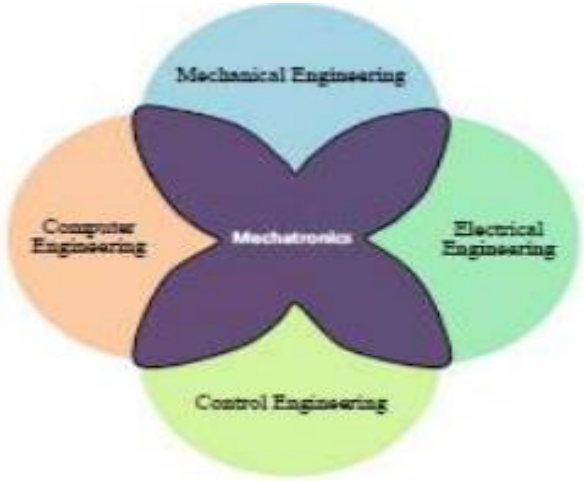
MODULE 5

MECHATRONICS

Mechatronics can be defined as an interdisciplinary approach to engineering design through an integration of mechanical engineering, electrical engineering, computer technology, electronics and control engineering.



Example: automatic washing machine, digital fuel injection system, engine management system. Etc.

CONTROL SYSTEM:

A control system is a system, which provides the desired response by controlling the output. The following figure shows the simple block diagram of a control system.

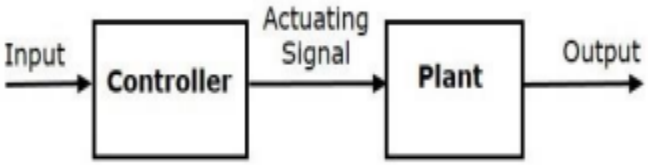
Here, the control system is represented by a single block. Since, the output is controlled by varying input, the control system got this name. We will vary this input with some mechanism. Examples − Traffic lights control system, washing machine.

Traffic lights control system is an example of control system. Here, a sequence of input signal is applied to this control system and the output is one of the three lights that will be on for some duration of time. During this time, the other two lights will be off. Based on the traffic study at a particular junction, the on and off times of the lights can be determined. Accordingly, the input signal controls the output. So, the traffic lights control system operates on time basis.

Control Systems can be classified as open loop control systems and closed loop control systems based on the feedback path.

OPEN LOOP CONTROL SYSTEM:

In open loop control systems, output is not fed-back to the input. So, the control action is independent of the desired output. The following figure shows the block diagram of the open loop control system.



Here, an input is applied to a controller and it produces an actuating signal or controlling signal. This signal is given as an input to a plant or process which is to be controlled. So, the plant produces an output, which is controlled. The traffic lights control system which we discussed earlier is an example of an open loop control system.

Practical examples of open loop control system

1. **Electric Hand Drier**: Hot air (comes out as long as you keep your hand under the machine, irrespective of how much your hand is dried
2. **Automatic Washing Machine**: This machine runs according to the pre set time irrespective of washing is completed or not.
3. **Bread Toaster**: This machine runs as per adjusted time irrespective of toasting is completed or not.
4. **Automatic Tea/Coffee Maker**: These machines also function for pre adjusted time only
5. **Timer Based Clothes Drier**: This machine dries wet clothes for pre adjusted time, it does not matter how much the clothes are dried
6. **Light Switch Lamps glow**: whenever light switch is on irrespective of light is required or not Volume on Stereo System: Volume is adjusted manually irrespective of output volume level.

Advantages of Open Loop Control System

1. Simple in construction and design.
2. Economical.
3. Easy to maintain.
4. Generally stable.
5. Convenient to use as output is difficult to measure.

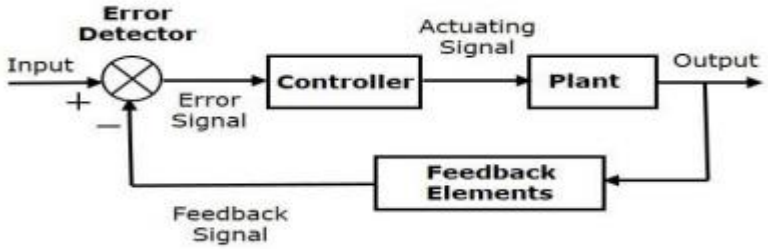
Disadvantages of Open Loop Control System

1. They are inaccurate.
2. They are unreliable.
3. Any change in output cannot be corrected automatically

CLOSED LOOP CONTROL SYSTEM:

In closed loop control systems, output is fed back to the input. So, the control action is dependent on the desired output.

The following figure shows the block diagram of negative feedback closed loop control system.



The error detector produces an error signal, which is the difference between the input and the feedback signal. This feedback signal is obtained from the block (feedback elements) by considering the output of the overall system as an input to this block. Instead of the direct input, the error signal is applied as an input to a controller.

So, the controller produces an actuating signal which controls the plant. In this combination, the output of the control system is adjusted automatically till we get the desired response. Hence, the closed loop control systems are also called the automatic control systems. Traffic lights control system having sensor at the input is an example of a closed loop control system.

Practical Examples of Closed Loop Control System

1. Automatic Electric Iron: Heating elements are controlled by output temperature of the iron. Servo Voltage Stabilizer: Voltage controller operates depending upon output voltage of the system.
2. Water Level Controller: Input water is controlled by water level of the reservoir.
3. Missile Launched and Auto Tracked by Radar: The direction of missile is controlled by comparing the target and position of the missile.
4. An Air Conditioner: An air conditioner functions depending upon the temperature of the room.
5. Cooling System in Car: It operates depending upon the temperature which it controls.

The differences between the open loop and the closed loop control systems are mentioned in the following table

Sl No	Open Loop Control Systems	Closed Loop Control Systems
1	Control action is independent of the desired output.	Control action is dependent of the desired output.
2	Feedback path is not present.	Feedback path is present.
3	These are also called as non-feedback control systems.	These are also called as feedback control systems.
4	Easy to design.	Difficult to design.
5	These are economical.	These are costlier.
6	Inaccurate.	Accurate.

SENSORS:

A sensor is defined as a device or a module that helps to detect any changes in physical quantity like pressure, force or electrical quantity like current or any other form of energy. After observing the changes, sensor sends the detected input to a microcontroller or microprocessor.

DISPLACEMENT SENSORS: A Displacement Sensor is a device that measures the distance between the sensor and an object by detecting the amount of displacement through a variety of elements and converting it into a distance.

Features

1. A physical quantity of an object can be measured.

A Displacement Sensor measures and detects changes (displacement) in a physical quantity: The Sensor can measure the height, width, and thickness of an object by determining the amount of displacement of that object. A Measurement Sensor measures the position and dimensions of an object.

2. Physical quantity output is also possible in addition to ON/OFF signal output: Analog output of physical quantities (current output or voltage output) can also be performed (excluding some models).

Some models also support digital (serial) communications.

PROXIMITY SENSORS: A proximity sensor is a non-contact sensor that detects the presence of an object (often referred to as the "target") when the target enters the sensor's field. Depending on the type of proximity sensor, sound, light, infrared radiation (IR), or electromagnetic fields may be utilized by the sensor to detect a target.

For Examples: This sensor is most frequently used in mobile phones, so the role of the proximity sensor in mobile is to detect a nearby person. For instance, an IR proximity sensor is used in mobile phones to detect a human ear when the operator places the phone on the ear, then the mobile display will be turned off automatically, so power consumption can be reduced.

ACTUATORS:

Actuators are machines capable of converting a form of energy into physical force or mechanical motions. In easier language, actuators are components that enable motion in a machine or in an object.

To perform the motion, actuators need a control signal and a source of energy.

The energy can be in the form of electrical energy, hydraulic fluid pressure, pneumatic pressure, etc.

Classification based on the basis of source of energy

On the basis of the source of energy used to power an actuator, there are eight types of actuators:

1. Electric Actuators

Electric actuators are devices that take electrical energy both AC or DC as an input to provide a mechanical torque or linear motion. Electric motors are becoming one of the most commonly used actuators due to their easier control, longer life spans, and high efficiency.

Advantages of Electric Actuators

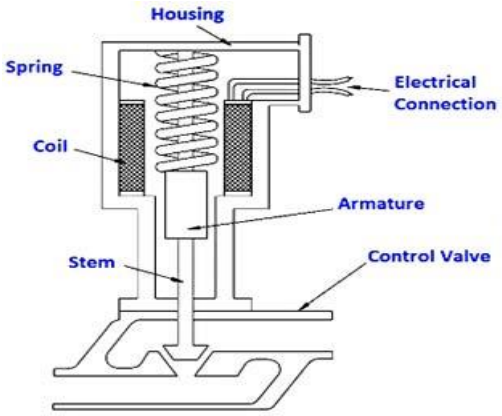
- Electric actuators offer the highest precision among all types of actuators.
- They are highly modular and scalable for different purposes and force requirements.
- Electric actuators are capable of working in extreme conditions.
- Easy to construct and repair.
- Lack of oil and other fluids make them much more durable for a given weight.
- They produce less sound than hydraulic and pneumatic actuators.

Disadvantages of Electric Actuators

- Higher initial cost for higher powered applications.
- Control mechanism is more complex
- Requires highly skilled people for maintenance and repair.
- These are unsuitable for hazardous and flammable areas.
- Electric motors require a gear mechanism, thus higher maintainability.

2. Hydraulic Actuators

- The hydraulic actuators consist of a cylinder or fluid-based motor which utilizes the power of hydraulics to create mechanical actions.
- Hydraulic actuators are capable of providing linear as well as rotary motions.
- They utilize incompressible fluids such as oils from a pump that fills the cylinder to apply power to either one or both sides of the pistons.
- The speed and force can be adjusted by increasing the pressure of the fluid inside the cylinder.



Advantages of Hydraulic Actuators

- They are capable of producing high speed and high power
- Hydraulic actuators can hold constant force even without a pump consuming extra energy for supplying fluids to the cylinder as they utilize incompressible fluids.

Disadvantages of Hydraulic Actuators

- They require higher maintenance cost
- Leaks in the fluid may result in loss of efficiency, the fluids can also impact the environment adversely.
- They are not suitable for extreme temperatures as the fluid property may vary depending on temperatures.

3. Pneumatic Actuators

- Pneumatic Actuators are similar to hydraulic actuators.
- The difference is the fluid used for driving the pistons is gaseous in nature.
- The energy is from either a high-pressured compressed air or vacuum is used to get a liner or rotary mechanical motion. Similar to hydraulic actuators, they convert pressure into force.

Advantages of Pneumatic Actuators

- Very fast response rate
- High forces can be produced with small pressure changes
- Cheaper to construct and operate than electrical and hydraulic actuators.
- Pneumatic actuators produce higher power than electric or hydraulic actuators.
- It can be used in extreme temperatures and hazardous conditions as it is safer to operate air in hazardous places than chemicals or electricity.

Disadvantages of Pneumatic Actuators

- Even if no movement is required a compressor must operate continuously since pressure losses and compressibility of air make pneumatic actuators loose power.
- Small leaks are difficult to identify than in hydraulic actuators.

ROBOTICS:

Robotics is the engineering and operation of machines that can autonomously or semi-autonomously perform physical tasks on behalf of a human.

An industrial robot is a programmable, multi-functional manipulator designed to move materials, parts, tools, or special devices through variable programmed motions for the performance of a variety of tasks. An industrial robot consists of a number of rigid links connected by joints of different types, controlled and monitored by a computer.

Robot anatomy

1. Manipulator: Just like the human arm, the robot consists of what is called a manipulator having several joints and links.

2. End Effector: The base of the manipulator is fixed to base support and at its other free end, the End effector is attached. The End effector is expected to perform tasks normally performed by the palm and finger arrangements of the human arm.

Various types of end-effectors are designed for the same robot to make it more flexible and versatile.

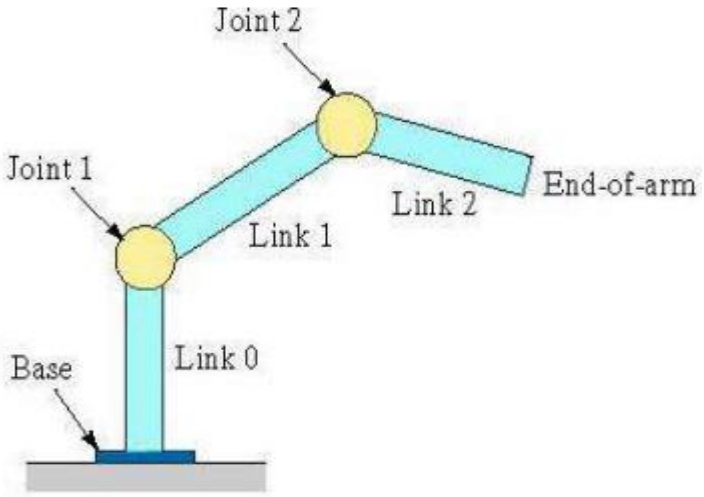
Grippers: are generally used to grasp and hold an object and place it at a desired location. Grippers can be classified as mechanical grippers, vacuum or suction cups, magnetic grippers, adhesive grippers, hooks, scoops, and so forth.

Tools: a robot is required to manipulate a tool to perform an operation on a work part. Here the tool acts as end-effector. Spot-welding tools, arc-welding tools, spray-painting nozzles, and rotating spindles for drilling and grinding are typical examples of tools used as end-effectors.

3. The Locomotion Device: In the case of Human Beings, the power for the movement of the arm, the palm and fingers are provided by muscles. For the robot the power for the movement (locomotion) is provided by the motors. The motors used for providing locomotion in robots are of three types depending on the source of energy: Electric, Hydraulic or Pneumatic.

4. The Controller: The digital computer (both the hardware and the software) acts as a controller to the robot. The controller functions in a manner analogous to the human brain. With the help of this controller, the robot is able to carry out the assigned tasks. The controller directs and controls the movement of the Manipulator and the End effector. In other words, the controller controls the robot.

5. The Sensors: Without the data supplied by the sense organs, the brain would be incapable of intelligence. In other words, the controller (the computer) of the robot cannot do any meaningful task, if the robot is not with a component analogous to the sense organs of the human body. Thus, the fifth and the most important component of the robot is the set of sensors. Sensors are nothing but measuring instruments which measures quantities such as position, velocity, force, torque, proximity, temperature, etc.



Joints and links

Manipulator consists of joints and links

➢ Joints provide relative motion

➢ Links are rigid members between joints

➢ Various joint types: linear and rotary

➢ Each joint provides a "degree-of-freedom"

➢ Most robots possess five or six degrees-of-freedom

➢ Robot manipulator consists of two sections:

i. Body-and-arm – for positioning of objects in the robot's work volume

ii. Wrist assembly – for orientation of objects

ROBOT CONFIGURATION:

Robot configuration specifies the possible movements provided by different robots. The majority of present commercially available robots possess one of these four basic configurations.

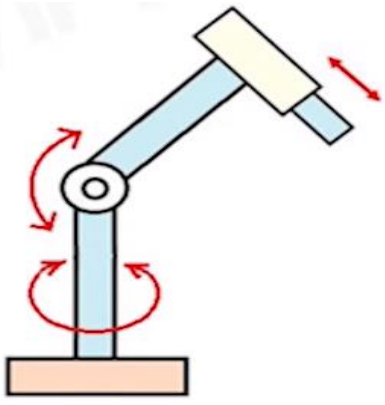
1. Polar configuration
2. Cylindrical configuration
3. Cartesian configuration
4. Jointed arm configuration

1. Polar configuration:

Polar configuration robot uses a telescopic arm that can be raised or lowered about a horizontal joint.

This robot consists of 1 T-joint, 1 L-joint & 1 R-joint. Hence it is also called as T-L-R configuration robot.

The workspace in which it moves is spherical.

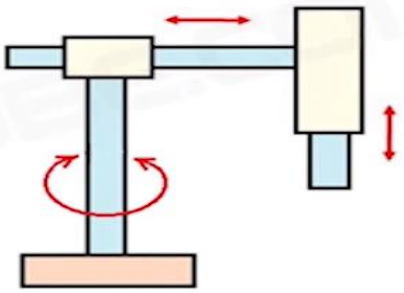


2. Cylindrical configuration:

Cylindrical configuration robot consists of a vertical column and a slide which can be moved up and down.

This robot consists of 1 T-joint, 1 L-joint & 1 O-joint. hence it is also called as T-L-O configuration robot.

The workspace in which it moves is cylindrical.

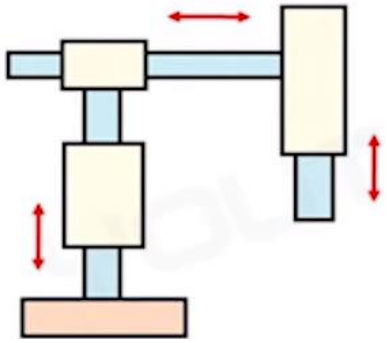
	**Applications:** • Material handling • Small assembly task • Machine loading & unloading

3. Cartesian configuration:

Cartesian configuration robot consists of 3 perpendicular slides arranged in X, Y & Z directions.

This robot consists of 1 L-joint & 2-O joint. Hence it is also called as L-O-O configuration robot.

The workspace in which it moves is a rectangular or box.

	**Applications:** 1. Carrying high payloads 2. Pick & place 3. Material handling 4. Used in a sealing 5. 3D printing

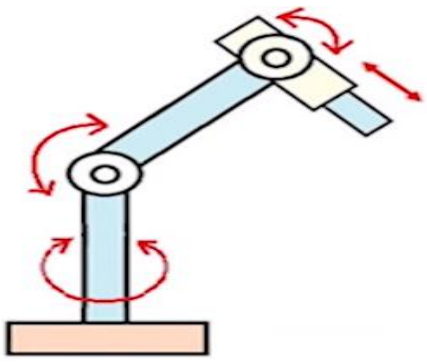
Advantages	**Disadvantages**
1. High accurate & high speed 2. Cost is less 3. Simple operating procedure	1. This robot requires large volume space to operate

6. Joined-arm configuration:

Jointed arm configuration robot consists of 2 straight components that corresponds to human forearm and upper arm.

This robot consists of 1 T-joint and 2 R-joint. Hence it is also called as T-R-R configuration robot.

The workspace in which it moves is irregular.

	**Applications:** • Manufacturing of steel bridges • Cutting steel • Flat glass handling • Heavy duty robots • Automation if foundry industries • Metal casting

Advantages:	**Disadvantages:**
1. High speed 2. Large working envelope 3. Great unique control over welding & painting applications	1. This robot requires dedicated robot controller like PLC

AUTOMATION IN INDUSTRY:

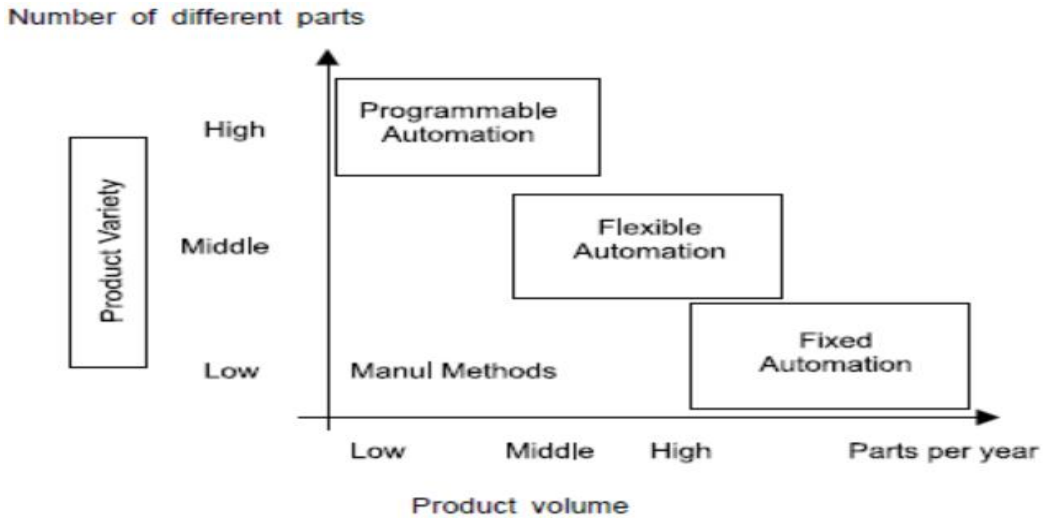
Definition: - It is technology concerned with the application of Mechanical, electronic & computer –based systems to operate and control production in order to improves productions.

The advantages of automation are:

- Reduced human labour required
- Consistency in quality
- Fewer risks of human error
- Improved health & safety
- Improved efficiency

Automation systems are classed into three different types of automation:

- Fixed automation
- Programmable automation
- Flexible automation



1. Fixed automation: Fixed automation is a type of automation where the process of manufacturing stays fixed by the way it is configured, following a fixed sequence of automated processes. An example of this is flow production, where products are continuously being made. This is often also known as "hard automation".

Fixed automation can be expensive to set up initially due to the equipment required, but in return, it provides high production rates. However, it is relatively inflexible when it comes to making changes to the product.

This is relatively useful for many companies who use automation to create food products of one type and variant. It allows them to effectively produce that item and package it in bulk. Foods that require chemical processes, for example, may use this to ensure the consistency of the chemical processes.

Advantages of fixed automation include:

1. High levels of production
2. Consistent quality in production
3. Low cost per unit produced

Disadvantages of fixed automation include:

1. High initial cost
2. Difficult to accommodate changes

This type of automation is best suited for: **High demand and generic products that require no change.**

Example: Coca Cola continues to use this automation in their factories. As seen above, this allows for the production of large quantities of the soft drink, allowing Coca Cola to meet the high demands of their classic soft drink.

2. Programmable Automation

Programmable automation allows the production equipment and automation to be altered to changing needs. This is done by controlling the automation through a program, which can be coded in certain ways for the automation to change the sequence of automation.

It's used more commonly in low to medium levels of production, often being most suitable for **batch production**.

Programmable automation will often be used by factories who make different variants of foods. This allows them to make batches, from a few dozen to potentially thousands at a time, of one product. If the product needs changing, it simply needs to be reprogrammed.

Advantages include:

1. Flexibility to change products if needed
2. Suitable if batch production is required

Disadvantages include:

1. Expensive for equipment
2. Lower production levels
3. Often time-consuming to change products

This type of automation is well suited for: **Low/Medium demand and occasional changes in products.**

3. Flexible Automation

Flexible automation, also known as "soft automation", is similar to programmable automation, although a little more complicated. Essentially, flexible automation enables the production of different types of products without losing time when reprogramming.

A flexible automation system can produce various combinations of products efficiently without having to separate them into different batches, as required in batch production. This type of automation tends to have medium levels of production.

Advantages include:

1. Flexibility of products
2. No time lost with new changes to production

Disadvantages include:

1. High custom machinery/automation cost
2. Higher cost per unit

INTERNET OF THINGS (IOT)

Definition: - IoT is a technology transition in which devices will allow us to sense and control the physical world by making objects smarter and connecting them through an intelligent network.

GOAL: The basic premise and goal of IoT is to "connect the unconnected." This means that objects that are not currently joined to a computer network, namely the Internet, will be connected so that they can communicate and interact with people and other objects.

When objects and machines can be sensed and controlled remotely across a network, a tighter integration between the physical world and computers is enabled.

This allows for improvements in the areas of efficiency, accuracy, automation, and the enablement of advanced applications.

- **Characteristic of IoT:**

1. **Connectivity:** in IoT, anything, anywhere, anytime should be connected to the infrastructure without connection nothing makes sense.
2. **Intelligence:** extraction of knowledge from the generated data is important, sensor generate data and this data should be interpreted properly.
3. **Scalability:** the number of devices that need to be managed & that communicate with each other will much larger than the devices connected to the current internet. Hence an IoT setups shall be able to handle the massive expansion (handling the growing things & the increase in data)
4. **Heterogeneity:** devices in IoT are based on different hardware platforms & networks & can interact with other devices or service platforms through different networks. IoT architecture should support direct network connectivity between heterogeneous networks.

5. **Unique identity:** each IoT device has as IP address. This is helpful in tracking the equipment & at times to query its status.
6. **Dynamic & self-adapting:** The IoT device must dynamically adopt itself to the changing context. (Temperature, location, speed).

   Example: a camera meant for surveillance may have to work in different conditions & at different light situations.
7. **Safety:** IoT devices are vulnerable to security threats. As our personal data is shared with the help of internet, it can be tempered if proper safety measures are not taken. So the personal data of the user needs to be secured from any data theft & security of expensive IoT things.

Physical design of IoT: it refers to

- IoT devices
- IoT protocols

➢ **IoT Devices:**

- Things in IoT are IoT devices.
- They have unique identities.
- They perform remote sensing, actuating & Monitoring.
- Types of IoT devices- sensing devices, smart watches, smart electronic appliances, wearable sensors, automobiles, industrial machines, etc.
- Data generated by IoT devices processed by data analysis systems leads to useful information to guide further actions locally or remotely.
- IoT devices can exchange data with other connected devices & applications directly or indirectly or collect data from other devices.

Generic block diagram of IoT devices:

Connectivity Use host RI45/ETHERNET	Processor CPU	Audio/video interfaces HDML 3-5mm audio RCA video	I/O Interface (for sensors, actuators) UART SPI I2C CAN
Memory NAND/NOR DDR/1/2/3	Graphics GPU	Storage interface SD MMC SDIO	

IoT protocols:

helps to establish communication between I/O devices & cloud based serves over the internet. It also helps to send commands to IoT devices and service data from an IoT device over the internet.

IoT protocols used at different layers-

Application layer

HTTP COAP web sockets

MQTT XMPP DDS AMQP

Transport layer

TCP UDP

Network layer

IPVC

FUNCTIONAL BLOCKS OF IOT:

COMMUNICATION MODELS IN IoT:

Communication models determine the mechanism or the manner in which data or information is exchanged or transferred or shared between various devices in the IoT network.

There are various types of communication models that are used for data exchange in the IoT network.