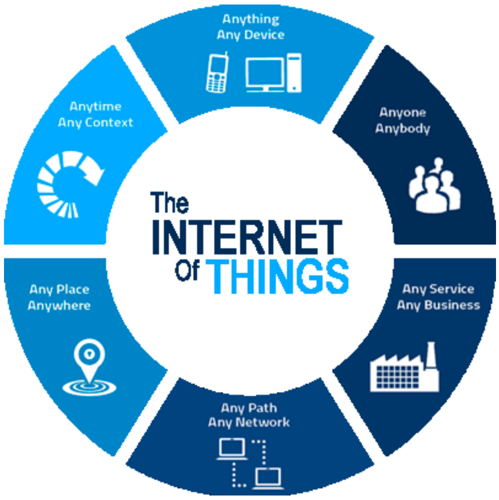
UNIT I

INTRODUCTION : **Overview:** Definition, features & it's components, IoT Principles, Challenges & Applications Conceptual Framework & IoT Architecture, IoT reference model, **IoT development Tools:** Arduino : Types, Fundamentals and Configuration, Raspberry Pi: Introduction, configuration, board setting

DEFINITION :

- Kevin Ashton is the first person who defines the term IOT or Internet of things in 1999. He used this term to describe the supply chain management where the real time entities can be managed through the computer system via internet connectivity
- The concept of connecting any device (physical object) to the internet and to other connected devices.
- IBM writes that IoT refers to " the growing range of internet connected devices that captures or generate an enormous amount of information every day.
- The Internet of things as "the vast network of devices connected to the internet , including smartphones, and tablets and almost anything with a sensor on it. These things collect and exchange data.
- IoT is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment.



FEATURES OF IOT

1. Connectivity: Connectivity refers to establish a proper connection between all the things of IoT to IoT platform it may be server or cloud. After connecting the IoT devices, it needs a high speed messaging between the devices and cloud to enable reliable, secure and bi-directional communication.

2. Sensing: The sensor devices used in IoT technologies detect and measure any change in the environment and report on their status. IoT technology brings passive networks to active networks. Without sensors, there could not hold an effective or true IoT environment.

3. Active Engagement: IoT makes the connected technology, product, or services to active engagement between each other.

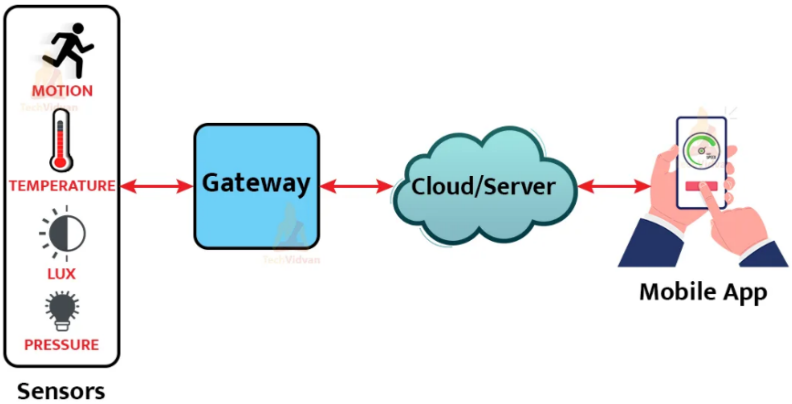
4. Analyzing: After connecting all the relevant things, it comes to real-time analyzing the data collected and use them to build effective business intelligence.

5. Scalability: IoT devices should be designed in such a way that they can be scaled up or down easily on demand. In general, IoT is being used from smart home automation to automating large factories and work stations, so the use cases vary in scale.

6. Dynamic Nature: For any IoT use case, the first and foremost step is to collecting and converting data in such a way that means business decisions can be made out of it. In this whole process, various components of IoT need to change their state dynamically. For example, the input of a temperature sensor will vary continuously based on weather conditions, locations, etc. IoT devices should be designed this keeping in mind.

7. Energy : From end components to connectivity and analytics layers, the whole ecosystems demand a lot of energy. While designing an IoT ecosystem, we need to consider design methodology such that energy consumption is minimal.

8. Integration: IoT integrates various cross-domain models to enrich user experience. It also ensures proper trade-off between infrastructure and operational costs.



IOT COMPONENTS :

1. Smart devices and sensors – Device connectivity

- Devices and sensors are the components of the device connectivity layer. These smart sensors are continuously collecting data from the environment and transmit the information to the next layer.

2. Gateways:

- IoT Gateway manages the bidirectional data traffic between different networks and protocols. Another function of gateway is to translate different network protocols and make sure interoperability of the connected devices and sensors.
- Gateways can be configured to perform pre-processing of the collected data from thousands of sensors locally before transmitting it to the next stage. In some scenarios, it would be necessary due to compatibility of TCP/IP protocol.

3. Analytics:

- It is the process of converting analog data from billions of smart devices and sensors into useful insights which can be interpreted and used for detailed analysis. Smart analytics solutions are inevitable for IoT system for management and improvement of the entire system.

4. Cloud Storage:

- Cloud storage is used to store the data which has been collected from different devices or things. Cloud computing is simply a set of connected servers that operate continuously (24*7) over the Internet.

5. User Interface:

- The user interface (UI) is the visible, tangible portion of the IoT device that people can interact with. Developers must provide a well-designed user interface that requires the least amount of effort from users and promotes additional interactions.

6. Network Interconnection:

- IoT is enabled by a variety of technologies. The network used to communicate with other devices in an IoT deployment is critical to the field, a position that numerous wireless or wired technologies can fill.

IOT CHALLENGES

1. Challenges in the Manufacturing sector

- Smart sensory data are used to prevent abnormal breakdowns, requirement analysis, and resource optimization.
- IIoT solutions help organizations in smart asset management, performance monitoring, which reduces asset downtime and increases hardware legibility.
- Maintenance of IoT sensors and preprocessing of large-scale unstructured data is always a pain for IoT use cases in this sector.
- Also, determining the proper use case and developing proper IoT infrastructure, defining the scope and KPI will be among the topmost challenges needed to be addressed.

2. Challenges in Agriculture Sector

- IoT is thought of as the greatest change agent in the agriculture industry for upcoming years.
- As per researchers, IoT probably will be the most powerful weapon for the agriculture and farming industry to fight with environmental change, huge demand-supply gap and need for human interventions.
- IoT enables farm managers with real-time corp monitoring, precision farming, livestock management, smart greenhouse management, etc.

3. Challenges in Automobile and Transportation

- In the era of cheap internet and connected devices, upgrades can be made on-demand.
- Modern cars are equipped with IoT-based smart sensors that help in real-time car tracking, speed control, fuel consumption control, car renting solutions, etc.
- IoT and deep learning help in developing automated parking systems, semi autopilots, and even self-driving cars.
- Maintaining safety and privacy benchmarks are the main challenges in the automobile sector.
- The data is vulnerable to interruption and coordinated malware attacks from the hardware endpoint to the analysis center and blockchains. Proper data governance and firewalls are essential to overcome the challenges.

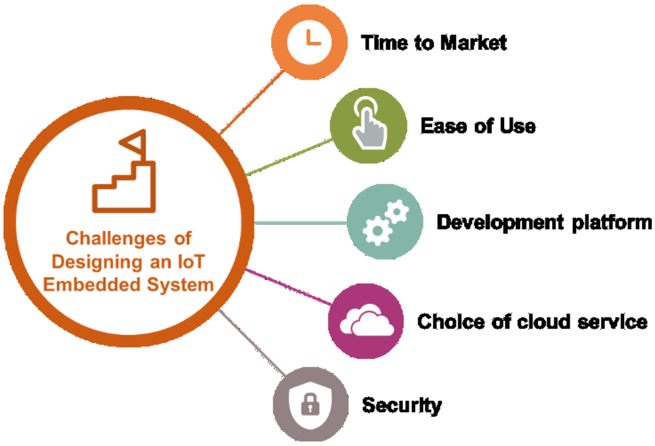
4. Challenges in the Energy sector

- IIoT solutions can bring changes in energy sectors with valuable insights on power consumption, hardware maintenance, forecasting dynamic pricing, etc.

- Traditionally Energy and Power sectors are considered as sectors with unstructured data.
- Deploying the right set of hardware, acquiring and managing the huge data, preprocessing and gaining valuable insights will be the key challenges to incorporate IoT solutions in the energy sector.

5. Enforcing security measures and data governance:

- Managing huge data and ensuring privacy and proper security measures is a big challenge of incorporating IoT solutions.
- Suppose you are using an automatic or semi-automatic car. Now, if the automotive IoT infrastructure is compromised, it will lead to real threats.
- With the advancement in technology and social media, user's data is always available on the internet and with the things being connected with the internet, hackers are provided with yet another tool to be able to break into the network and steal the information.
- One might want some space in life that is personal, so it's not easy to always stay connected with family and friends and give them every aspect of our life operation. There is every possibility that your data can be misused.



IOT APPLICATIONS :

IoT application has been introduced in many domains such as social media, health, transport, medicine, etc. The advantages and requirements of IoT solution dependents on the needs of the industry. Few domains such as health care, business analytics, transport and smart homes/city.

1. Medicine and Health care :

- Health care has been a major user of IoT applications, where IoT applications are helping the users to gather statistical data and further control and automate the medical process.
- According to a recent survey, the IoT market share has been increased from USD $298 Billion in the year 2014 to USD $700 Billion in the year 2017.
- IoT technology is being embedded in health care devices, including wearable and implantable devices used to monitor and improve patients' medical conditions. With the advancement in IoT in the medical and health care domain, investors and the public will benefit in many ways.

2. Business Analytics

- IoT devices embedded in machines generate a large amount of data that is being used by BI (Business Intelligence tools) such as Power BI to generate useful insights and predict future outcomes.

- With the help of business analytics tools, the data generated from IoT are used to study customer behavior to increase customer satisfaction rates and provide a better customer experience.
- In the near future, BI tools will be embedded within things such as wearable health monitoring systems, which can make instant decisions based on the current data.
- Data recorded from the user's behavior and everyday habits will give better opportunities for the caretakers and hospitals to tackle any sickness in advance.

3. Entertainment System:

- Several smart apps such as car navigation systems and voice assistance systems are already making their way to the cars. With the help of IoT, these features have been embedded in vehicles. Automakers have partnered with Google for their apps such as google maps, google assistant, and Play store services.

4. Smart city

- Smart city IoT application is designed to provide improved and better-living conditions. With the growth in technology and population, IoT will play a major role in managing the city and population. Many services such as energy-saving lights, weather reporting systems, and streetlights will be embedded with IoT solutions for sustainable and cost-effective reasons.

5. Smart Home:

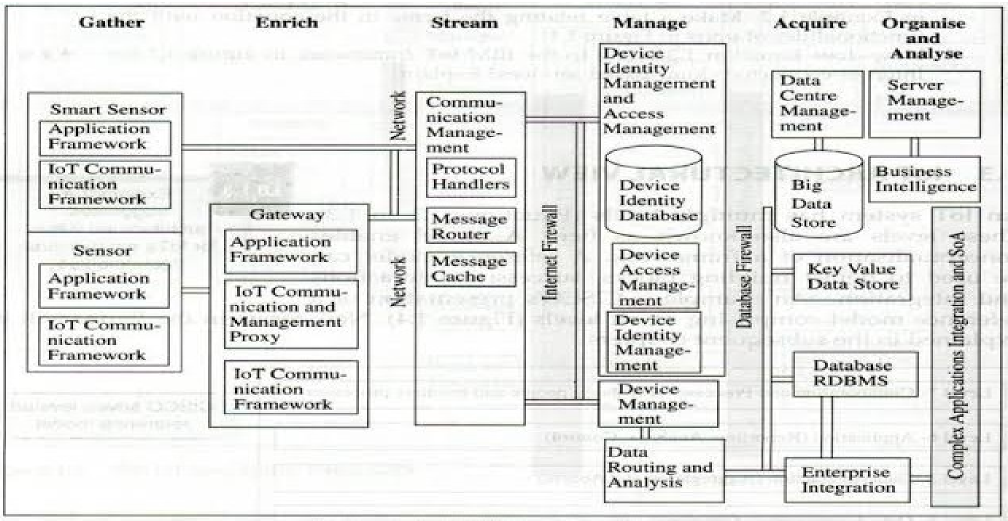
- Home automation has seen rapid growth in recent times. Consumers have been provided with services like lightning control for their homes, voice-based controlling, smart air quality adjustment, AI experience, and smart locks with the IoT enabled in homes.

6. **Smart Agriculture**
7. **Smart Education**
8. **Industrial and Manufacturing**

IOT CONCEPTUAL FRAMEWORK :

- The main tasks of this framework are to analyze and determine the smart activities of these intelligent devices through maintaining a dynamic interconnection among those devices.
- The proposed framework will help to standardize IoT infrastructure so that it can receive e-services based on context information leaving the current infrastructure unchanged.
- This model is capable of logical division of physical devices placement, creation of virtual links among different domains, networks and collaborate among multiple application without any central coordination system.

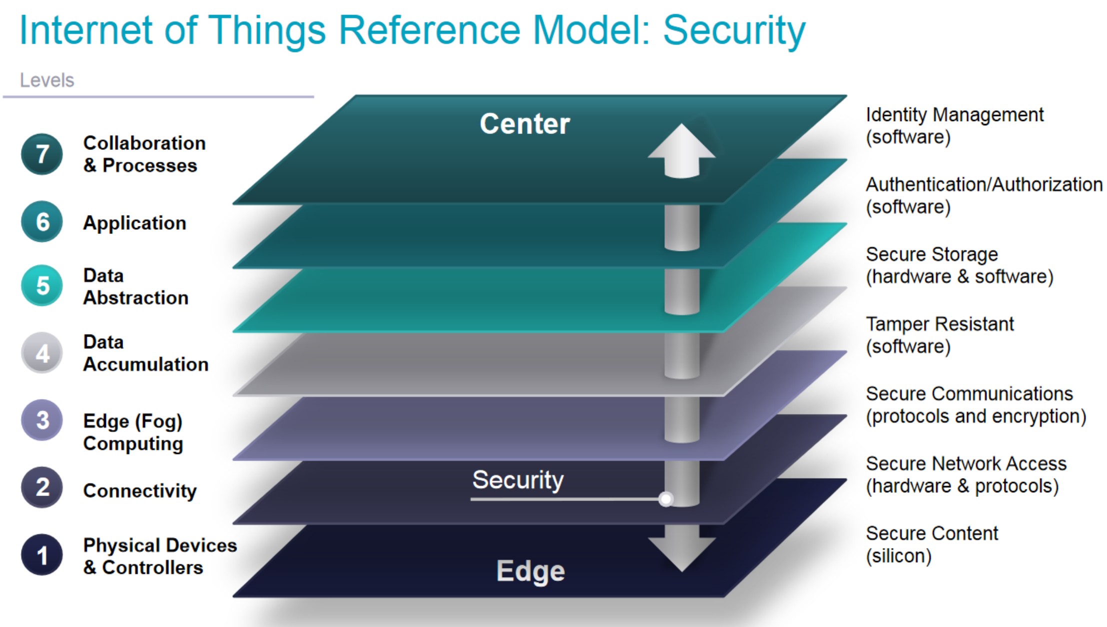
- Level 1 : Gather,
- Level 2 : Enrich,
- Level 3 : Stream,
- Level 4 : Manage,
- Level 5 : Aquire,
- Level 6 : Organise



- **In level 1** we can see smart sensor and sensor (smart sensor have ability to compute and communicate). Smart sensor collect the data and then transmit it to level 2 through transcode. Transcode does coding and decoding.
- **Level 2:** Gateway - Data comes to Gateway after the encoding. when data go to the next level from Gateway decoding is done.
- **Level 3**: Communication management present there and it send send receive the data.
- **Level 4:**In level 4 it receive the device data (means the hardware which we are using also registered and only they can access the data). For eg: Considere that two mobile phones connected to each other if first mobile phone wants to communicate with second mobile phone so the first mobile phone is registered and the data of their mobile phone is on level 4. and that mobile data contained the data of device register and connection or the device identity.
- **Level 5:** It is a database which stores the data.
- **Level 6:**In level 6 the data comes in all previous levels are analysed and organized.(Data is analysed and decide whether the data is authenticated sensitive or non sensitive)

IOT REFERENCE MODEL

- The IoT Reference Model defines a set of levels with control flowing from the center (this could be either a cloud service or a dedicated data center), to the edge, which includes sensors, devices, machines, and other types of intelligent end nodes.



Layer 1: Physical Devices and Controllers Layer

- The first layer of the IoT Reference Model is the physical devices and controllers layer.
- The "things" in the Internet of Things, including the various endpoint devices and sensors that send and receive information.
- The size of these "things" can range from almost microscopic sensors to giant machines in a factory. Their primary function is generating data and being capable of being queried and/or controlled over a network.

Layer 2: Connectivity Layer

- In the second layer of the IoT Reference Model, the focus is on connectivity. The most important functionof this IoT layer is the reliable and timely transmission of data.
- More specifically, this includes transmissions between Layer 1 devices and the network and between the network and information processing that occurs at Layer 3 (the edge computing layer).

Layer 3: Edge Computing Layer

- Edge computing is the role of Layer 3.
- Edge computing is often referred to as the "fog" layer.
- At this layer, the emphasis is on data reduction and converting network data flows into information that is ready for storage and processing by higher layers.
- One of the basic principles of this reference model is that information processing is initiated.

Layer 4: Data Accumulation

- Captures data and stores it so it is usable by applications when necessary.

Converts event based data to query based processing.

Layer 5: Data Abstraction Layer

- Reconciles multiple data formats and ensures consistent semantics from various sources. Confirms that the data set is complete and consolidates data into one place or multiple data stores using virtualization.

Layer 6: Application Layer

- Interprets data using software applications. Applications may monitor , control and provide reports based on the analysis of the data.

Layer 7: Collaboration and Process Layer

- Consumes and shares the application information. Collaborating on and communicating IoT information often requires multiple steps and it is what makes iot useful.
- This layer can change business processes and delivers the benefits of IoT.

IoT Architectural View

IOT architectural view-

- IoT architecture consists of different layers of technologies supporting IoT. It serves to illustrate how various technologies relate to each other and to communicate the scalability, modularity and configuration of IoT deployments in different scenarios. The functionality of each layer is described below:

Smart device / sensor layer:

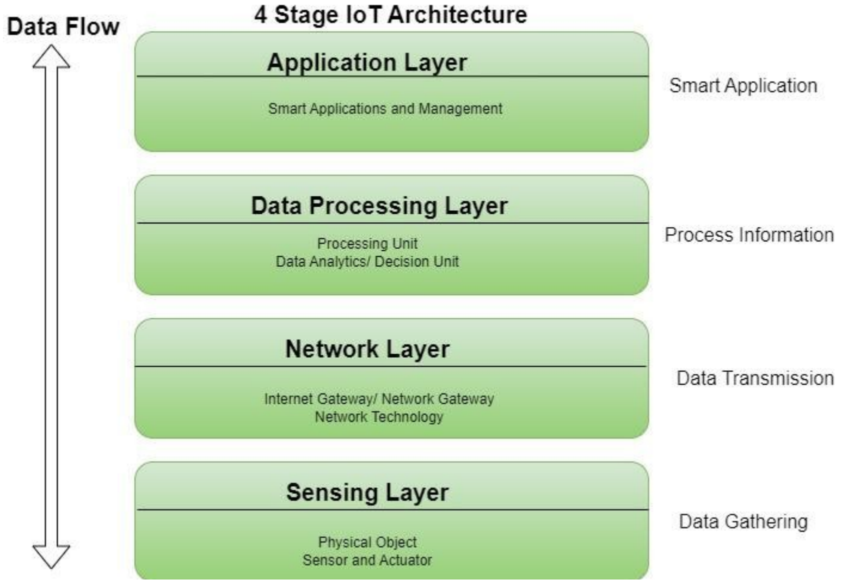
- The lowest layer is made up of smart objects integrated with sensors.
- The sensors enable the interconnection of the physical and digital worlds allowing real-time information to be collected and processed.
- There are various types of sensors for different purposes. The sensors have the capacity to take measurements such as temperature, air quality, speed, humidity, pressure, flow, movement and electricity etc.
- In some cases, they may also have a degree of memory, enabling them to record a certain number of measurements. A sensor can measure the physical property and convert it into signal that can be understood by an instrument. Sensors are grouped according to their unique purpose such as environmental sensors, body sensors, home appliance sensors and vehicle telemetric sensors, etc

Gateways and Networks-

- Massive volume of data will be produced by these tiny sensors and this requires a robust and high performance wired or wireless network infrastructure as a transport medium.
- Current networks, often tied with very different protocols, have been used to support machine-to-machine (M2M) networks and their applications.
- With demand needed to serve a wider range of IoT services and applications such as high speed transactional services, context- aware applications, etc, multiple networks with various technologies and access protocols are needed to work with each other in a heterogeneous configuration.
- These networks can be in the form of a private, public or hybrid models and are built to support the communication requirements for latency, bandwidth or security. Various gateways (microcontroller, microprocessor) & gateway networks (WI-FI, GSM, GPRS).

Management Service Layer-

- The management service renders the processing of information possible through analytics, security controls, process modeling and management of devices.
- One of the important features of the management service layer is the business and process rule engines.
- IoT brings connection and interaction of objects and systems together providing information in the form of events or contextual data such as temperature of goods, current location and traffic data.
- Some of these events require filtering or routing to post-processing systems such as capturing of periodic sensory data, while others require response to the immediate situations such as reacting to emergencies on patient’s health conditions.
- The rule engines support the formulation of decision logics and trigger interactive and automated processes to enable a more responsive IoT system.



Architecture of IoT

The architecture of IoT is divided into 4 different layers i.e. Sensing Layer, Network Layer, Data processing Layer, and Application Layer.

- **Sensing Layer:** The sensing layer is the first layer of the Internet of Things architecture and is responsible for collecting data from different sources. This layer includes sensors and actuators that are placed in the environment to gather information about temperature, humidity, light, sound, and other physical parameters. Wired or wireless communication protocols connect these devices to the network layer.

- **Network Layer:** The network layer of an IoT architecture is responsible for providing communication and connectivity between devices in the IoT system. It includes protocols and technologies that enable devices to connect and communicate with each other and with the wider internet. Examples of network technologies that are commonly used in IoT include WiFi, Bluetooth, Zigbee, and cellular networks such as 4G and 5G technology. Additionally, the network layer may include gateways and routers that act as intermediaries between devices and the wider internet, and may also include security features such as encryption and authentication to protect against unauthorized access.

- **Data processing Layer:** The data processing layer of IoT architecture refers to the software and hardware components that are responsible for collecting, analyzing, and interpreting data from IoT devices. This layer is responsible for receiving raw data from the devices, processing it, and making it available for further analysis or action. The data processing layer includes a variety of technologies and tools, such as data management systems, analytics platforms, and machine learning algorithms. These tools are used to extract meaningful insights from the data and make decisions based on that data. Example of a technology used in the data processing layer is a data lake, which is a centralized repository for storing raw data from IoT devices.

- **Application Layer:** The application layer of IoT architecture is the topmost layer that interacts directly with the end-user. It is responsible for providing user-friendly interfaces and functionalities that enable users to access and control IoT devices. This layer includes various software and applications such as mobile apps, web portals, and other user interfaces that are designed to interact with the underlying IoT infrastructure. It also includes middleware services that allow different IoT devices and systems to communicate and share data seamlessly. The application layer also includes analytics and processing capabilities that allow data to be analyzed and transformed into meaningful insights. This can include machine learning algorithms, data visualization tools, and other advanced analytics capabilities.

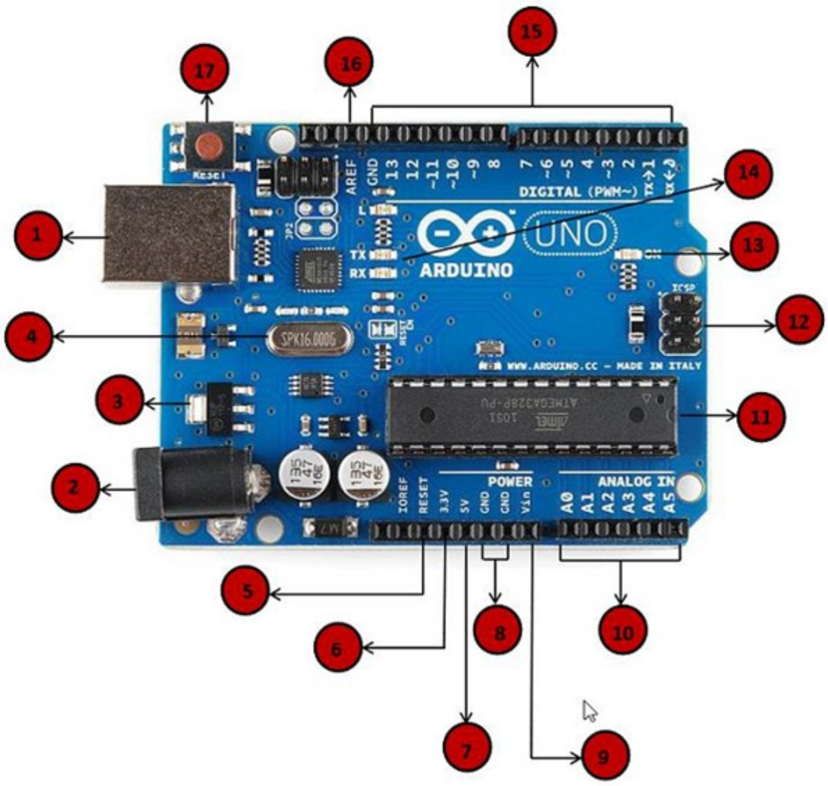
ARDUINO : TYPES, FUNDAMENTALS AND CONFIGURATION

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board.

The key features of Arduino are:

- Arduino boards are able to read analog or digital input signals from different sensors and turn it into an output such as activating a motor, turning LED on/off, connect to the cloud and many other actions.
- You can control your board functions by sending a set of instructions to the microcontroller on the board via Arduino IDE (referred to as uploading software).
- Finally, Arduino provides a standard form factor that breaks the functions of the micro-controller into a more accessible package.

Different components in Arduino Uno board are shown in the below figure.



{1} Power USB : Arduino board can be powered by using the USB cable from your computer. All you need to do is connect the USB cable to the USB connection.

{2} Power (Barrel Jack) : Arduino boards can be powered directly from the AC mains power supply by connecting it to the Barrel Jack.

{3} Voltage Regulator : The function of the voltage regulator is to control the voltage given to the Arduino board and stabilize the DC voltages used by the processor and other elements.

{4} Crystal Oscillator : The crystal oscillator helps Arduino in dealing with time issues. How does Arduino calculate time? The answer is, by using the crystal oscillator. The number printed on top of the Arduino crystal is 16.000H9H. It tells us that the frequency is 16,000,000 Hertz or 16 MHz.

{5} Arduino Reset : You can reset your Arduino board, i.e., start your program from the beginning. You can reset the UNO board in two ways. First, by using the reset button (17) on the board. Second, you can connect an external reset button to the Arduino pin labelled RESET.

Pins (3.3, 5, GND, Vin)

- {6} 3.3V − Supply 3.3 output volt
- {7} 5V − Supply 5 output volt
- Most of the components used with Arduino board works fine with 3.3 volt and 5 volt.
- {8} GND(Ground) − There are several GND pins on the Arduino, any of which can be used to ground your circuit.
- {9} Vin − This pin also can be used to power the Arduino board from an external power source, like AC mains power supply.

{10} Analog pins : The Arduino UNO board has six analog input pins A0 through A5. These pins can read the signal from an analog sensor like the humidity sensor or temperature sensor and convert it into a digital value that can be read by the microprocessor.

{11} Main microcontroller : Each Arduino board has its own microcontroller. You can assume it as the brain of your board. The main IC (integrated circuit) on the Arduino is slightly different from board to board. The microcontrollers are usually of the ATMEL Company. You must know what IC your board has before loading up a new program from the Arduino IDE. This information is available on the top of the IC. For more details about the IC construction and functions, you can refer to the data sheet.

{12} ICSP pin : Mostly, ICSP is an AVR, a tiny programming header for the Arduino consisting of MOSI, MISO, SCK, RESET, VCC, and GND. It is often referred to as an SPI (Serial Peripheral Interface), which could be considered as an "expansion" of the output. Actually, you are slaving the output device to the master of the SPI bus.

{13} Power LED indicator : This LED should light up when you plug your Arduino into a power source to indicate that your board is powered up correctly. If this light does not turn on, then there is something wrong with the connection.

{14} TX and RX LEDs : On your board, you will find two labels: TX (transmit) and RX (receive). They appear in two places on the Arduino UNO board. First, at the digital pins 0 and 1, to indicate the pins responsible for serial communication. Second, the TX and RX led. The TX led flashes with different speed while sending the serial data. The speed of flashing depends on the baud rate used by the board. RX flashes during the receiving process.

{15} Digital I/O : The Arduino UNO board has 14 digital I/O pins (of which 6 provide PWM (Pulse Width Modulation) output. These pins can be configured to work as input digital pins to read logic values (0 or 1) or as digital output pins to drive different modules like LEDs, relays, etc. The pins labeled "~" can be used to generate PWM.

{16} AREF : AREF stands for Analog Reference. It is sometimes, used to set an external reference voltage (between 0 and 5 Volts) as the upper limit for the analog input pins.

CONFIGIRATION OF ARDUINO

Raspberry Pi

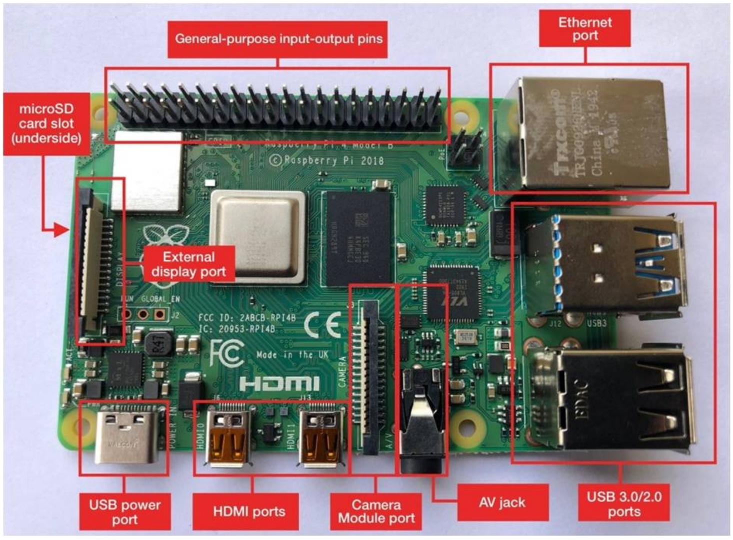
Raspberry Pi is a small single board computer. By connecting peripherals like Keyboard, mouse, display to the Raspberry Pi, it will act as a mini personal computer. Raspberry Pi is popularly used for real time Image/Video Processing, IoT based applications and Robotics applications. Raspberry Pi is slower than laptop or desktop but is still a computer which can provide all the expected features or abilities, at a low power consumption.

It has ARM based Broadcom Processor SoC along with on-chip GPU (Graphics Processing Unit). The CPU speed of Raspberry Pi varies from 700 MHz to 1.2 GHz. SDRAM that ranges from 256 MB to 1 GB. Raspberry Pi also provides on-chip SPI, I2C, I2S and UART modules.

There are different versions of raspberry pi available as listed below:

- Raspberry Pi 1 Model A
- Raspberry Pi 1 Model A+
- Raspberry Pi 1 Model B
- Raspberry Pi 1 Model B+
- Raspberry Pi 2 Model B
- Raspberry Pi 3 Model B
- Raspberry Pi 3 Model B+
- Raspberry Pi 4 Model B
- Raspberry Pi Zero

Different components on Raspberry Pi 4 Model B board are as shown in the figure below.



The Raspberry Pi 4 board contains the following components:

- **General-purpose input–output pins:** These pins are used to connect the Raspberry Pi to electronic components

- **Ethernet port:** This port connects the Raspberry Pi to a wired network. The Raspberry Pi also has Wi-Fi and Bluetooth built in for wireless connections

- **Two USB 3.0 and two USB 2.0 ports:** These USB ports are used to connect peripherals like a keyboard or mouse. The two black ports are USB 2.0 and the two blue ports are USB 3.0

- **AV jack:** This AV jack allows you to connect speakers or headphones to the Raspberry Pi
- **Camera Module port:** This port is used to connect the official Raspberry Pi Camera Module, which enables the Raspberry Pi to capture images
- **HDMI ports:** These HDMI ports connect the Raspberry Pi to external monitors. The Raspberry Pi 4 features two micro HDMI ports, allowing it to drive two separate monitors at the same time
- **USB power port:** This USB port powers the Raspberry Pi. The Raspberry Pi 4 has a USB Type-C port, while older versions of the Pi have a micro-USB port
- **External display port:** This port is used to connect the official seven-inch Raspberry Pi touch display for touch-based input on the Raspberry Pi
- **microSD card slot (underside of the board):** This card slot is for the microSD card that contains the Raspberry Pi operating system and files

The pin out diagram for Raspberry Pi board is as shown below.