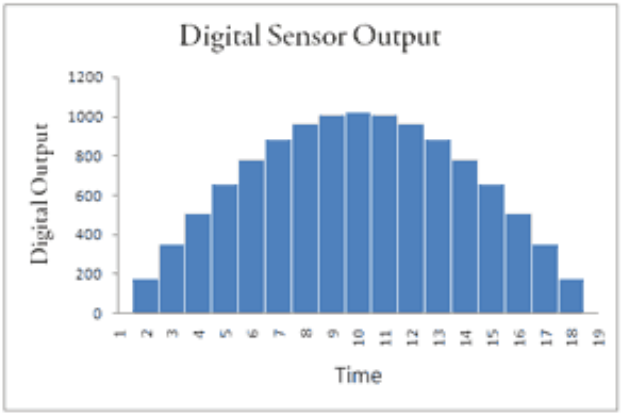
Uses Analog to Digital Circuit (ADC) - Internal in microcontroller or in the circuit between sensor and microcontroller

ADC converts input signal to a digital number



Digital Sensor

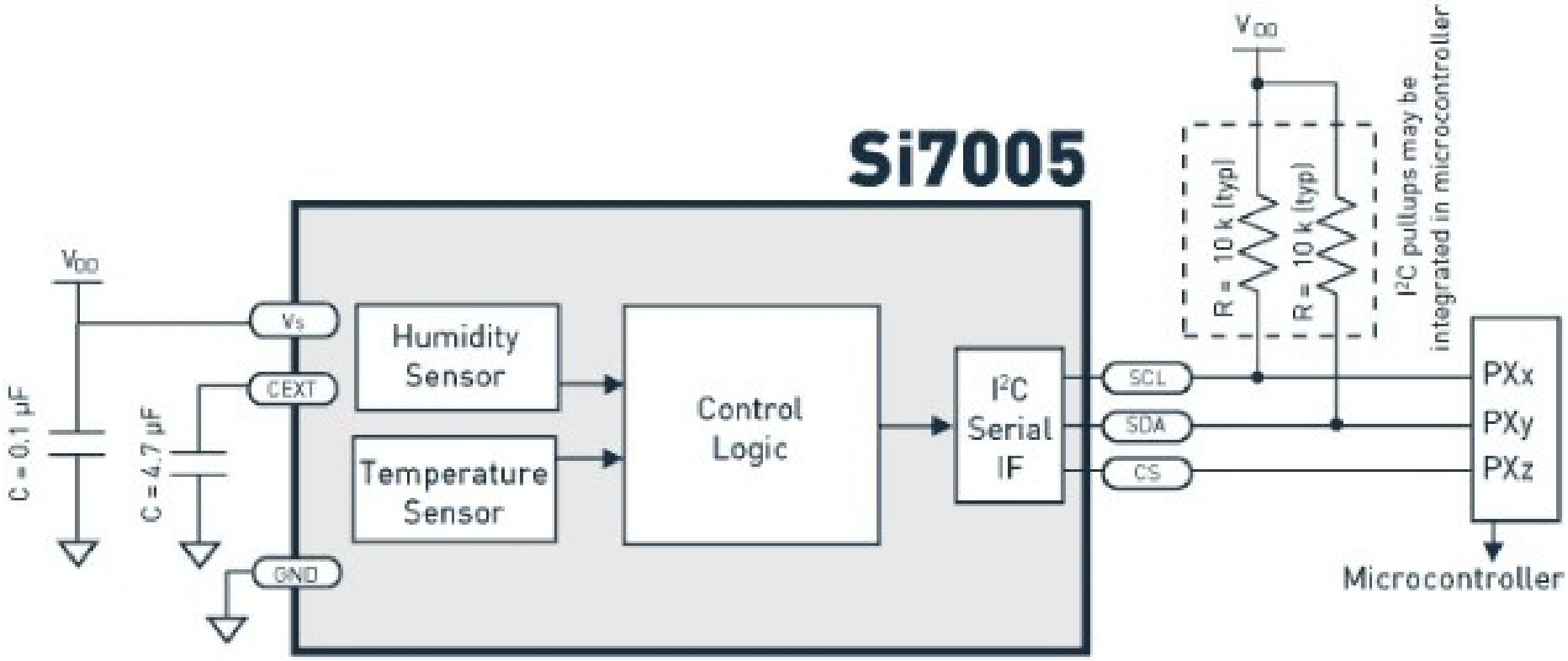




Senses ON and OFF states : Output 0's and 1's

1/0 : Certain Range of Voltage, Current or Frequency or other electronic parameter

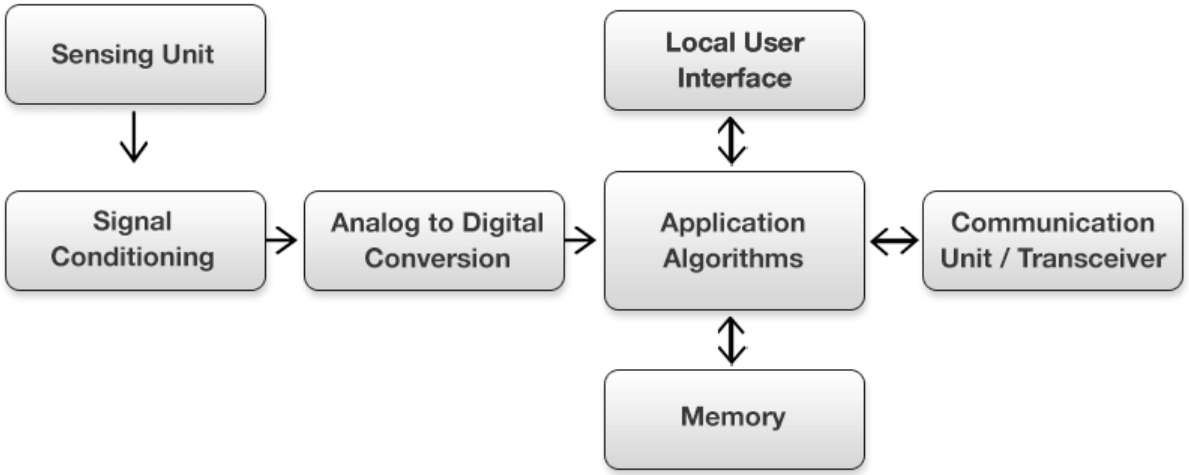
Digital Sensor Circuit



Smart Sensor

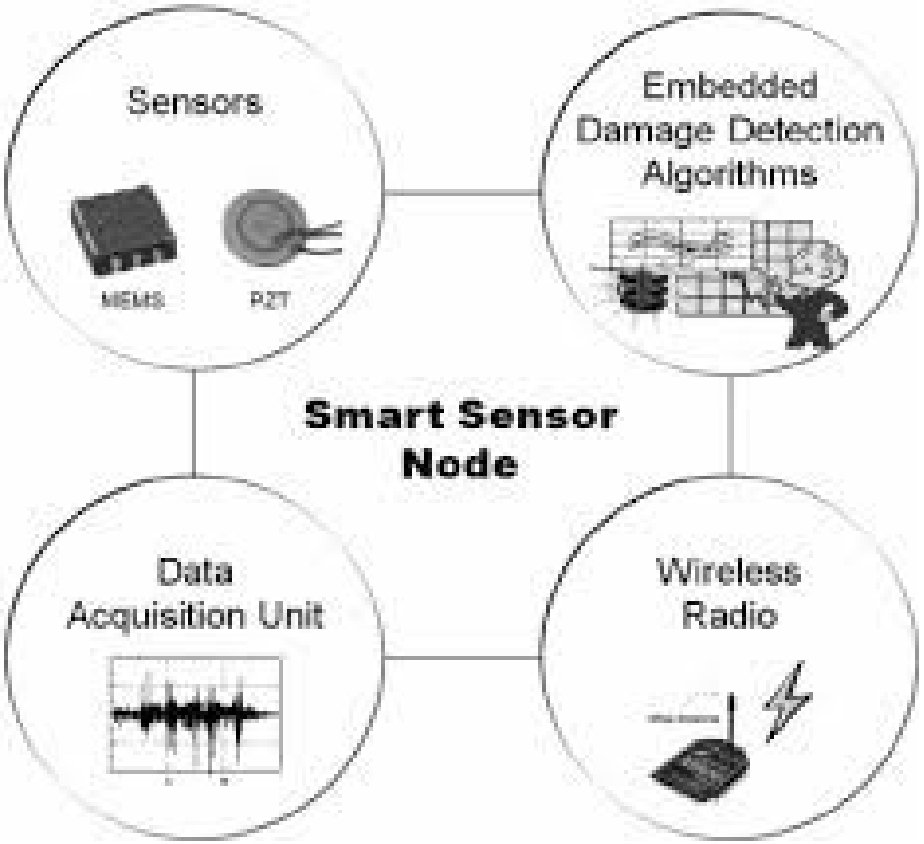
Sensors with integrated electronics that can perform Data conversion, Bidirectional communication, take decisions and perform logical operations

A sensor with built-in integrated circuit (microcontroller, and sensor) which provides the physical parameter as output on connecting it to a supply voltage and programming it.

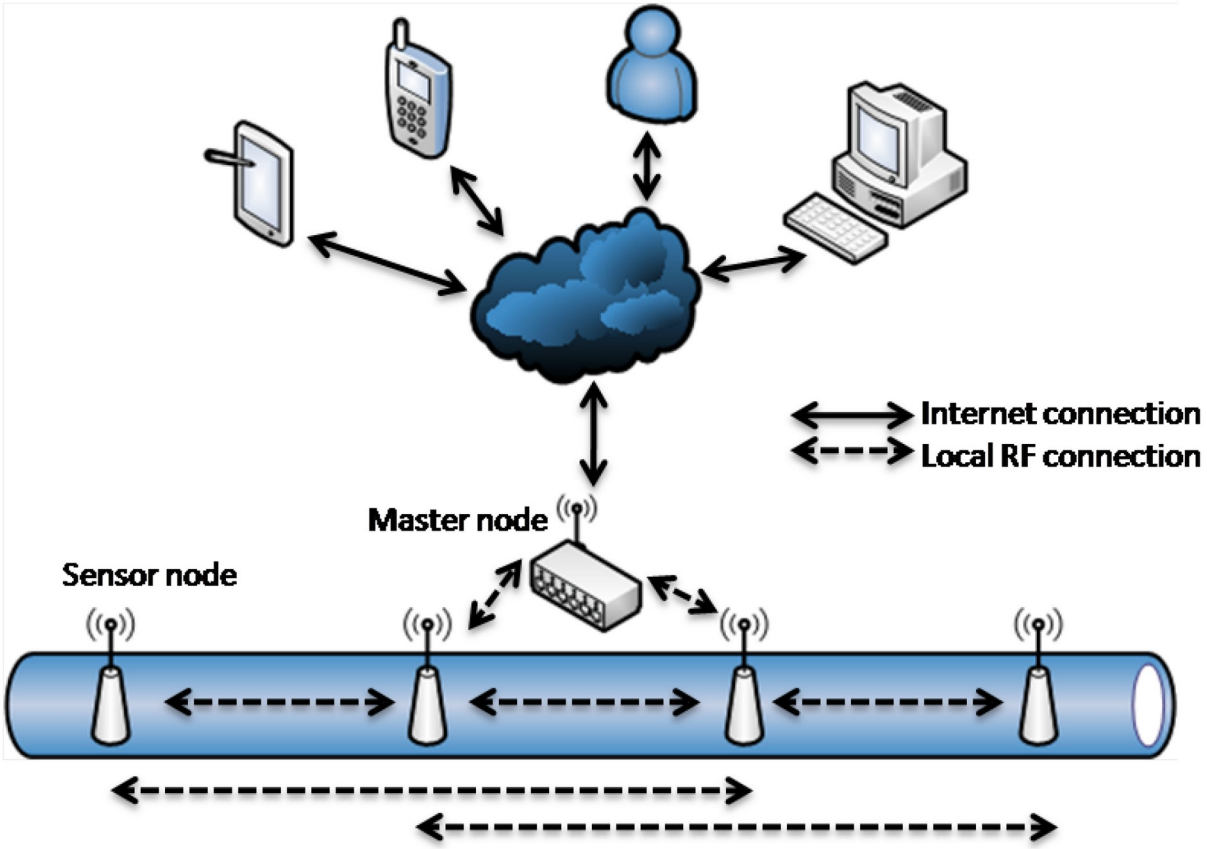


A smart sensor for temperature gives output as hex-digit - 10 UART serial bits according to the degree celsius. For ex. 01100100 is obtained for 100 degree Celsius considering the sensor has been calibrated

Smart Sensor Node



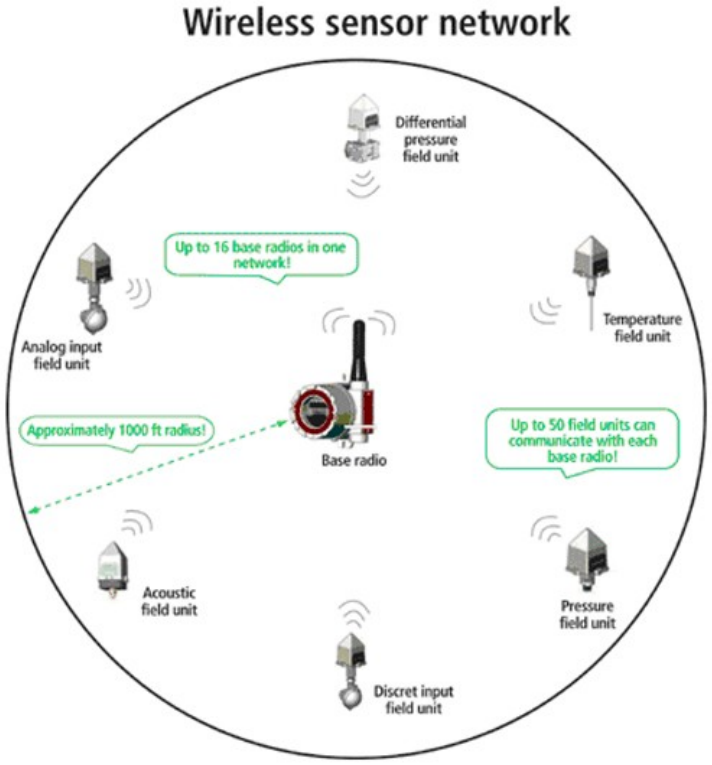
Smart Sensor Network



Wireless Sensor Network (WSN)

Network of sensor nodes which connect wirelessly

Nodes have capability of computation, data compaction, aggregation and analysis, communication and networking. Each node has independent computing power and capability to send and receive responses, data forward and routing capabilities



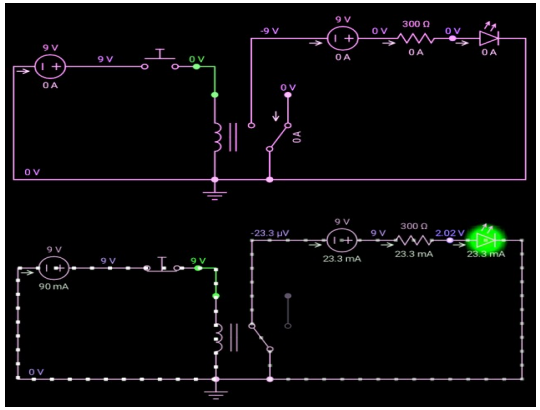
Actuator

A device that takes the actions as per the input command, pulse, state (1/0), set of 1s and 0s or control signal. An attached motor, speaker, LED or an output device converts electrical energy into physical action

Piezoelectric vibrator : Piezoelectric crystals when applied varying electric voltages at input generate vibrations

Motor : can be dc/ac; I/O modules available to receive control digital inputs of 1/0 deliver high currents. A cam converts rotator motion into linear motion when motor rotates.

Relay Switch : An electronic switch can be controlled by 1/0 from the port pin of microcontroller. A relay switch makes mechanical contact when input magnetizes with a control circuit and pulls a lever to make the contact



Control Unit

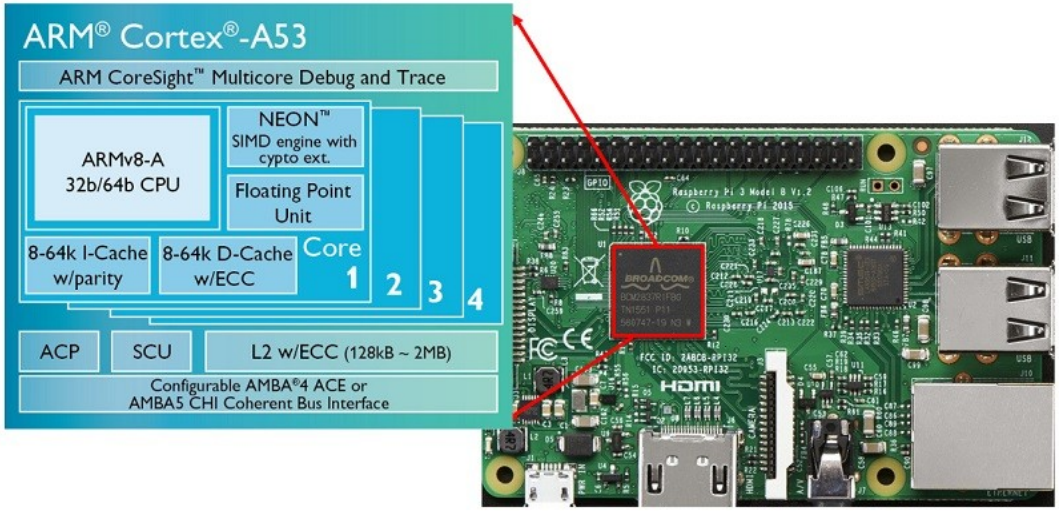
Single VLSI Chip ; A core in an application specific instruction set processor, called microcontroller

Commonly used control unit in IoT - Microcontroller unit; A core in System-on-Chip (SoC) with SD card for embedded software and OS software

Ex : ARM Cortex, ATmega328

Microcontroller components : Processor, Internal RAM, Internal Flash and

Firmware, Timers, Programmable I/O Ports, General purpose I/Os, Serial I/O Ports, PWM, ADC, Communication Network Interfaces

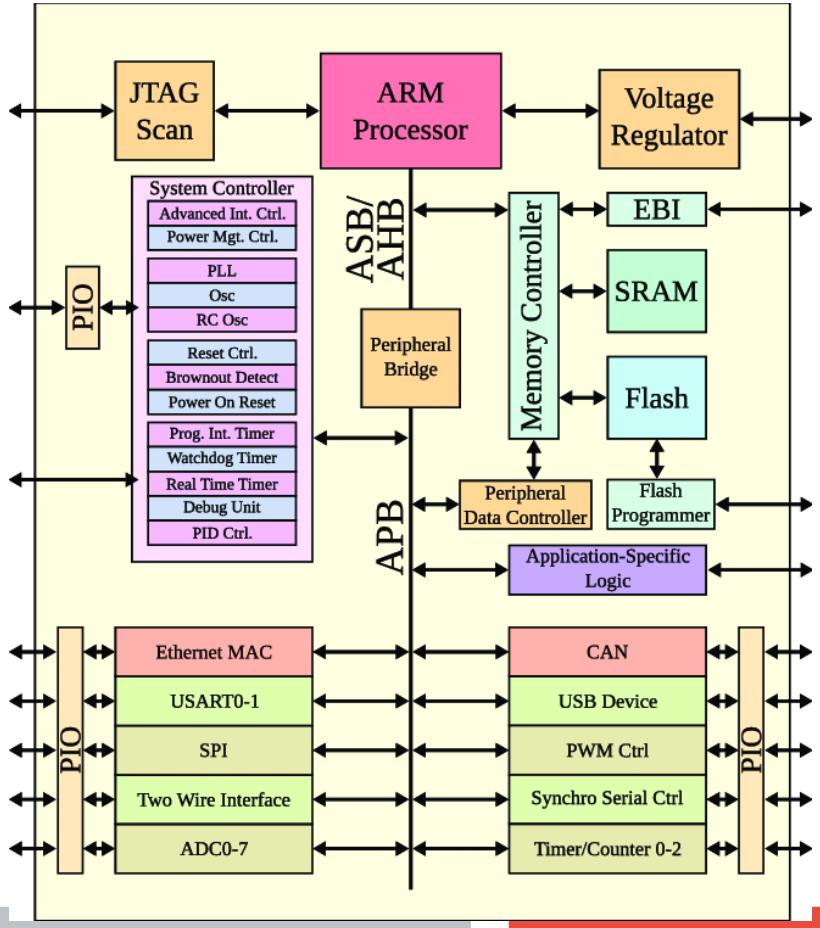


System on Chip

A circuit on a single silicon chip, consisting of multiple processors, hardware units and the embedded software

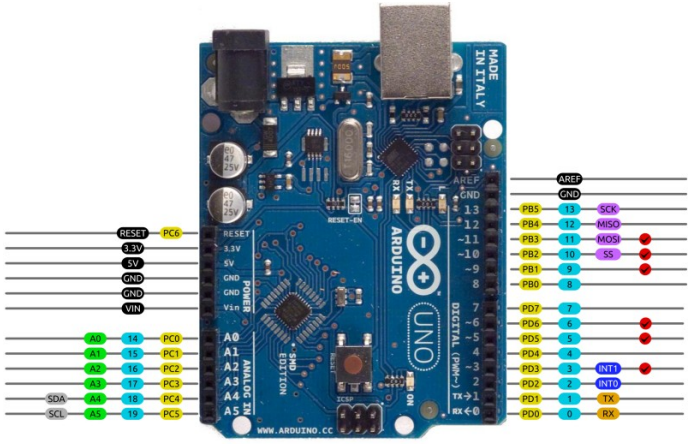
A VLSI chip that has multiple processors, software and all the needed digital as well as analog circuits' on-chip; A SD card stores external programs and OS and enables use of the chip distinctly for a particular purpose

A SoC can be of different platforms : Raspberry Pi

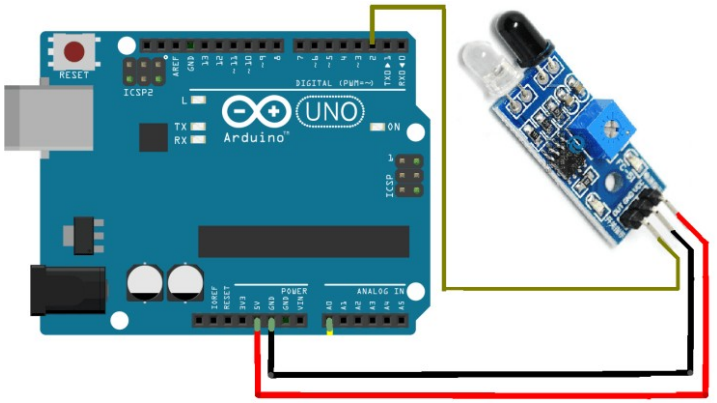


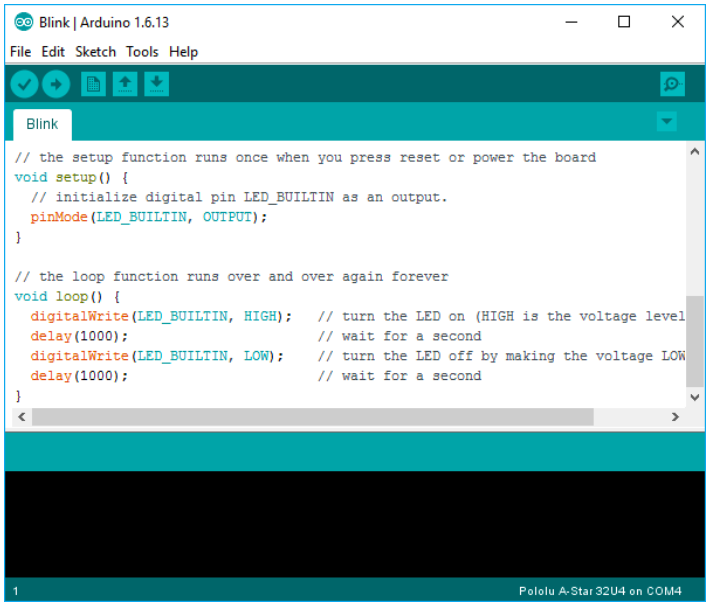
Arduino

Arduino Uno SMD Pinout



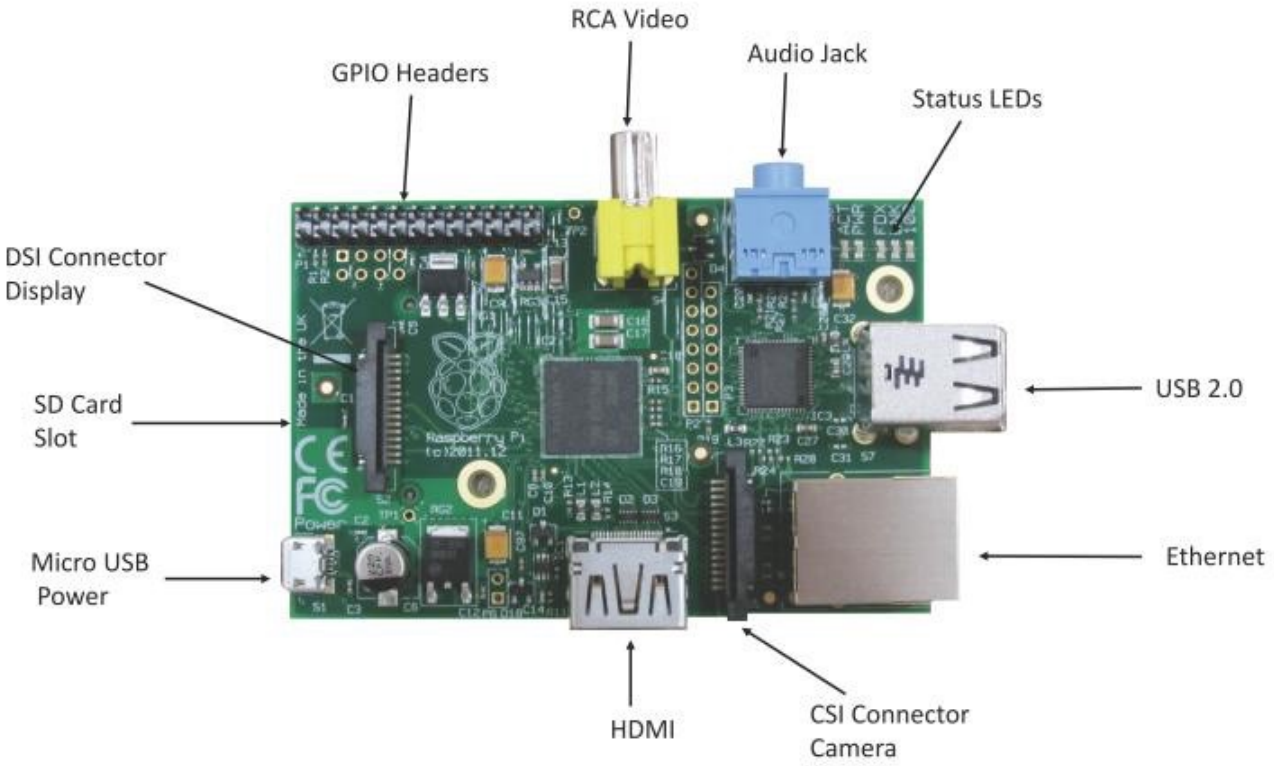
AVR DIGITAL ANALOG POWER SERIAL SPI I2C PWM INTERRUPT



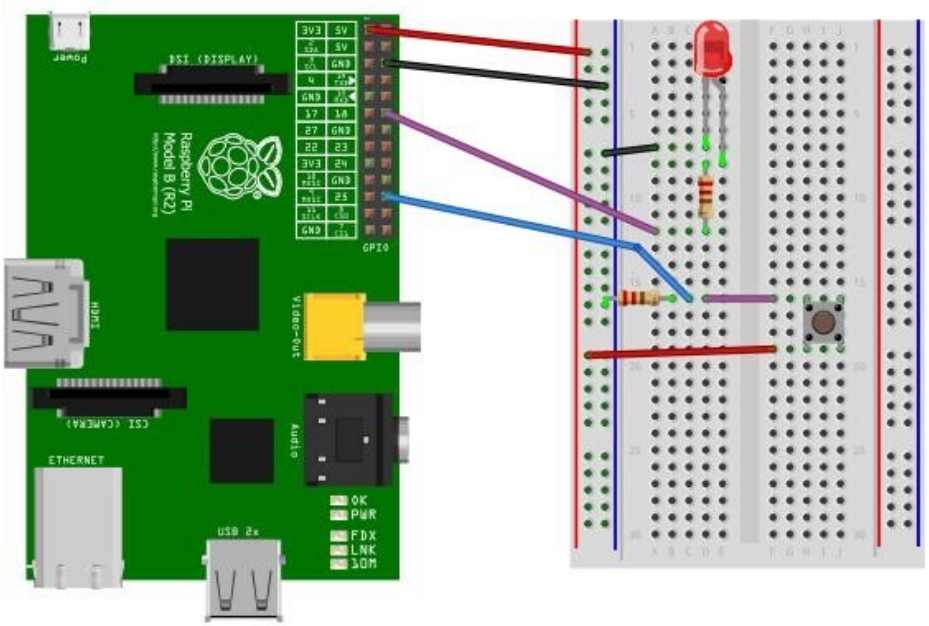


Raspberry Pi

Low cost mini computer, allows interfacing sensors though GPIOs, runs Raspbian OS (a Liux variant), supports Python



Programming Raspberry Pi




```
from time import sleep
import RPi.GPIO as GPIO
GPIO.setmode(GPIO.BCM)

 #Switch Pin
 GPIO.setup(25, GPIO.IN) #LED Pin
 GPIO.setup(18, GPIO.OUT) state=false

   def toggleLED(pin):
        state = not state
        GPIO.output(pin, state)

    while True:
         try:
              if (GPIO.input(25) == True):

                   toggleLED(pin)
              sleep(.01)
              except KeyboardInterrupt:
                   exit()
```

Node MCU

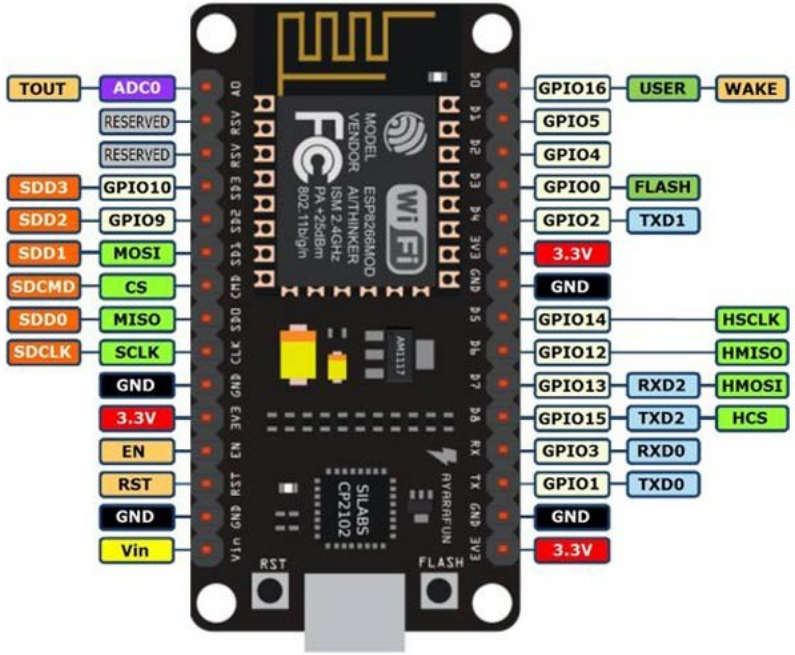
NodeMCU is a low-cost open source IoT platform. It initially included firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which was based on the ESP-12 module. Later, support for the ESP32 32-bit MCU was added.

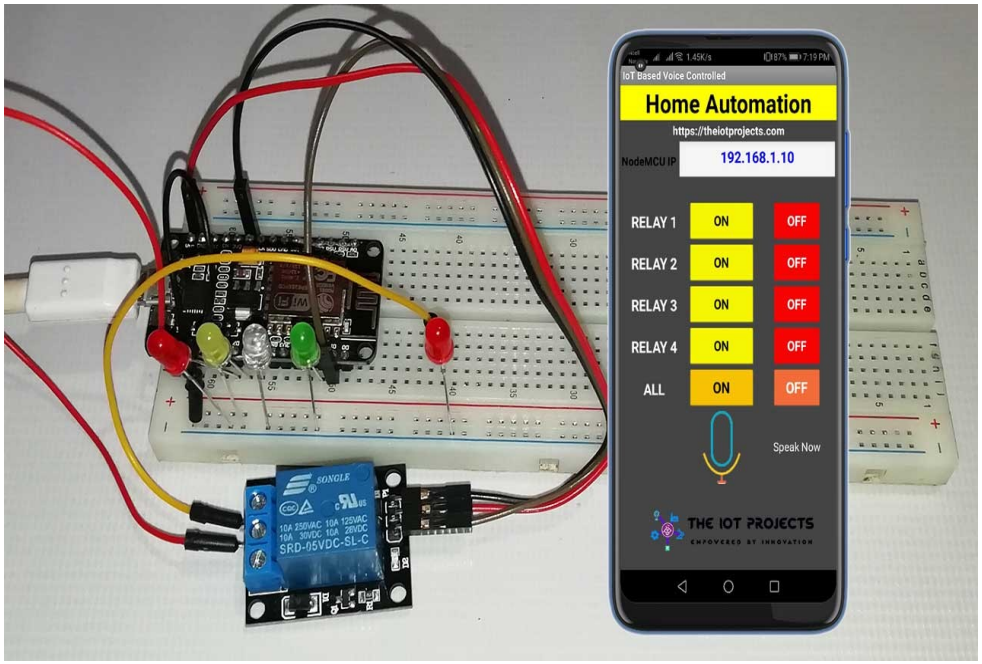
Memory: 128kBytes

Developer: ESP8266 Opensource Community

CPU: ESP8266(LX106)

Storage: 4MBytes





RFID (Radio Frequency ID) Technology in IoT

Identification System – Tagging and Labelling

Tiny chips : Passive/Active; battery powered when reader near wireless

Communication range : 10cm to 200m

Standard frequency : 120-150KHz, 13.56MHz,433MHz and higher in UHF regions

Applications : Tracking, inventory