Overview

- Introduction to IoT
  - What is IoT?
  - IoT terms and Basic Definitions
  - Disambiguation of IoT vs IoE vs M2M vs Others
  - Characteristics of IoT
  - Applications of IoT
  - Things in IoT
  - IoT Reference Model
  - Building Blocks of IoT
  - 4 stages of IoT architecture

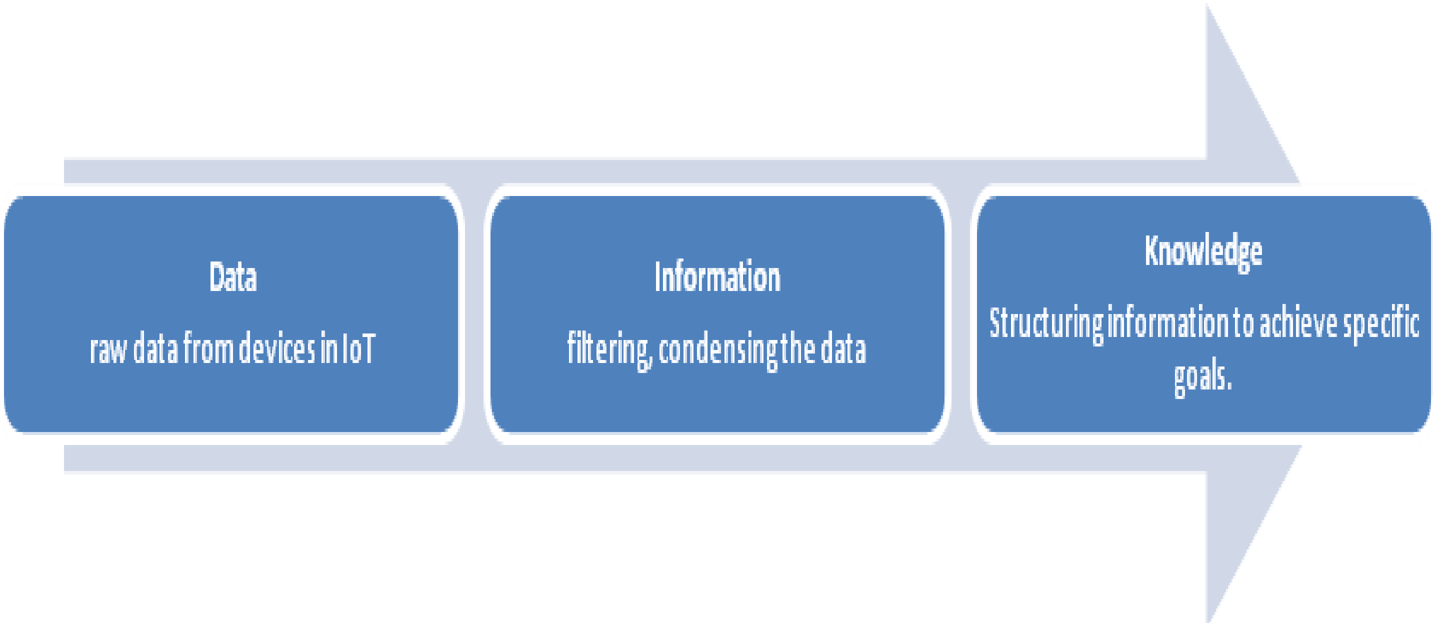
Introduction to IoT

- **“Internet”** is to provide a connection between computers worldwide.
- **“Things”** is referring to devices that are capable of communicating data electronically over an Internet connection
- **So what is the Internet of Things?** For now you can think of IoT as a system that uses the *infrastructure of the Internet to establish a connection to and between our electronic devices.*

Introduction to IoT

- **What Microsoft say about the Internet of Things:**
  - "The Internet of Things (IoT) is not a futuristic trend;
  - it’s the first step toward becoming a truly digital business and it starts with your things
  - your line-of-business assets and the data they produce, your cloud services, and your business intelligence tools.
  - That’s the Internet of Your Things, With an IoT strategy in place you can make your business thrive."

What is IoT?



Inferring information and knowledge from data

IoT terms and Basic Definitions

- **IoT**
- **IoT device**
- **IoT ecosystem**
- **Physical layer**
- **Network layer**
- **Application layer**
- **Remotes**
- **Dashboard**
- **Analytics**
- **Data storage**
- **Networks**

IoT terms and Basic Definitions

- **IoT:** The internet of things, or **IoT**, is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.
- **IoT device:** A standalone entity connected to a web which can be identified and monitored from a remote area.
- **IoT ecosystem:** It's a collective system of components that empower organizations, governance with the governments, and peer customers to associate with their useful IoT gadgets with additional components such a remotes, dashboards, systems, entryways, investigation, information stockpiling, and security.

IoT terms and Basic Definitions

- **Physical layer:** It’s a layer which constitutes an IoT device/gadget which includes automating sensors and an administrative unit of systems.
- **Network layer:** It’s a layer Responsible for the communication via transmitting the information gathered by the physical layer to route across various devices.
- **Application layer:** It’s a layer which incorporates the set of protocols and the catalytic interfaces that devices use in order to recognize and speak often with each other.

IoT terms and Basic Definitions

- **Remotes:** Empower substances which use IoT devices in order to associate with device components and control them with advent use of a dashboard, for example, a versatile application which can incorporate cell phones, tablets, PCs, shrewd watches, associated Televisions.
- **Dashboard:** It Displays data about the IoT biological community to peer clients which empowers clients control their integrated components in IoT environment, which is their by termed as large housed data on a remote.
- **Analytics:** It's a Software framework which examines the information produced by IoT devices. The information obtained from IoT devices can be utilized for an assortment of situations.

IoT terms and Basic Definitions

- **Data storage:** Where information from IoT gadgets is put away.
- **Networks:** The web correspondence layer that empowers the substance to speak with their gadget, and now and then empowers gadgets to speak with each other.

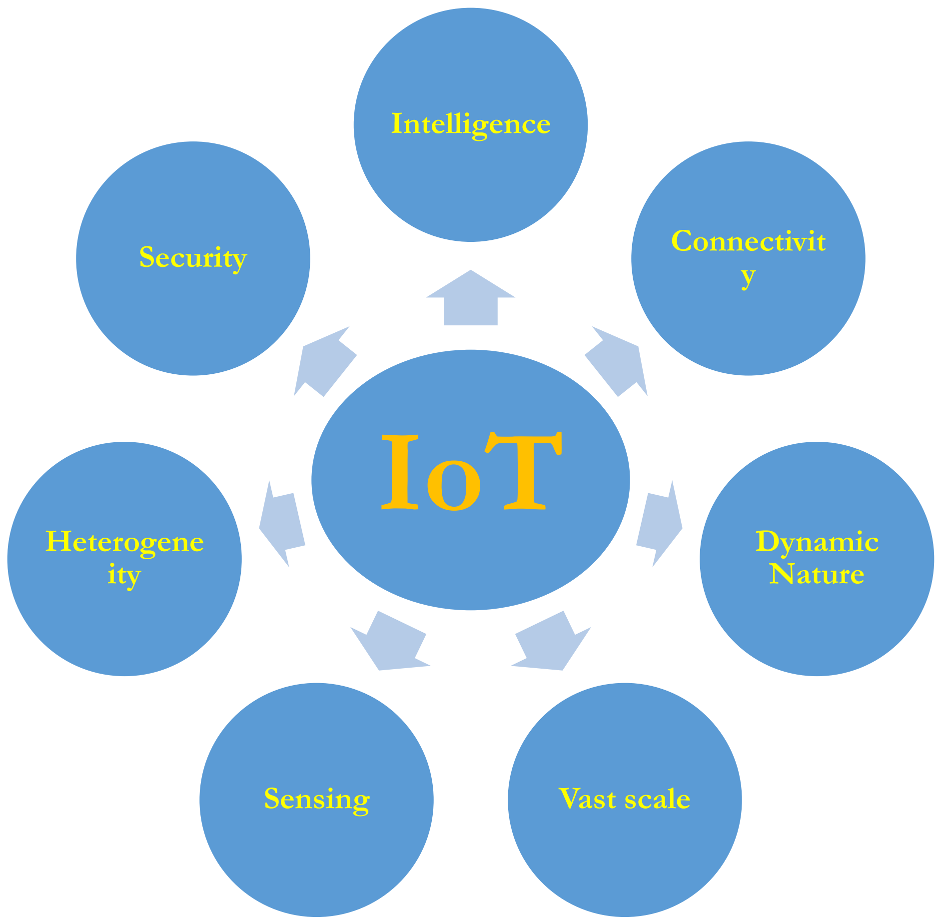
Disambiguation of IoT vs IoE vs M2M vs Others

- **M2M:** Machine to Machine (**M2M**) refers to a wireless or wired network setup that allows devices of the same type and ability to communicate freely.
- **IIoT:** The industrial internet of things, or IIoT, is the use of internet of things technologies to enhance manufacturing and industrial processes. Also known as the *industrial internet* or *Industrie 4.0*, IIoT incorporates machine learning and big data technologies to harness the sensor data, machine-to-machine (M2M) communication and automation technologies that have existed in industrial settings for years.

Disambiguation of IoT vs IoE vs M2M vs Others

- **IoE:** IoE as "the intelligent connection of people, process, data and things." Because in the Internet of Things, all communications are between machines, IoT and M2M are sometimes considered synonymous. The more expansive IoE concept includes, besides M2M communications, machine-to-people (M2P) and technology-assisted people-to-people (P2P) interactions.

Characteristics of IoT



Applications of IoT

Consumer	•Smart Home control, lighting, maintenance etc
Industrial	•Smart meters, Wear outs, Climate control, Product tracking
Automotive	•Parking, Traffic control, Anti theft location
Environmental	•Weather prediction, Resource managemet
Agriculture	•Crop management, soil analysis
Military	•troop monitoring, Threat analysis
Medical	•Wearable devices

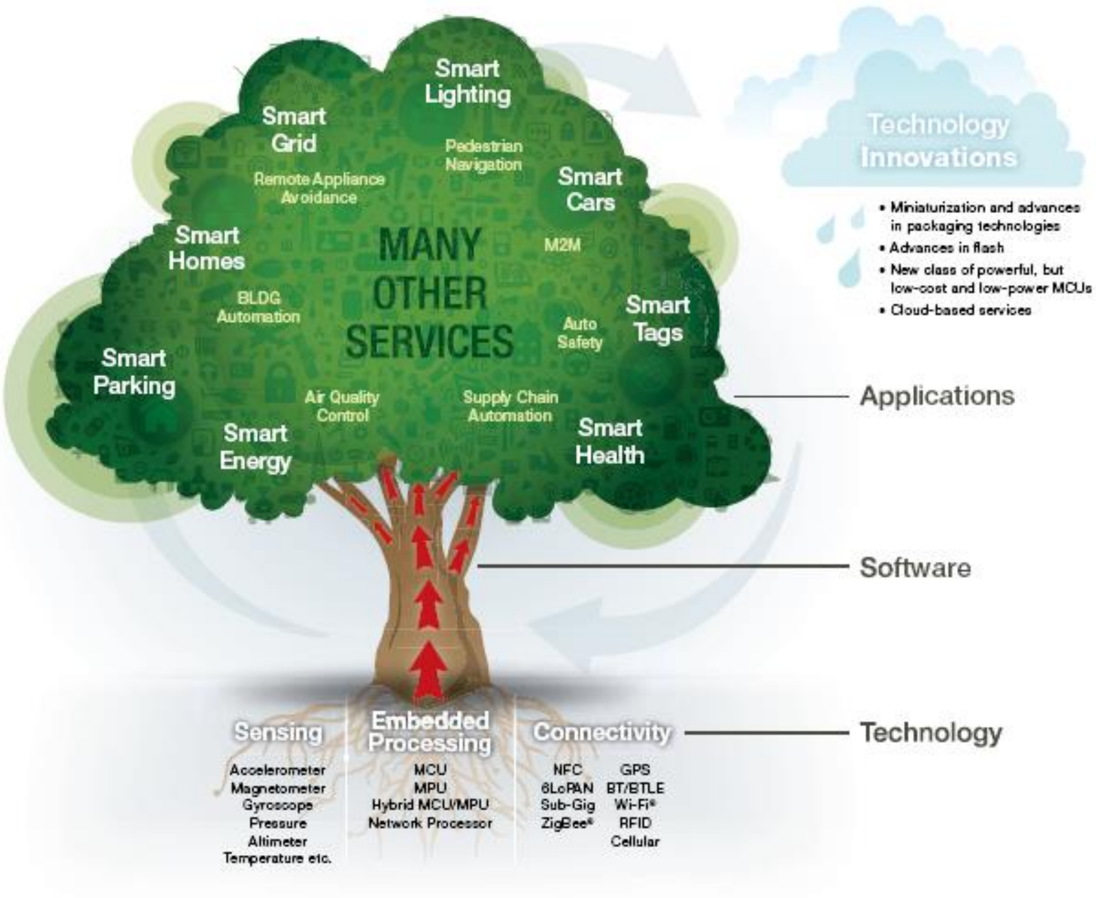
IoT Applications categories

- **Category one**
  - interconnected devices with unique IDs interacting with other machines/objects, infrastructure, and the physical environment.
  - the IoT largely plays a remote track, command, control and route (TCC&R) role.
  - not about data mining of people's behaviors but rather they extend the automation and machine-to-machine (M2M), machine-to-infrastructure (M2I) and machine-to-nature (M2N) communications that can help simplify people's lives.
  - **Monitoring home remotely, Asset tracking , Remote patient monitoring**

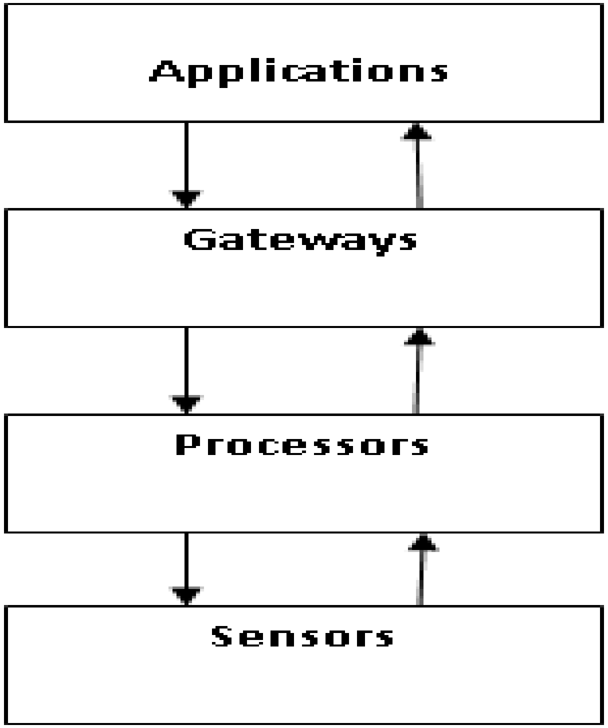
IoT Applications categories

- **Category two**
  - leveraging the data that gets collected by the end nodes (smart devices with sensing and connectivity capability) and data mining for trends and behaviors that can generate useful marketing information to create additional commerce.
  - Credit card companies and membership shopping clubs

The IoT: Different Services, Technologies, Meanings for Everyone



Things in IOT



Functional Blocks of IoT

Things in IOT

Things in IoT	Functionality
Sensors	• Front end devices • gathers information • identifiable devices with a IP address • dynamic in nature • deal with their own or can be made to work by the client . • **Examples of sensors are**: gas sensor, water quality sensor, dampness sensor and so on.
Processors	• Processors are the brain of the IoT framework. • Handle the information driven from Sensors to extract the knowledge from huge crude Processors for the most part work on continuous premise and can be effectively controlled by applications. Primarily installed on Microcontrollers.

Things in IOT

Things in IoT	Functionality
Gateways	• Gateways are in charge of directing the prepared information and send it to legitimate areas for its (information) appropriate usage. • Gateway causes to and fro information across devices and networks. • Gateways can be implemented as LAN, WAN, PAN and so forth are cases of system portals.
Applications	• Applications frame another end of an IoT framework. • Applications are fundamental for legitimate usage of the considerable number of information gathered. • These cloud based applications which are in charge of rendering powerful intending to the information gathered. • Applications are controlled by clients and are conveyance purpose of specific administrations. • Examples are: home mechanization applications, security frameworks, mechanical control center point and so on.

IOT REFERENCE MODEL

Level 7: Collaboration and Processes

- People and Business Processes

Level 6: Application

- Controll applications, Business intelligence and analytics

Level 5: Data Abstraction

- Aggregation and Access, Information Integration

Level 4: Data Accumulation

- Storage-Sampling,filtering,aggregation,converting the data

Level 3: Edge (Fog) Computing

- Peer to Peer communication, Data filtering, Cleanup, Packet content inspection

Level 2: Connectivity

- Edge Devices, Routers, Hubs etc, Protocols like Bluetooth, Wi-Fi

Level 1: Physical Devices and Controllers

- Sensors, Robots etc.

Level 1: Physical Devices and Controllers

Edge Devices in IoT	Functionality
• Sensors • Cameras • Robots	• Analog to digital conversion, as required • Generating the data • Being queried/controlled over the net

Level 1: Physical devices and controllers

Level 2: Connectivity

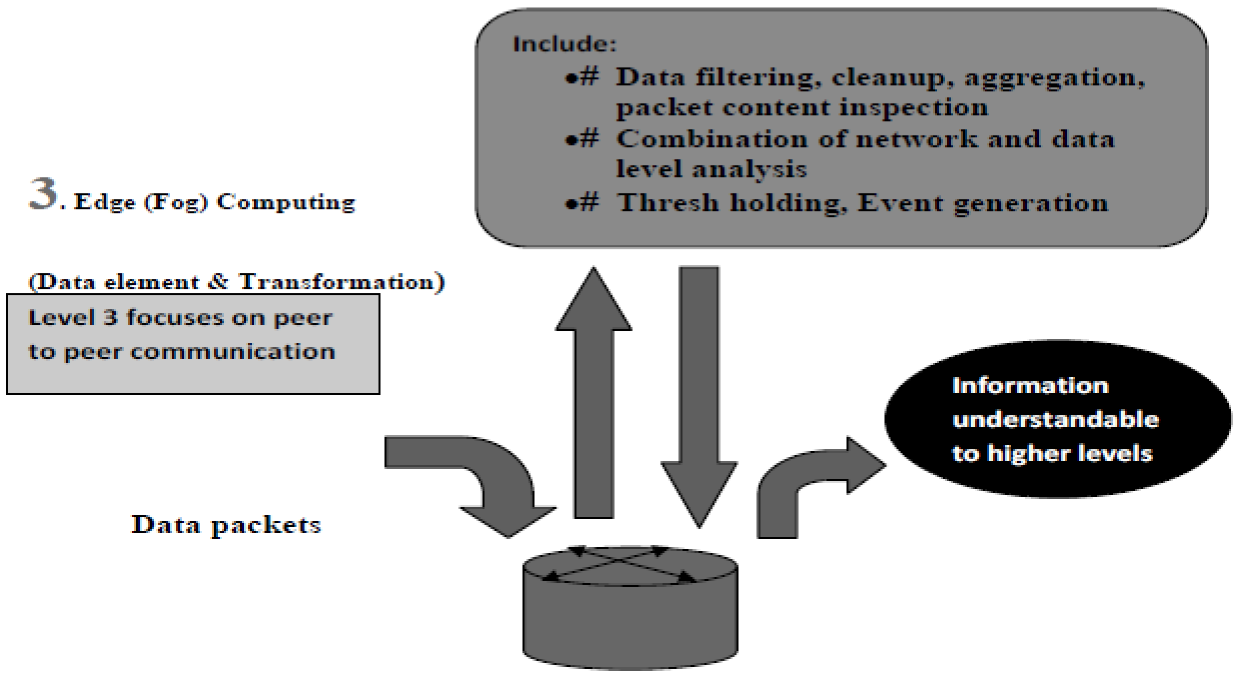
Communication and processing Units

- Edge devices
- Routers
- Hubs
- switches

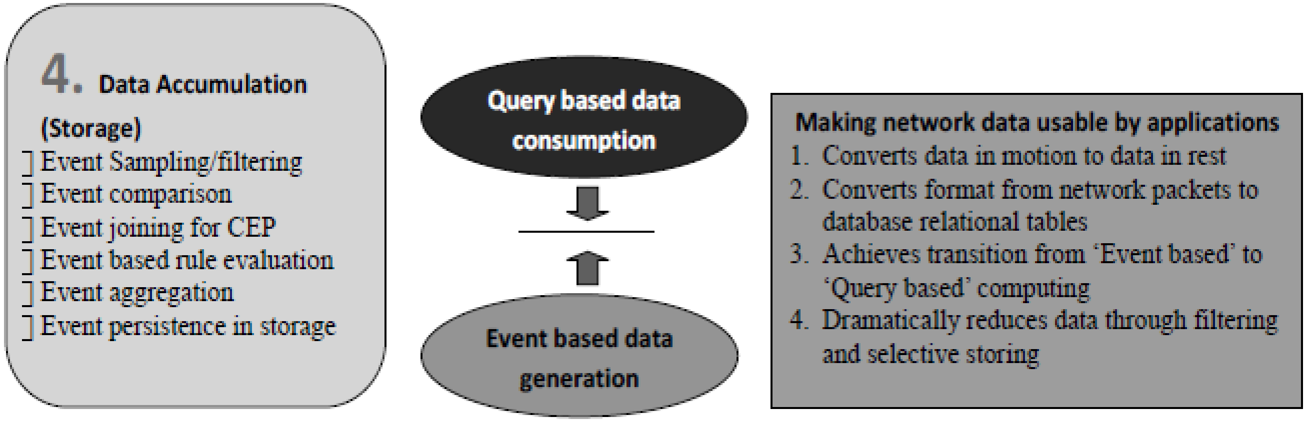
Connectivity includes

- Communicating with and between the level 1 devices
- Reliable delivery across the networks
- implementation of various protocols
- Switching & routing
- Translation between protocols
- Security at the network level
- Self learning - Networking analytics

Level 3: Edge (Fog) Computing



Level 4: Data Accumulation



Level 5: Data Abstraction

5. Data Abstraction

(Aggregation & access)

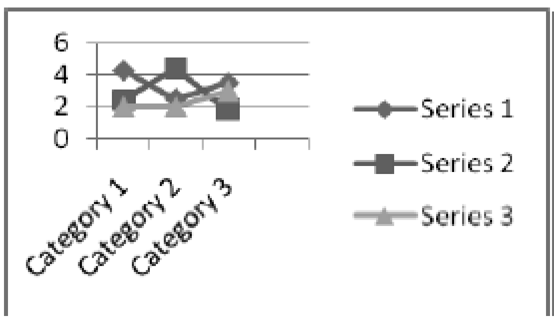
- Abstracting the data interface for applications

Information integration

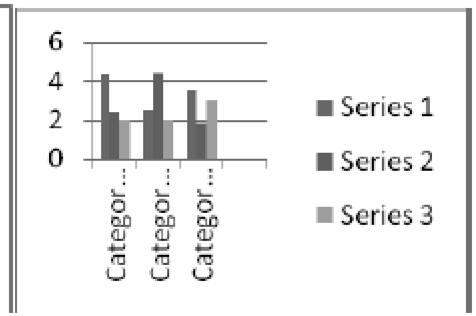
1. Creates schemas and views of data in the manner that applications want
2. Combines data from multiple source, simplyfing the application
3. Filtering, selecting, projecting, and reformatting the data to serve the client applications
4. Reconciles differences in data shape, format, semantics, access protocol, and security
5. Filtering, selecting, projecting, and reformatting the data

Level 6: Application

Control applications



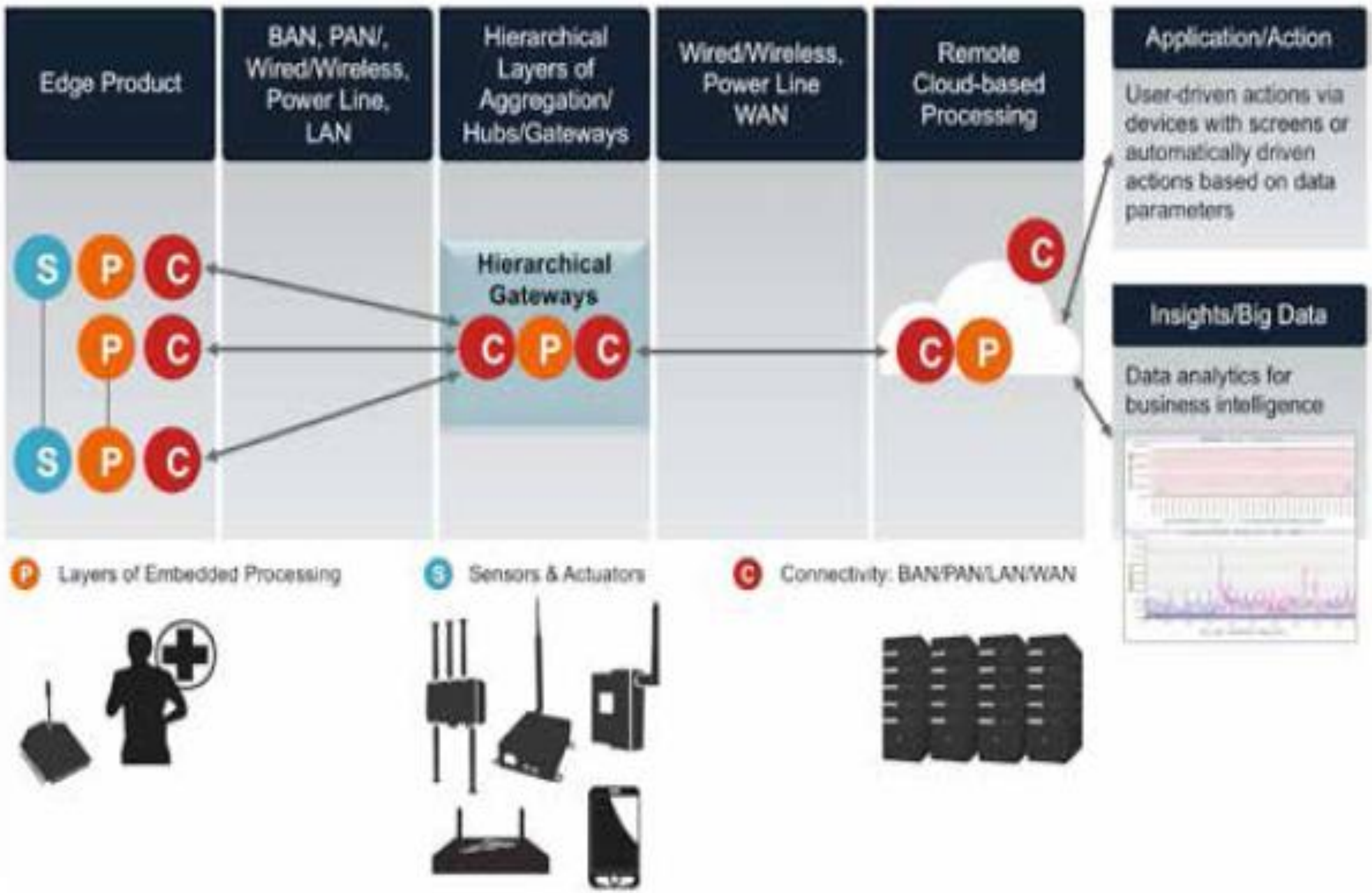
Business intelligence and analytics



Level 7: Collaboration and Processes

7. Collaboration and Processes	Involving People and business processes
Level 7: Collaboration and Processes	

Building Blocks of IoT



Building Blocks of IoT

Requirements common to all of the use cases of IoT include:

1) Sensing and data collection capability (sensing nodes)
2) Layers of local embedded processing capability (local embedded processing nodes)
3) Wired and/or wireless communication capability (connectivity nodes)
4) Software to automate tasks and enable new classes of services
5) Remote network/cloud-based embedded processing capability (remote embedded processing nodes)
6) Full security across the signal path

1. Sensing nodes

- The types of sensing nodes needed for the IoT vary widely, depending on the applications involved.
- Sensing nodes could include
  - a camera system for image monitoring
  - water or gas flow meters for smart energy
  - radar vision when active safety is needed
  - RFID readers sensing the presence of an object or person
  - doors and locks with open/close circuits that indicate a building intrusion
  - a simple thermometer measuring temperature.
- These nodes will all carry a unique ID and can be controlled separately via a remote command and control topology.

2) Layers of local embedded processing Nodes

- Embedded processing is at the heart of the IoT.
- Local processing capability is most often provided by MCUs, hybrid (MCUs/MPUs) or integrated MCU devices, which can provide the “real-time” embedded processing that is a key requirement of most IoT applications.
- Use cases vary significantly, and fully addressing the real-time embedded processing function requires a scalable strategy (using a scalable family of devices), as one size will not fit all.

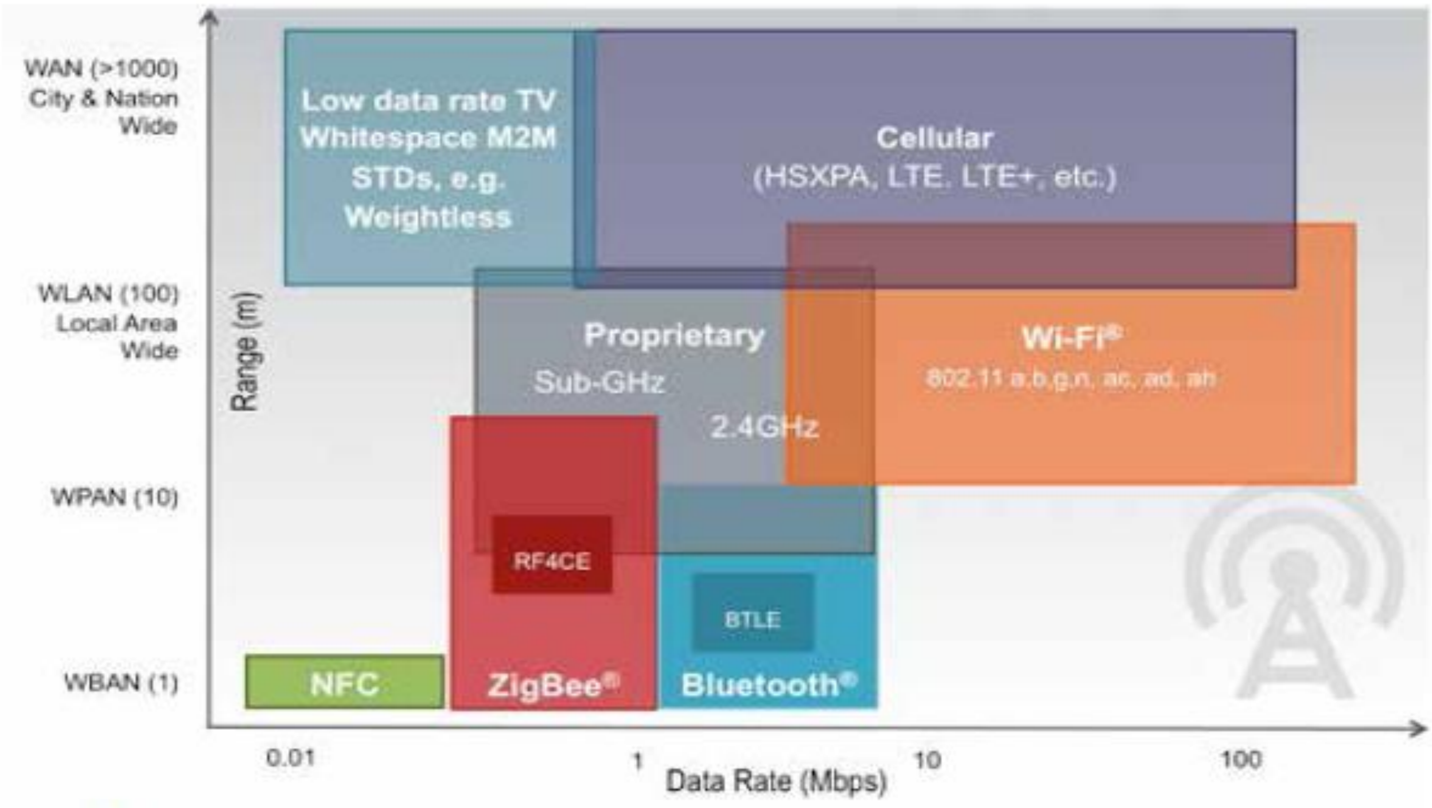
2) Layers of local embedded processing Nodes

- Requirements that make an MCU ideal for use in the IoT
  - Energy efficiency
  - Embedded architecture with a rich software ecosystem
  - Portfolio breadth that enables software scalability
  - Portfolio breadth that cost-effectively enables different levels of performance and a
  - robust mix of I/O interfaces
  - Cost-effectiveness
  - Quality and reliability
  - Security

3) Wired and/or wireless communication capability (connectivity nodes)

- The role of the communication node is to transfer information gathered by the sensing nodes and processed by local embedded processing nodes to the destinations identified by the local embedded processing nodes.
- And, once the data is remotely processed and new commands are generated, the communication node brings back the new commands to the local embedded processing nodes to execute a task.

3) Wired and/or wireless communication capability (connectivity nodes)- Todays wireless Landscape

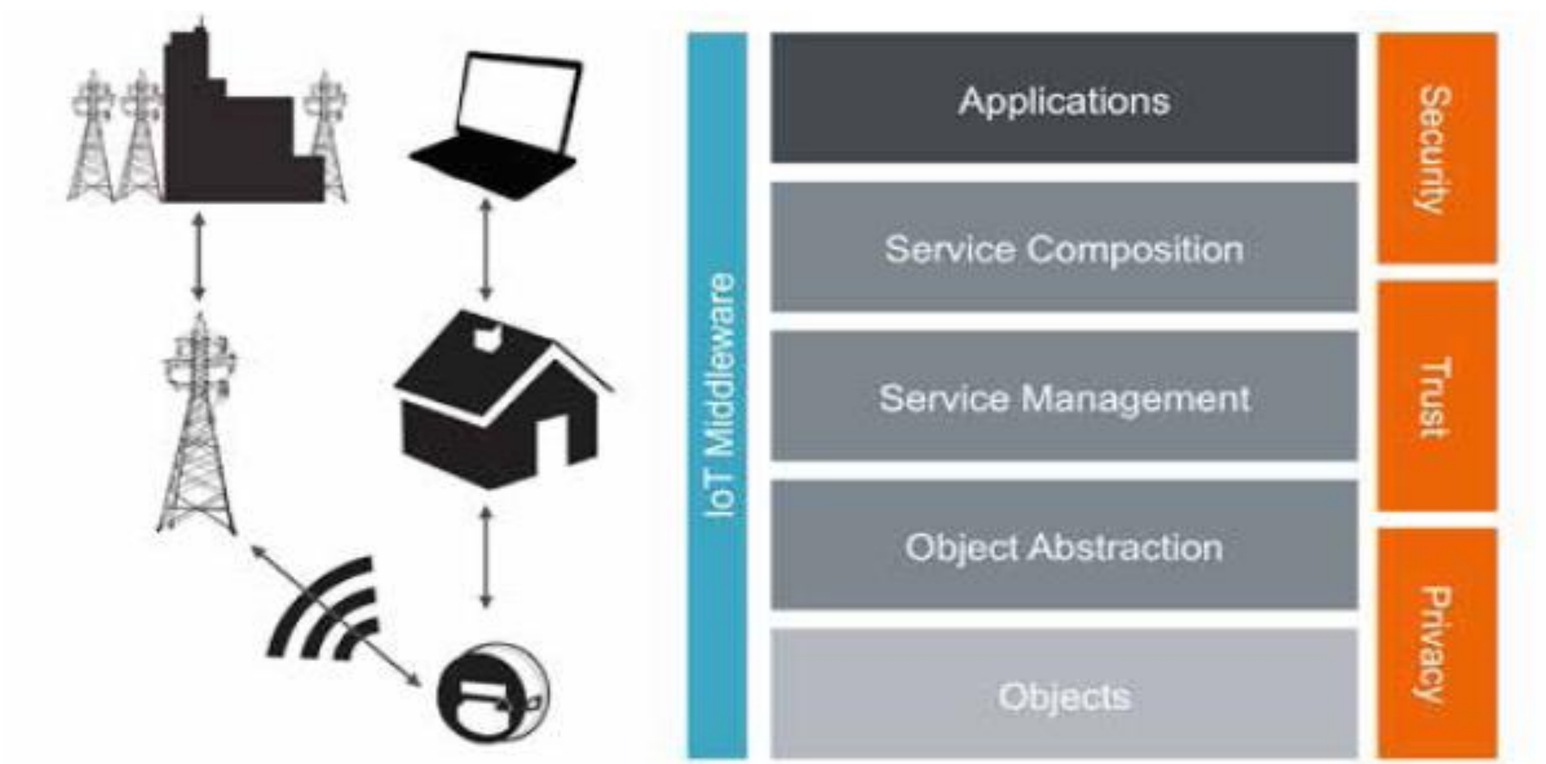


3) Wired and/or wireless communication capability (connectivity nodes)-Communication technologies

	NFC	RFID	Blue-tooth®	Blue-tooth® LE	ANT	Proprietery (Sub-GHz & 2.4 GHz)	Wi-Fi®	ZigBee®	Z-wave	KNX	Wireless HART	6LoWPAN	WiMAX	2.5–3.5 G
Network	PAN	PAN	PAN	PAN	PAN	LAN	LAN	LAN	LAN	LAN	LAN	LAN	MAN	WAN
Topology	P2P	P2P	Star	Star	P2P, Star, Tree Mesh	Star, Mesh	Star	Mesh, Star, Tree	Mesh	Mesh, Star, Tree	Mesh, Star	Mesh, Star	Mesh	Mesh
Power	Very Low	Very Low	Low	Very Low	Very Low	Very Low to Low	Low-High	Very Low	Very Low	Very Low	Very Low	Very Low	High	High
Speed	400 Kbs	400 Kbs	700 kbs	1 Mbs	1 Mbs	250 kbs	11-100 Mbs	250 kbs	40 Kbs	1.2 Kbps	250 kbs	250 Kbs	11-100 Mbs	1.8-7.2 Mbs
Range	<10 cm	<3 m	<30 m	5-10 m	1-30 m	10-70 m	4-20 m	10-300 m	30 m	800 m	200 m	800 m (Sub-GHz)	50 km	Cellular network
Application	Pay, get access, share, initiate service, easy setup	Item tracking	Network for data exchange, headset	Health and fitness	Sports and fitness	Point to point connectivity	Internet, multimedia	Sensor networks, building and industrial automation	Residential lighting and automation	Building automation	Industrial sensing networks	Senor networks, building and industrial automation	Metro area broadband Internet connectivity	Cellular phones and telemetry
Cost Adder	Low	Low	Low	Low	Low	Medium	Medium	Medium	Low	Medium	Medium	Medium	High	High

4) Software to Automate tasks

- Software Service Fabric for Metering Application



5) Remote network/cloud-based embedded processing

- Some companies promote that all devices will be “dumb nodes,” with all processing and decision-making done within “their cloud.”
- Alternatively, some believe only minimal access to the cloud for basic Internet related services will be required, with most of the “thinking” done locally.
- The architecture and building blocks of the IoT approaches, which will likely be necessary due to the wide variety of use cases and configurations anticipated.
- That flexibility will be needed to optimize system-level performance.

6) Full Security across the Entire Path

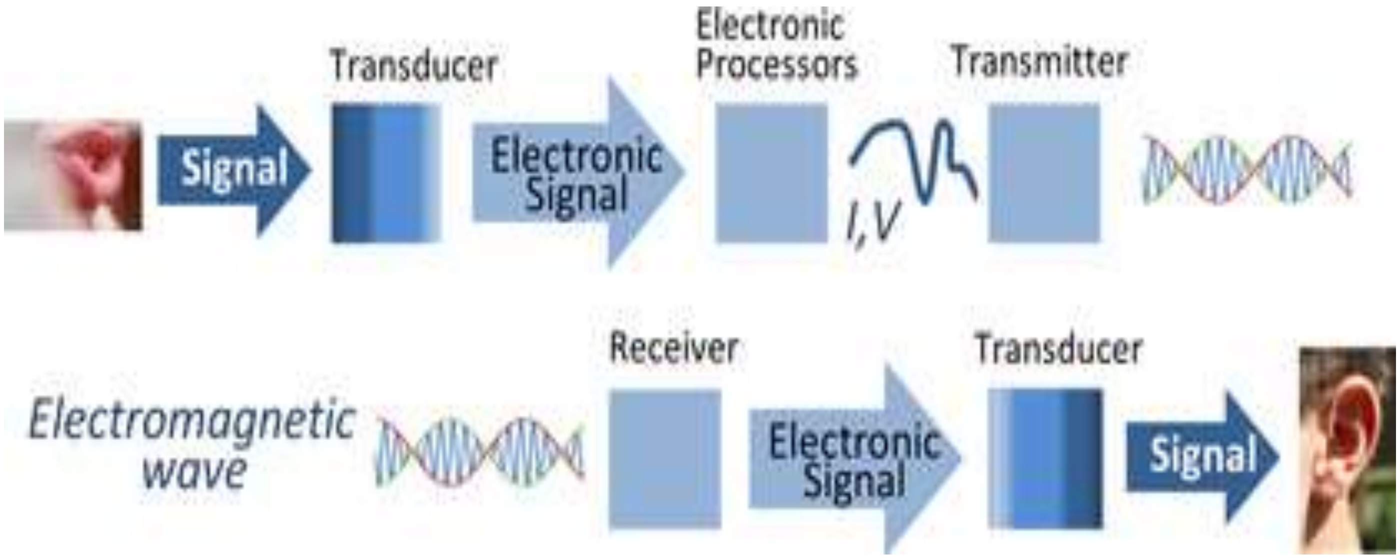
- Information needs to be available when needed
- Information needs to be confidential
- The integrity of data needs to be assured

Overview

- Defining Transducer, Sensor and Actuator
- Transducer
- Sensors
- Actuators
- Interfacing concepts to Embedded Systems
- Participating Wireless Sensing Technologies

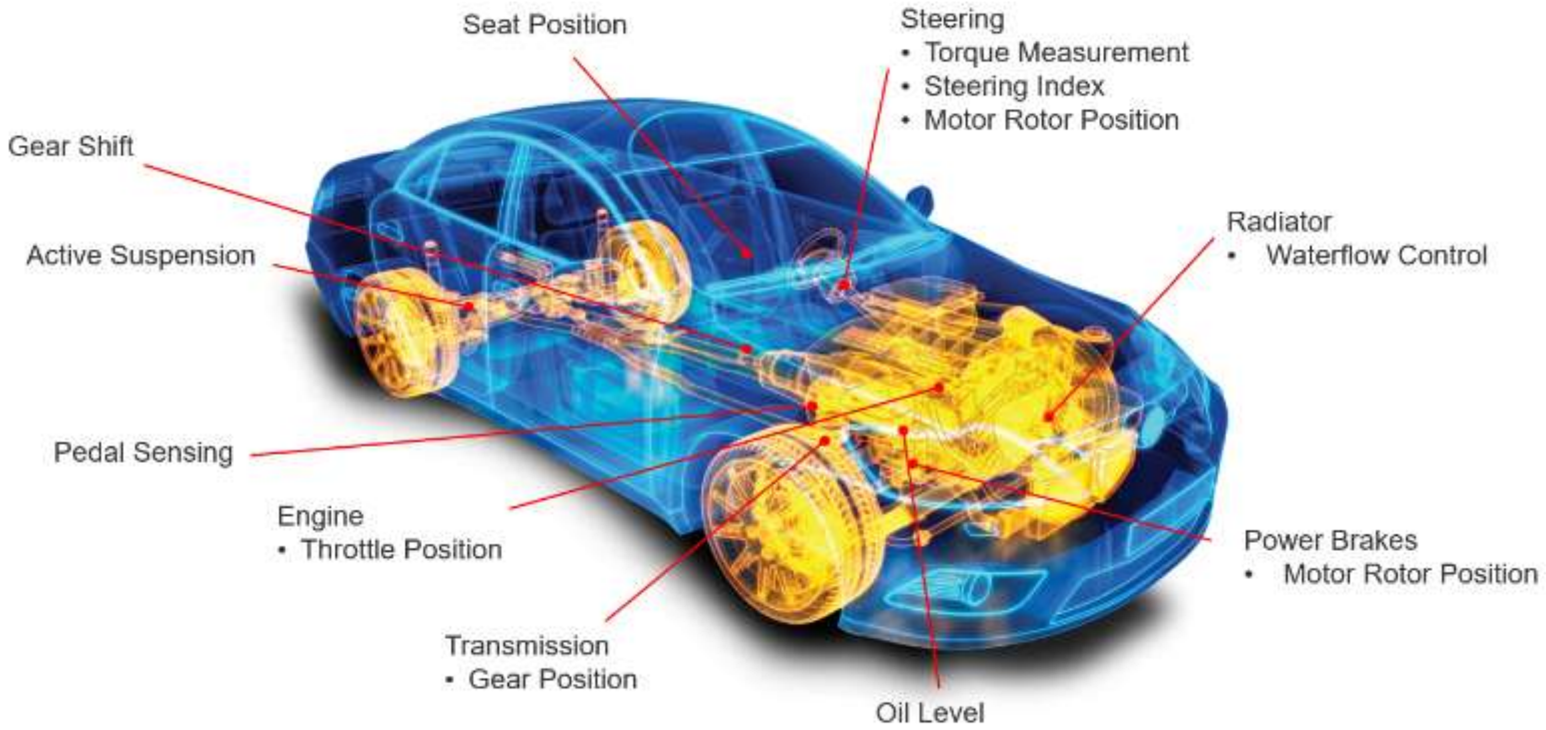
Defining Transducer, Sensor and Actuator

- **Transducers:** A Transducer basically converts some form of energy into some other form, common types of Transducers used in industrial applications can include sensors used to measure temperature, pressure, force, strain, liquid levels and flow rates and electrical conductivity.



Defining Transducer, Sensor and Actuator

- **Sensors:** A Sensor is a device that detects and responds to some type of input from the physical environment. The specific input could be Light, heat, Motion, Moisture, pressure, or any one of a great number of other environmental phenomena.

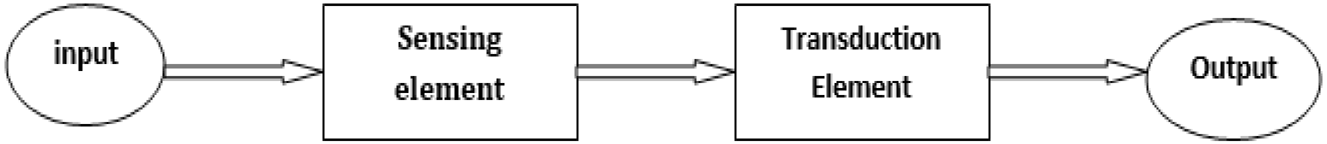


Defining Transducer, Sensor and Actuator

- **Actuators:** An Actuator is a component of a machine that is responsible for moving or controlling a mechanism or system. An Actuator requires a control signal and a source of energy.

Introduction to Transducers

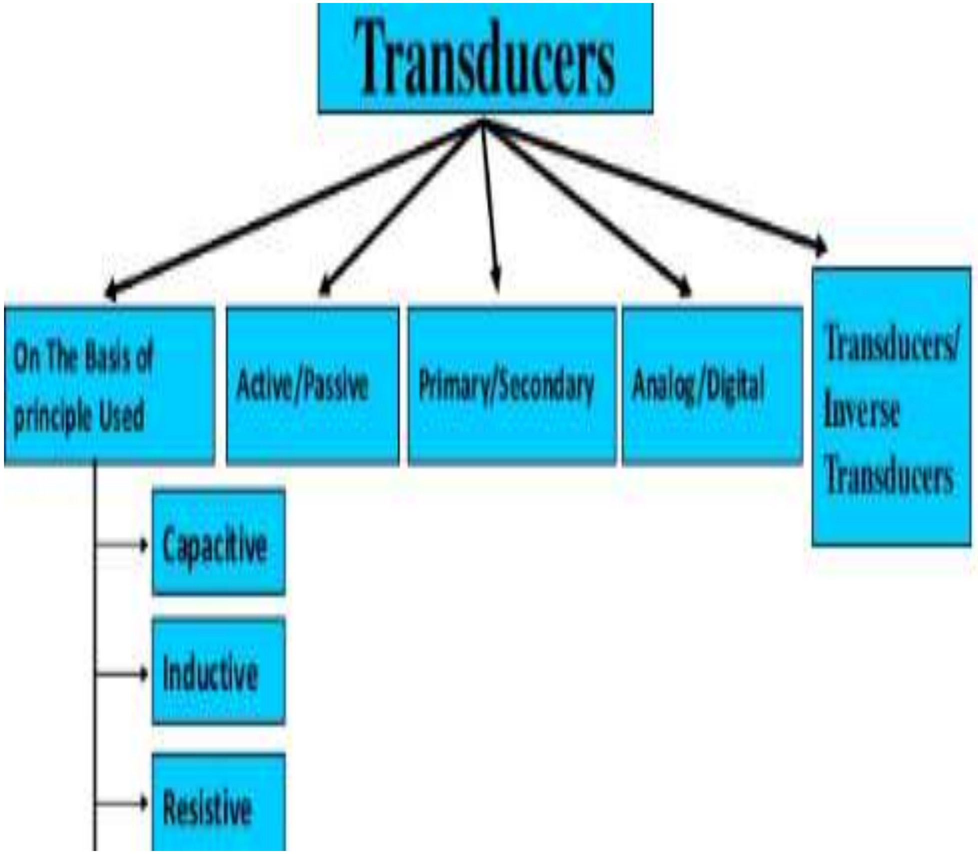
- Transducer is divided into two parts as shown one part is **Sensing element/Detector/Sensor** and the other part is **Transduction element**. Sensing element is basically sensing any physical quantity. Transduction element is measurably used for converting the non electrical quantity to the electrical quantity. So broadly in electrical instrumentation the Transducer is a device which can convert non electrical quantity to the electrical quantity.



Workflow of Transducer in a system

Introduction to Transducers

- **Classification of Transducers**
  - Primary transducer
  - Secondary transducer
  - Analog transducer
  - Digital transducer
  - Electrical transducer
  - Mechanical transducer
  - Active transducer
  - Passive transducer



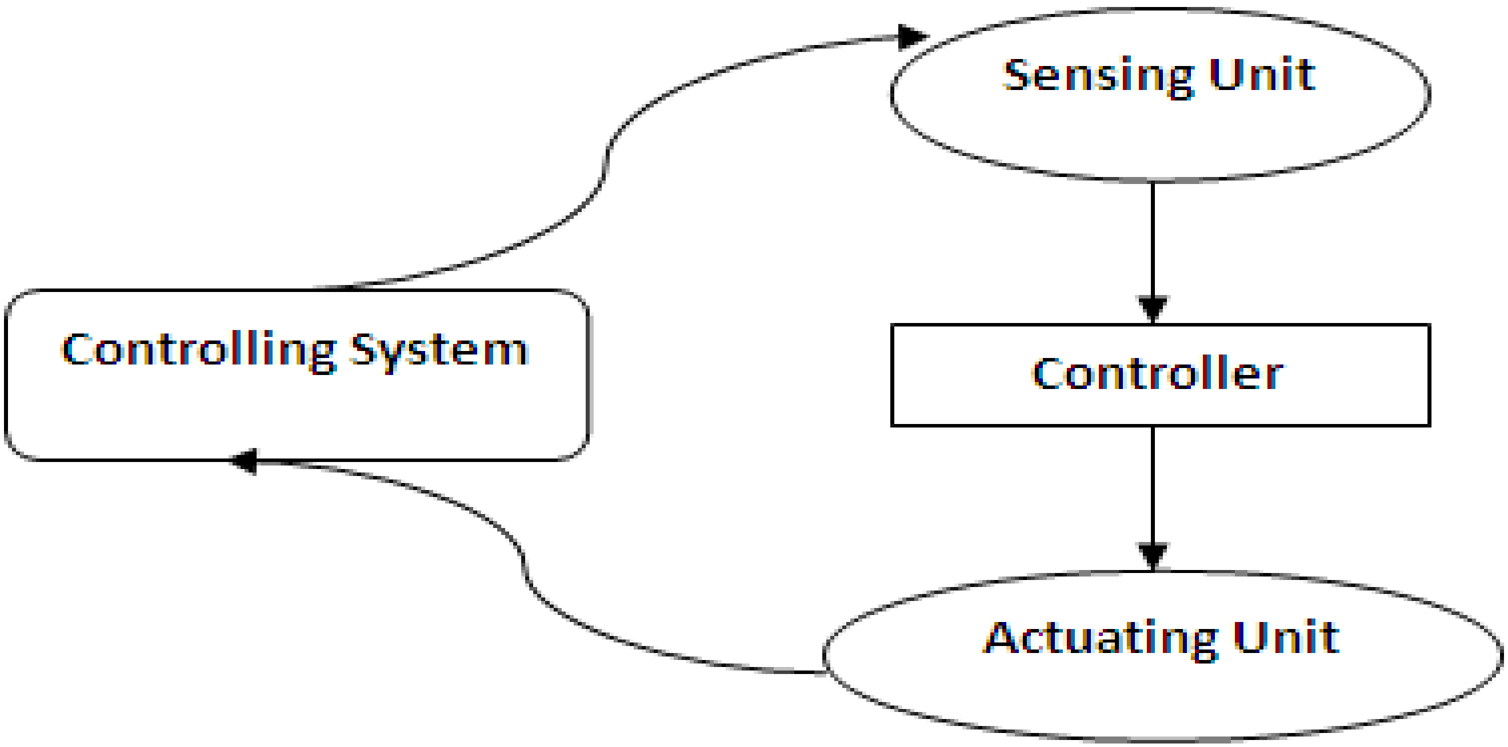
Introduction to Sensors

- **Introduction to Sensors**
- **Workflow of a Sensor in a typical system**
- **Classification of Sensors: Analog and Digital Sensors**
- **Comparison between Analog Signal and Digital Signal**
- **Sampling DAC and ADC conversion: DAC & ADC**
- **Types of Sensors**

Introduction to Sensors

- Sensor is a device which gives a usable yield in response to a specific physical input.
- Sensor takes input as a physical quantity and the output may be optical, electrical or mechanical.
- A few examples are automatic sliding doors, paper towel dispensers, security systems
- Two categories Digital sensors and Analog sensors.
- Digital sensors speak the language of computers in zeros and ones, while analog sensors convey the world with a wide variance of values which must be converted to a digital number for computers to use.

Workflow of a Sensor in a typical system

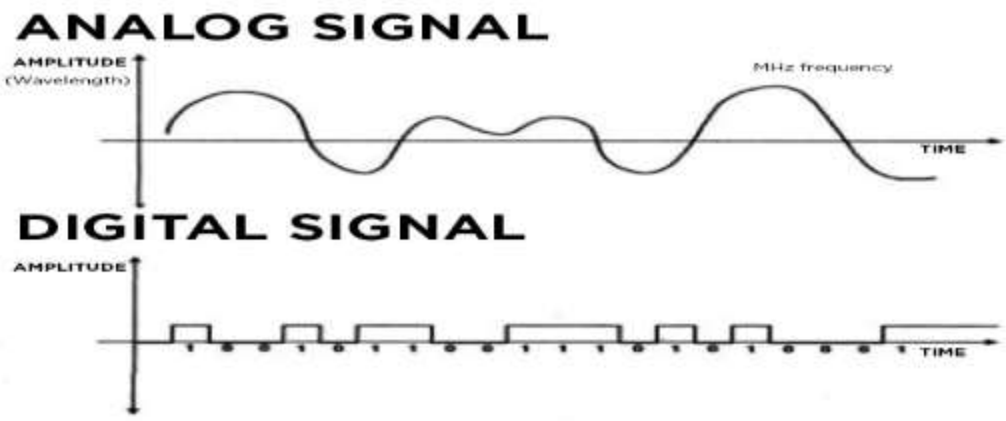


Workflow of a Sensor in a typical system

- A system comprises of basically a Sensing unit, Controller and an Actuator.
- A Sensing unit comprises of a single sensor or components such as signal generators, filters, modulators and so on.
- Data generated from a sensing unit is fed in to a controller, controller process the data based on some of the controlling mechanisms to take decisions and outputs the event to the Actuating unit.
- An Actuating unit will consists of an actuator which may or may not be connected to a power supply and comes with a coupling mechanism embedded with actuator

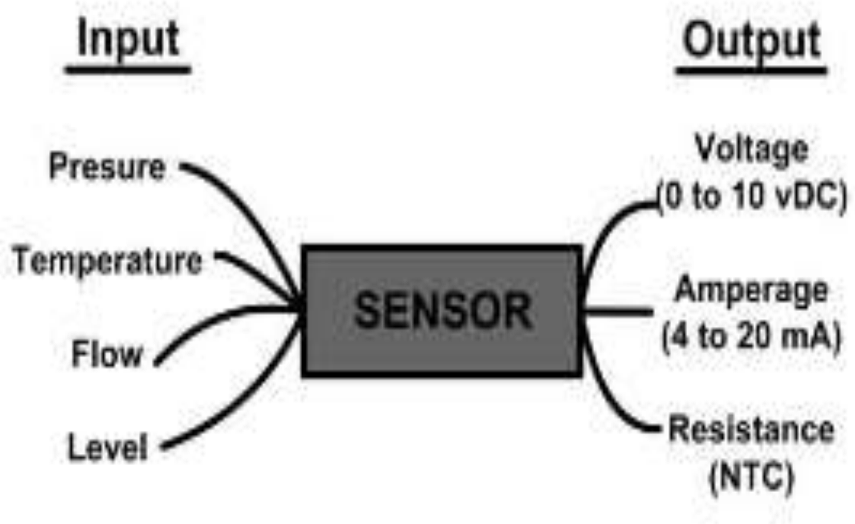
Classification of Sensors

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



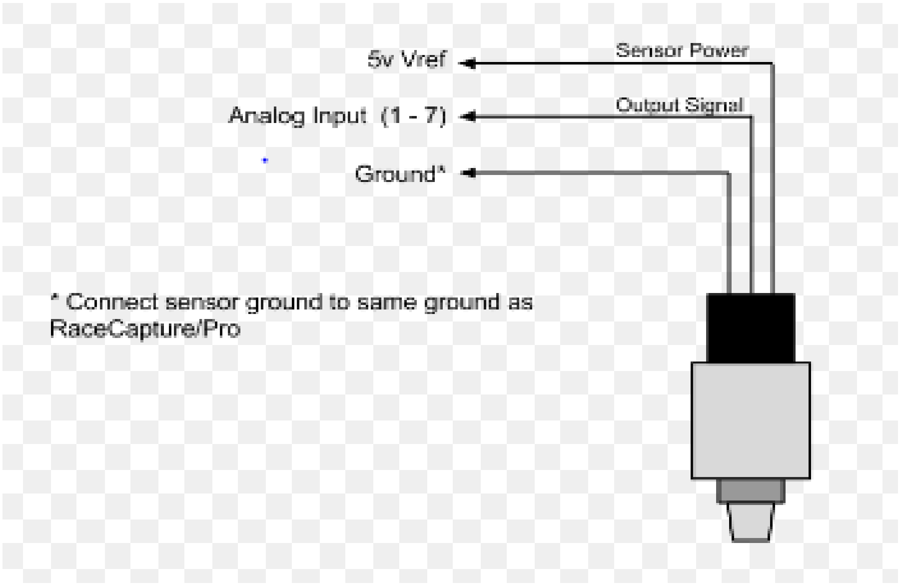
Classification of Sensors: Analog Sensors

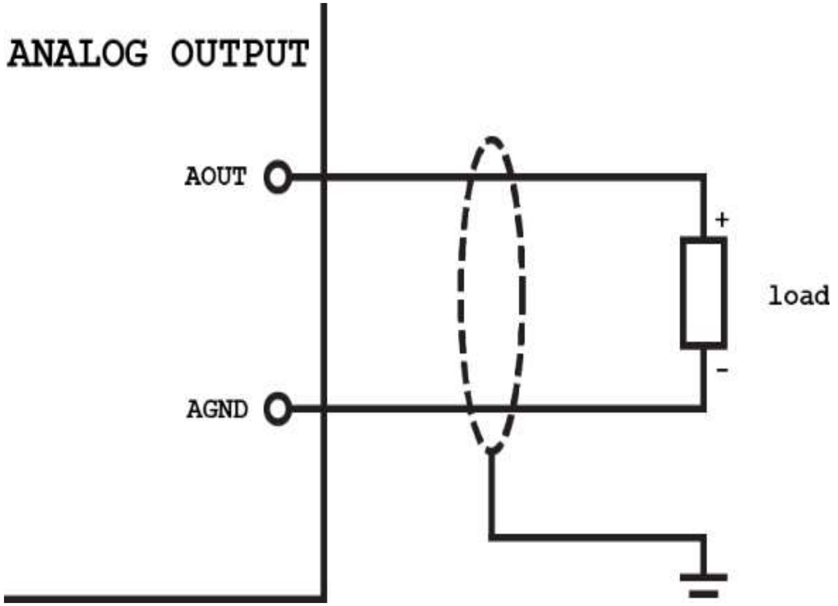
- An analog sensor will usually have two or three wires.
- Depending on the input to the sensor-analog sensors are really great because analog sensors can be easily used without a microcontroller and could hook these analog sensors to trigger things like relays or some other functions.



Classification of Sensors: Analog Sensors

- **Three wire** variant has two wires for power and a third as an output for the sensor reading. These sensors usually give a voltage proportional to the specific changes in its environment.
- **Two wire analog sensor** will be connected like a voltage divider, so output will be a varying voltage from usually 0 to 5 volts.





Classification of Sensors: Analog Sensors

Pros:

- Less quantization errors, low cost and requires less bandwidth because easily constructible by using less preprocessing requirements.
- Accurate since recording data is done through continuous wave forms to represent information.
- Configuring fault components is easier
- Good lifespan
- Low Weather dependencies
- Not expensive and easy to handle
- Easy to manipulate using mathematical formations and calculation.

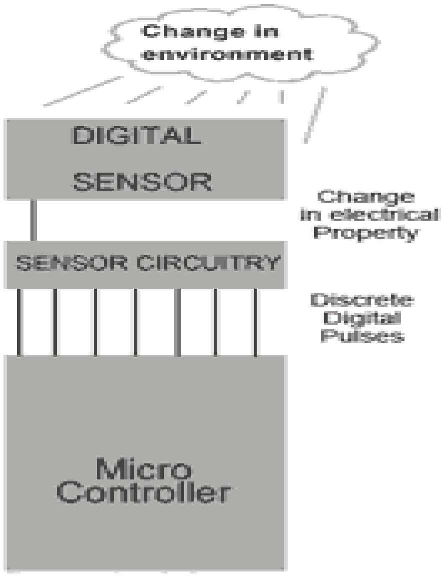
Classification of Sensors: Analog Sensors

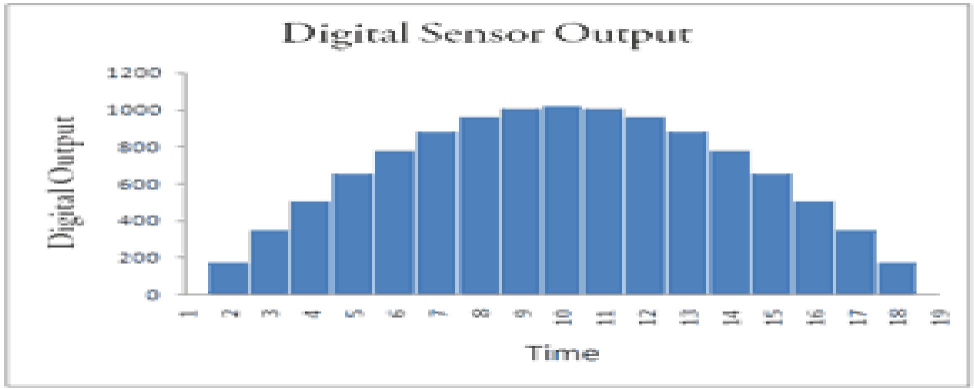
Cons:

- Analog sensors posses' unwanted variation when noise gets added.
- Analog sensors are measured with a scale henceforth at lower end they are cramped for errors.
- Due to the noise effect its consistence will be reduced and being reduced to its quality also.
- Transmitter and Receiver should be configured if there is a change in the deployment level.
- Security isn't there for transmitting data.
- Saving data when needed is prone to errors.

Classification of Sensors: Digital Sensors

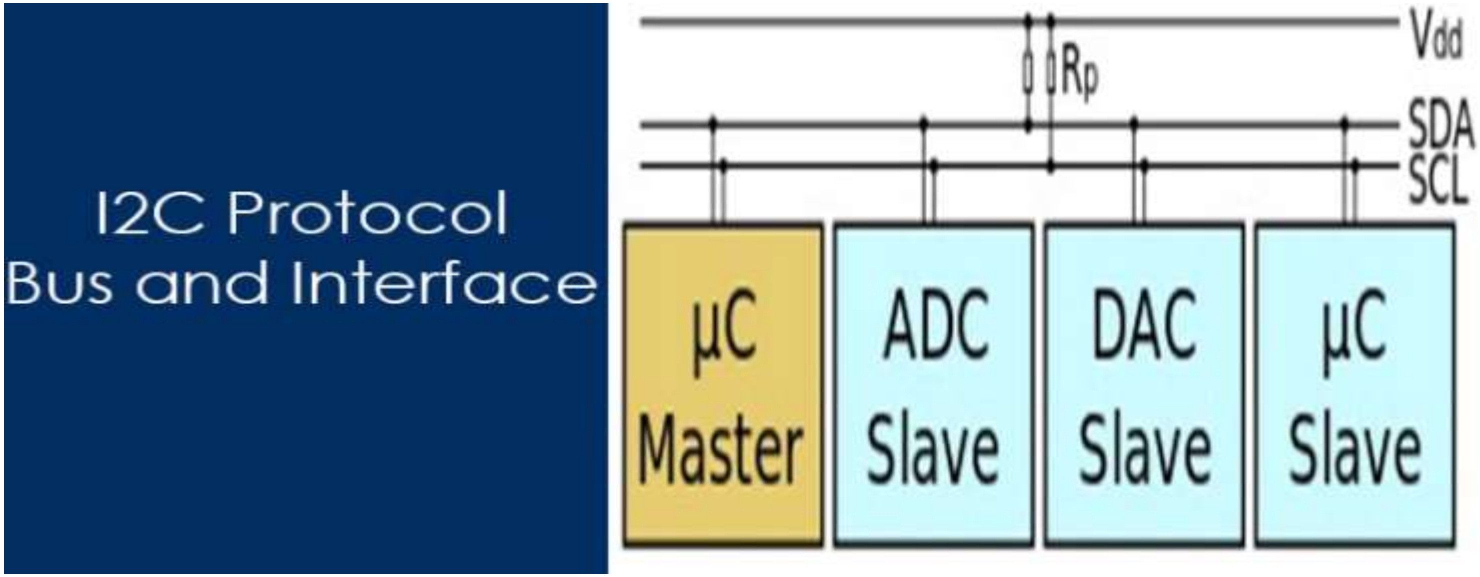
- In general digital sensors will need to communicate with the microcontroller using a communication protocol.
- The three most common protocols are: **I^{2}C(Inter-Integrated circuit), SPI(serial Peripheral Interface) and 1-wire**.
- There are several others but these three are the most commonly used.
- For digital sensors always needs to find a library for the component that is been used in your application.





Classification of Sensors: Digital Sensors

- In **I²C protocol** usually it has **power and ground pins** and then it **communicates on two wires** on **SDA** (Serial Data line) and **SCL** (Serial Clock line) which are easily distinguished by looking at the silk screen on the sensor.
- Two wires don't really seem beneficial at first because some of the sensors that basically communicate on one output wire.

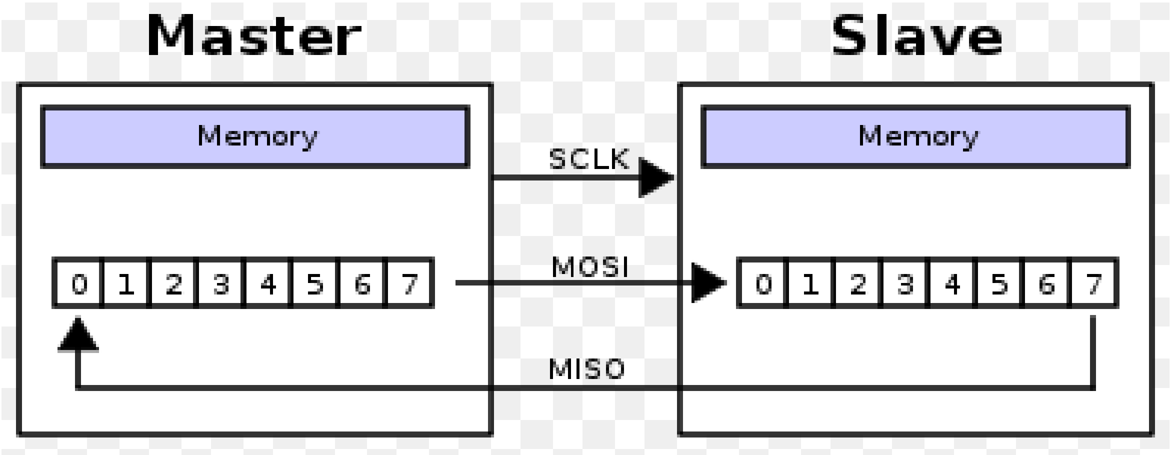


Classification of Sensors: Digital Sensors

- **How is it possible, a communication between so many devices with just to wires?** Well **each device has a preset ID** or a **unique device address** so the master can choose with which devices will be communicating.
- The two wires, or lines are called **Serial Clock (or SCL)** and **Serial Data (or SDA).** The SCL line is the clock signal which synchronize the data transfer between the devices on the I2C bus and it's generated by the master device. The other line is the SDA line which carries the data.
- The two lines are "**open-drain**" which means that pull up resistors needs to be attached to them so that the lines are high because the devices on the I2C bus are active low. Commonly used values for the resistors are from 2K for higher speeds at about 400 kbps, to 10K for lower speed at about 100 kbps.

Classification of Sensors: Digital Sensors

- **SPI** uses a ground and uses four pins to communicate.
- Benefit of SPI is being a lot faster than I^2C and it doesn't require unique addresses.
- SPI can handle a lot more data so they're usually found in more complicated parts like a 2.4 gigahertz transceiver, henceforth it has to process a lot of data really quickly.



Classification of Sensors: Digital Sensors

- The Pin **SS(Slave Select)** can be any digital output pin. **MISO(Master Input Slave Output)** and **MOSI(Master Output Slave Input)** are specified pins on the microcontroller, just like SDA and SCL.
- Slave select can be any digital output so want to leave that as high in the software and then can pull it low whenever application want to use this specific sensor, so that's how communication with multiple sensors using the same three bus line occurs.

Classification of Sensors: Digital Sensors

- The last most common protocol is **one wire**, one wire is a lot slower than both of the other protocols but it only uses power ground and output wire and which can be seen in basic sensors like digital temperature sensor

Classification of Sensors: Digital Sensors

Pros:

- Easy to implement because they are free from observational errors
- They are noise immune without any deterioration.
- Fast handling, less demanding for storage, solid resistance to noise, parallel preparing plausibility, conceivable outcomes, simple convey ability.
- Flexibility with framework change, utilization of institutionalized receiver and Transmitter.
- Security, you can include great encryption transmission.
- You can spare your information and recover when required.

Classification of Sensors: Digital Sensors

Cons:

- Less accurate because it samples analog wave forms into few numbers and records them.
- Higher cost and depends on weather conditions.
- Have quantization errors, less accurate to finite set of data.
- More immune to noise..
- You can't correct defective parts effectively as there is programming additionally related with chips.
- Highly delicate relying upon dealing with and electrical resistance. Somewhere in the range of few voltage changes could harm the hardware inside couple of moments.
- You couldn't move propel chip innovation as programming is again related.
- Low life traverse as more Dependencies on external source.
- Sampling error is most basic on many cases.

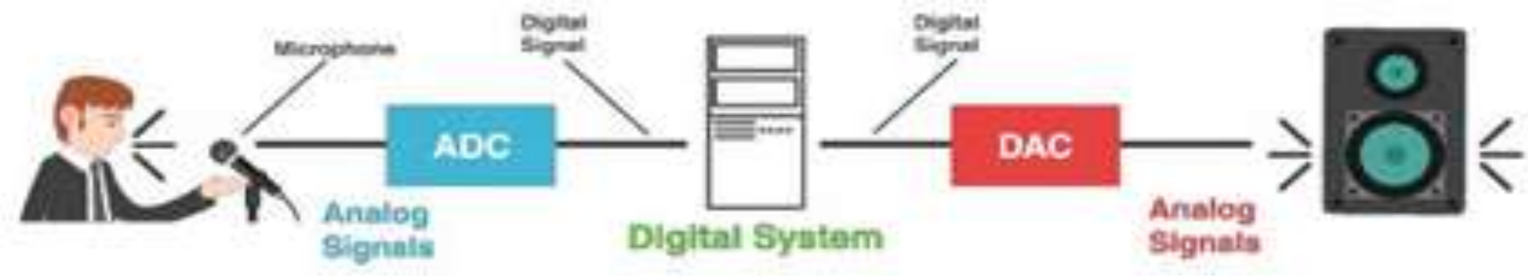
Comparison between Analog Signal and Digital Signal

Analog	Parameter	Digital
Continuous signal	**Signal**	Discrete time signal
Noise in air	**Example**	Digital electronic devices
Continuous values to represent information	**Representation**	Discrete values to represent information
Sine waves	**Waves**	Squared Waves
Prone to noise during transmission	**Data transmission**	Can be noise immune during transmission
Records waveforms as it is	**Technology**	Sampling of waveform is done
Audio and Video transmissions	**Uses**	Digital electronics and computing systems
Thermometer	**Applications**	PCs
Processed in real time and consumes less bandwidth	**Bandwidth**	NO guarantee for real time processing and consumes more bandwidth
Stored as wave forms	**Memory**	Stored as binary bits
Low	**Cost**	High
Uses Large power	**Power**	Uses only negligible power
Low	**Impedance**	High
Not Flexible	**Flexibility**	Highly Flexible
Affected and reduces accuracy	**Response to noise**	Less affected
Considerable observational errors	**Errors**	Free from observational errors

Sampling DAC and ADC conversion

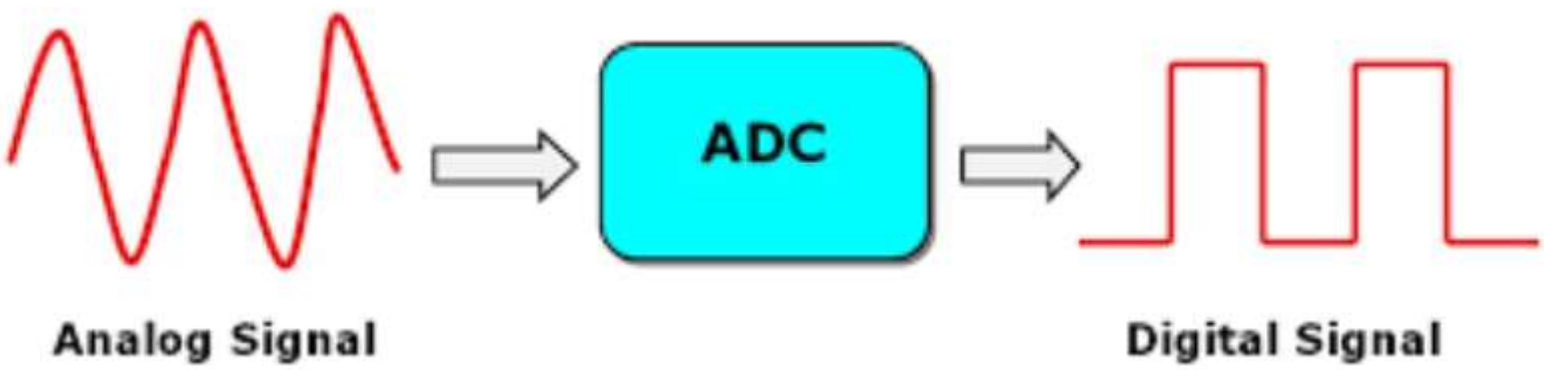
❑ Digital to Analog Converters (DAC)

- Weighted resistors D/A converter
- R–2R ladder D/A converter



Sampling DAC and ADC conversion

- **Analog to Digital Converters (ADC)**
  - Simultaneous A/D Converter
  - Counter type A/D converter
  - Successive Approximation Method

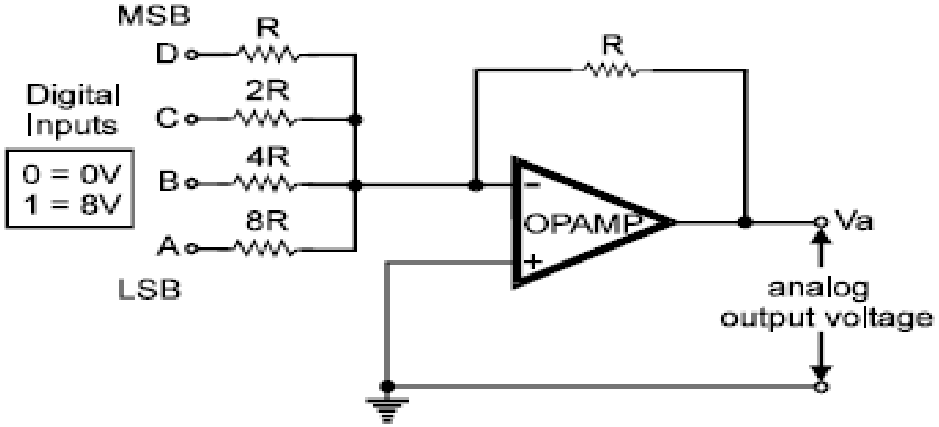


Weighted resistors D/A converter

- The circuit of weighted resistors D/A converter is shown in **Figure**
- The circuit uses an summing amplifier which is an opamp here. The circuit uses a variable resistor network at the input terminal of the opamap with four resistors named as R, 2R, 4R and 8R with inputs for the circuit being termed as D, C, B and A.
- In the circuit input D is at MSB and A is at LSB.
- An *V DC voltage is connected to the circuit as level-1 logic assuming 0=0V and 1=8V.
- The circuit is being a summing amplifier; this circuit works as follows with output is given by the equations:

$$\mathbf{V_0 = -R * (D/R + C/2R + B/4R + A/8R)}$$

Weighted resistors D/A converter



Digital inputs				Analog output Voltage (V_a)
D	C	B	A	
0	0	0	0	0V
0	0	0	1	–1V
0	0	1	0	–2V
0	0	1	1	–3V
0	1	0	0	–4V
0	1	0	1	–5V
0	1	1	0	–6V
0	1	1	1	–7V
1	0	0	0	–8V
1	0	0	1	–9V
1	0	1	0	–10V
1	0	1	1	–11V
1	1	0	0	–12V
1	1	0	1	–13V
1	1	1	0	–14V
1	1	1	1	–15V

Weighted resistors D/A converter

Some disadvantages of the circuit are:

1) Each resistor in the circuit has different value.

2) So error in value of each resistor adds up.

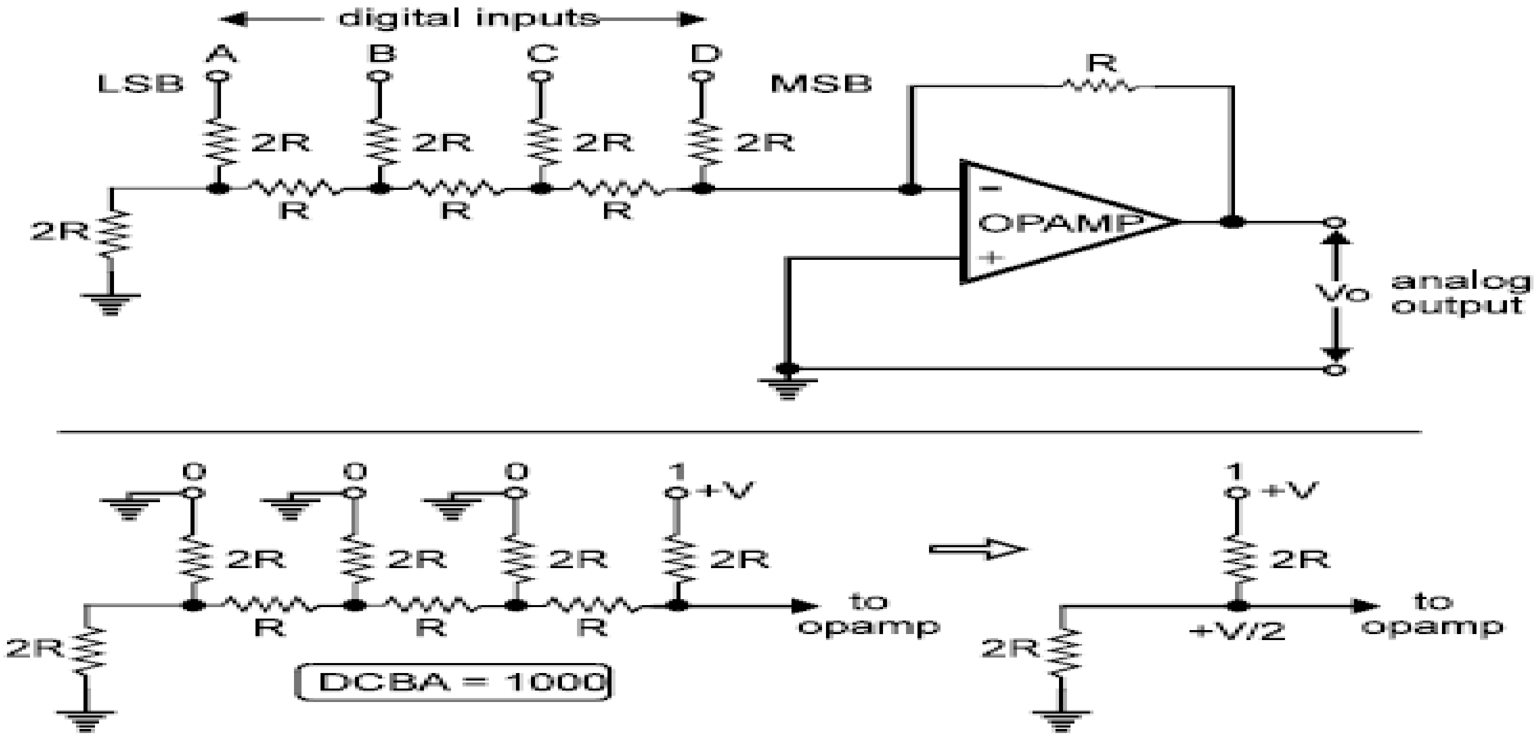
3) The value of resistor at MSB is the lowest. Hence, it draws more current.

4) Also, its heat & power dissipation is very high.

5) There is the problem of impedance matching due to different values of resistors.

R–2R ladder D/A converter

- R-2R ladder D/A converter is termed as Resistor network which has two resistors with values given as R and 2R, repeats in the entire circuit. In order to scale the output voltage an opamap is used.



R–2R ladder D/A converter

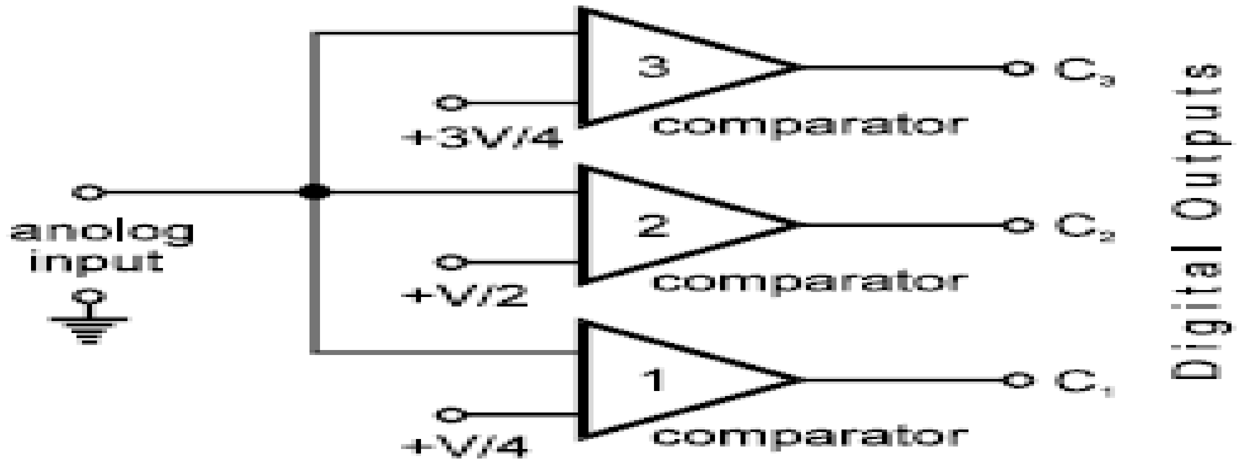
Working Principle:

- Assuming there is no opamp in the circuit with digital input for DCBA=1000, circuit is reduced to the smallest level by giving its output by the equation below

  Output= (2R/(2R + 2R)) * (+V) = V/2
- If input for DCBA=0100 output will be V/4.
- If input for DCBA=0010 output will V/8.
- If input for DCBA=0001 output will be V/16.
- The general formula for R-2R ladder, including opamp also will be
- V_0= --R * (D/2R + C/4R + B/8R + A/16R)
- Solving the above equation equation,
- V_0= -- (V/2 + V/4 + V/8 + V/16)
- With this formula, for any combination of digital input its equivalent analog voltage can be calculated.

Simultaneous A/D Converter

- In the circuit shown in **Figure** , comparison of a known voltage value is compared with an unknown voltage value using a comparator, which produces an proportional output which will be either 0 or 1.
- In the circuit shown three of the comparators are connected with two inputs, one input is an analog voltage and other input being a fixed reference voltage of +3/4V, +V/2 and +V/4.
- The circuit is also called as parallel A/D converter since comparators are connected in parallel in the circuit.



Simultaneous A/D Converter

Working Principle:

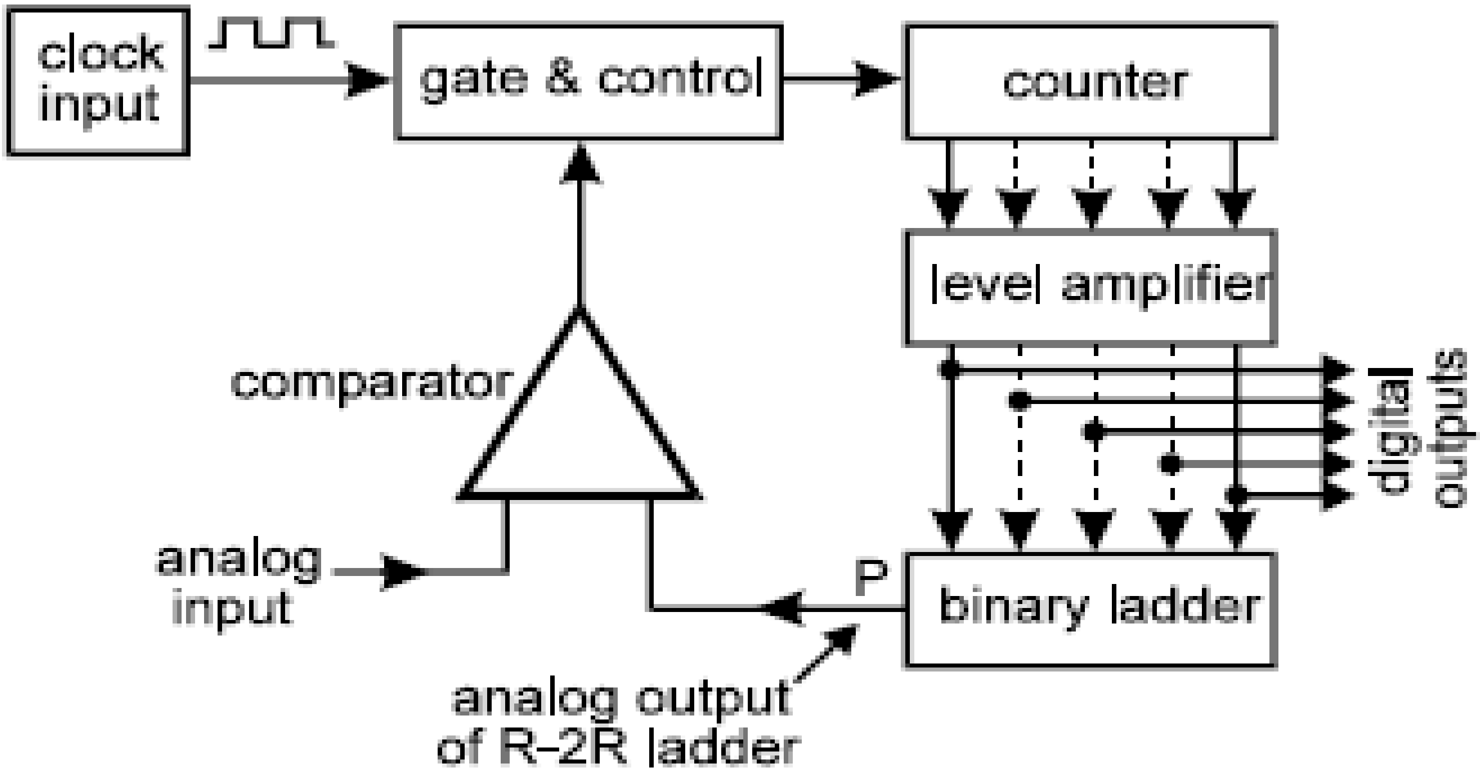
- Each comparator should be connected to a reference voltage of +3/4V, +V/2 and +V/4 with outputs as $C_3C_2C_{1.}$ If analog voltage changes from 0-4V the actual reference voltages will be +3/4V=3V, +V/2=2V and +V/4=1V with following conditions of the circuit.
- Input voltage between 0-1V output is $C_3C_2C_{1=}000$
- Input voltage >1V <= 2V output is $C_3C_2C_{1=}001$
- Input voltage >2V <= 3V output is $C_3C_2C_{1=}011$
- Input voltage >3V <= 4V output is $C_3C_2C_{1=}111$

In this way, the circuit can convert the analog input voltage into its equivalent or proportional Binary number in digital style.

Counter type A/D converter

- In Counter type A/D converter shown a comparator is connected with one analog signal and the other input will be an analog output from the binary ladder.
- The clock generates square waves which are connected to gate-control block.
- When comparator output is HIGH (logic-1), clock pulse is connected to the counter else if comparator output is low (logic-0), clock pulse is cut off.
- These clock pulses are dependent on the analog voltage value.
- If analog voltage value is higher, it results in more number of clock pulses which are counted on the counter, producing a proportionate binary output.
- The output is again fed to level amplifier, which amplifies the counter output voltage and fed to binary ladder, which produces a proportionate analog voltage.

Counter type A/D converter

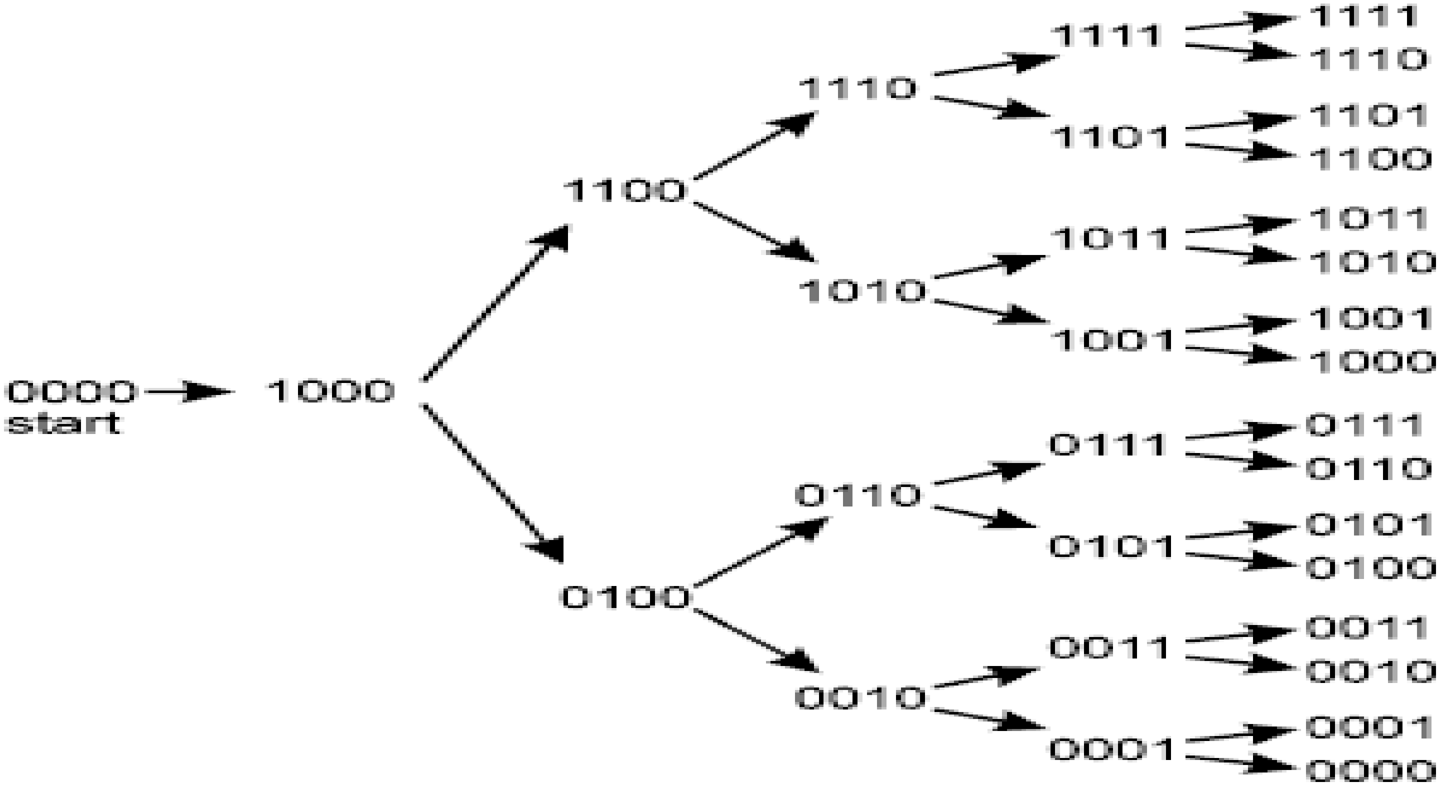


Counter type A/D converter

- Consider if circuit is on with initial value of circuit is 00000. If analog voltage=9V, there will be difference in input voltages of comparator, hence output will be HIGH.
- The counter counts the number of clock pulses generated and producing equivalent binary number whose output gradually changes from 0001, 0010, 0011 and so on.
- Hence the output 1001 is 9V, comparator will have both input voltages of same value resulting in output of LOW, so the gate will cutoff and counter stops counting, with final result is being 1001 In this way, any analog voltage can be converted into its equivalent digital output.

Successive Approximation Method

- Counter method discussed in the previous section requires longer duration for the conversion of analog signal into digital signal, since it starts always from 0000 until corresponding analog voltage is matched. This drawback is overcome by Successive Approximation method.



Successive Approximation Method

- In Successive approximation method shown in **Figure**, when unknown voltage (V_a) is applied, the circuit starts from 0000 and the output advances with each MSB as shown in Figure.
- The output of SAR does not increase incrementally at every step but it starts from high starting of MSB setting MSB (1000), the second (0100).
- Each time, SAR output is converted by binary ladder to equivalent analog voltage, which is then compared with the unknown voltage V_a. This comparison process goes on until binary equivalent of analog voltage is obtained.
- The comparison process goes on, in binary search style, until the binary equivalent of analog voltage is obtained.

Successive Approximation Method

In this way following steps are carried out during conversion

1) The unknown analog voltage (Va) is applied.

2) Starts up from 0000 and sets up first MSB 1000.

3) If Va > 1000, the first MSB is fixed.

4) If Va < 1000, the first MSB is removed and second MSB is set.

5) The fixing and removing the MSBs continues up to last bit (LSB), until equivalent binary output is obtained.

Types of Sensors

- Sensors are classified based on the nature of quantity they measure. Following are the types of sensors with few examples for each.

Sensors	Examples
Thermal Sensors	▪ **Thermometer-** Measures absolute temperature ▪ **Thermocouple gauge-** measures temperature by its effect on two dissimilar metals. ▪ **Calorimeter-** measures the heat of chemical reactions or physical changes and heat capacity.
Mechanical Sensors	▪ **Pressure Sensor-** measures pressure ▪ **Barometer-** measures atmospheric pressure ▪ **Altimeter**-measures the altitude of an object above a fixed level ▪ **Liquid flow sensor-** measures liquid flow rate ▪ **Gas flow Sensor**-measures velocity, direction, and or flow rate of a gas. ▪ **Accelerometer**-measures acceleration

Types of Sensors

- Sensors are classified based on the nature of quantity they measure. Following are the types of sensors with few examples for each.

Sensors	Examples
Electrical Sensors	▪ **Ohmmeter-** Measures resistance ▪ **Voltmeter-** measures voltage. ▪ **Galvanometer-** measures current. ▪ Watt-hour meter- measures the amount of electrical energy supplied to and used by a residence or business.
Chemical Sensors	▪ Chemical sensors detect the presence of certain chemicals or classes of chemicals and quantify the amount and /or type of chemical detected ▪ **Oxygen sensor-** measures percentage of oxygen in a gas or liquid being analyzed. ▪ **Carbon di oxide detector-** detects the presence of CO2.
Biological Sensor	▪ Detect and measure the amount of glucose in ones blood.

Types of Sensors

- Sensors are classified based on the nature of quantity they measure. Following are the types of sensors with few examples for each.

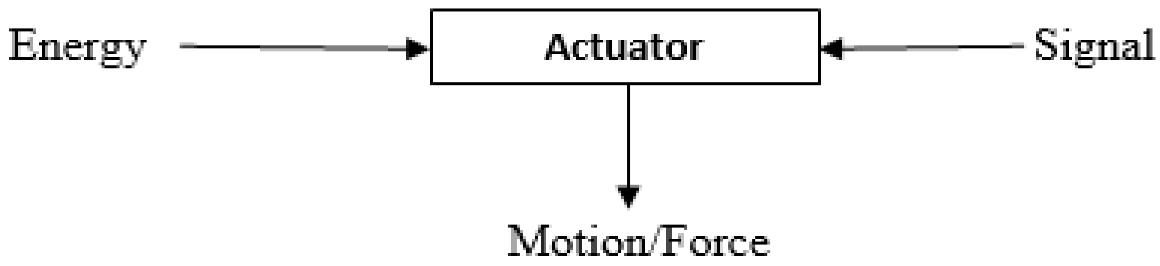
Sensors	Examples
Acoustic Sensors	▪ **Seismometers-** Measures seismic waves ▪ **Acoustic wave sensors-** measures the wave velocity in the air or an environment to detect the chemical species present..
Optical Light Sensors	▪ Detects light and electromagnetic energy ▪ Photocells (photo resistor)- a variable resistor affected by intensity changes in ambient light. ▪ Infra red sensor- detects infra red radiation
Other Motion Sensors	▪ Detects Motion ▪ Speedometer- measures speed ▪ Geiger counter- detects atomic radiation.

Actuators

- An Actuator is a component of a machine that is responsible for moving or controlling a mechanism or system. An Actuator requires a control signal and a source of energy. The control signal is relatively low energy and may be electric voltage or current, pneumatic or hydraulic pressure or human power.
  - **Hydraulic Actuators**
  - **Pneumatic Actuators**
  - **Electric Actuators**

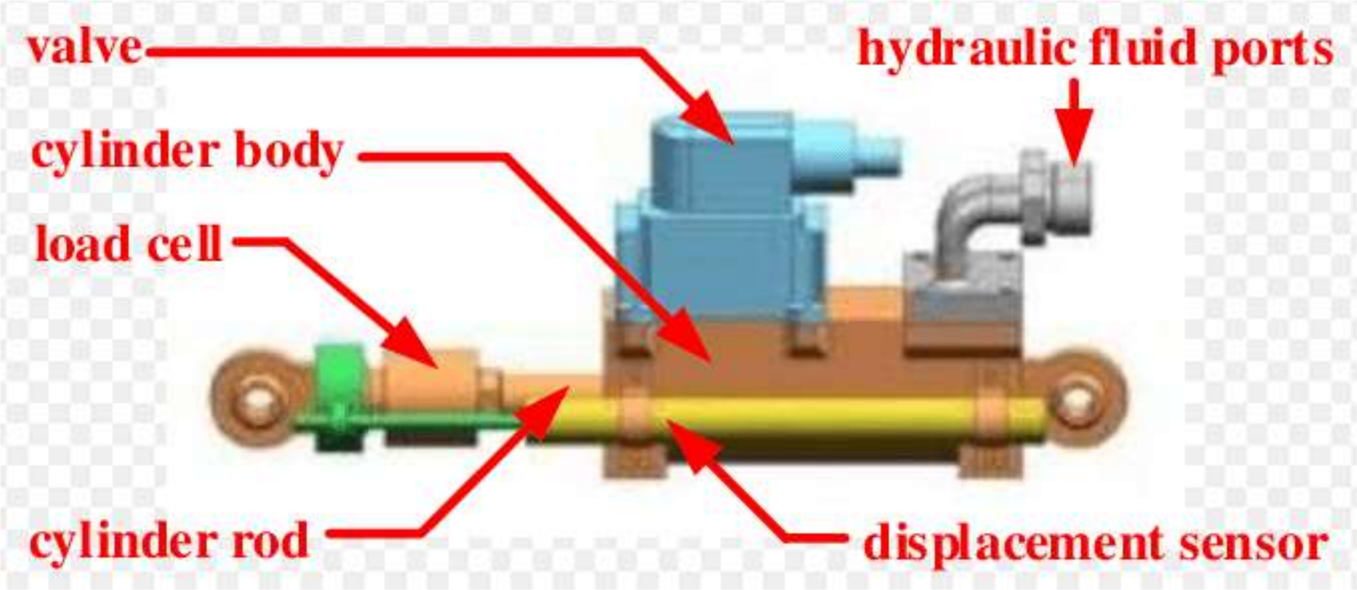
Workflow of a Actuator in a system

- An actuator is a sort of engine that controls or moves instruments or frameworks.
- It takes pressure driven liquid, electric current or different wellsprings of energy and proselytes the energy to encourage the movement.
- Actuators are greatly valuable devices and have an assorted scope of employments in fields, for example, building, electronic designing and can be found in numerous sorts of hardware, for example, printers, autos. Most actuators deliver either direct (straight line), revolving (round) or oscillatory movement.
- Actuators permit more load, compel, control, roughness, speed and obligation cycle to be upheld. Speed is crucial particularly on account of movement control hardware. The way toward changing over wellsprings of energy into vitality has been an extraordinary development to apparatus.



Hydraulic Actuator

- Hydraulic systems are used to control and transmit power.
- A pump driven by a prime mover such as an electric motor creates a flow of fluid, in which the pressure, direction and rate of flow are controlled by valves.
- An actuator is used to convert the energy of fluid back into the mechanical power.
- The amount of output power developed depends upon the flow rate, the pressure drop across the actuator and its overall efficiency.



Hydraulic Actuator

- Thus, hydraulic actuators are devices used to convert pressure energy of the fluid into mechanical energy.
- Depending on the type of actuation, hydraulic actuators are classified as follows:
  1. Linear actuator: For linear actuation (hydraulic cylinders).
  2. Rotary actuator: For rotary actuation (hydraulic motor).
  3. Semi-rotary actuator: For limited angle of actuation (semi-rotary actuator).

Hydraulic Actuator

- Hydraulic linear actuators, as their name implies, provide motion in a straight line.
- The total movement is a finite amount determined by the construction of the unit. They are usually referred to as cylinders, rams and jacks.
- All these items are synonymous in general use, although ram is sometimes intended to mean a single-acting cylinder and jack often refers to a cylinder used for lifting.
- The function of hydraulic cylinder is to convert hydraulic power into linear mechanical force or motion. Hydraulic cylinders extend and retract a piston rod to provide a push or pull force to drive the external load along a straight-line path.
- Continuous angular movement is achieved by rotary actuators, more generally known as a hydraulic motor. Semi-rotary actuators are capable of limited angular movements that can be several complete revolutions but 360^0 or less is more usual.

Pneumatic Actuator

- Pneumatic actuators are the devices used for converting pressure energy of compressed air into the mechanical energy to perform useful work.
- In other words, Actuators are used to perform the task of exerting the required force at the end of the stroke or used to create displacement by the movement of the piston.
- The pressurized air from the compressor is supplied to reservoir. The pressurized air from storage is supplied to pneumatic actuator to do work.

- The air cylinder is a simple and efficient device for providing linear thrust or straight line motions with a rapid speed of response.
- Friction losses are low, seldom exceeds 5 % with a cylinder in good condition, and cylinders are particularly suitable for single purpose applications and /or where rapid movement is required.
- They are also suitable for use under conditions which preclude the employment of hydraulic cylinders that is at high ambient temperature of up to 200 to 250.

Pneumatic Actuator

- Their chief limitation is that the elastic nature of the compressed air makes them unsuitable for powering movement where absolutely steady forces or motions are required applied against a fluctuating load, or where extreme accuracy of feed is necessary. The air cylinder is also inherently.
- Pneumatic cylinders can be used to get linear, rotary and oscillatory motion. There are three types of pneumatic actuator: they are

  i) Linear Actuator or Pneumatic cylinders

  ii) Rotary Actuator or Air motors

  iii) Limited angle Actuators

Electric Actuator

- An electric actuator is basically a geared motor.
- The motor can be of various voltages and is the primary torque-generating component.
- To prevent heat damage from overwork or excessive current draw, electric actuator motors are usually equipped with a thermal overload sensor embedded in the motor windings.
- This sensor is wired in series with the power source and opens the circuit should the motor be overheated, then closes the circuit when the motor reaches a safe operating temperature.
- An electric motor consists of an armature, an electrical winding, and a gear train.
- When power is supplied to the winding, a magnetic field is generated causing the armature to rotate.
- The armature will rotate as long as there is power to the windings when the power is cut, the motor stops.
- Standard end of travel limit switches, which are a necessity for an electric actuator, handle this task.

Electric Actuator

- **Types of Motors:** There are two types of motors used for electric actuators: unidirectional and bidirectional (commonly known as reversing motors).
- **Unidirectional motors** are motors in which the armature rotates in one direction, causing the valve to rotate in one direction. These actuators are typically used with a ball valve and rotate in 90 or 180 degree increments strictly for an on/off type of service.
- **Reversing motors** are motors in which there are two sets of windings allowing the armature to rotate in either direction depending on which set of windings is powered. One set of windings controls the clockwise direction for closing a valve, while the other set of windings controls the counter-clockwise direction for opening the valve. A major benefit of a bidirectional actuator is precise flow control, as the actuator is not required to travel the full stroke to begin the reverse stroke.
- Electric actuators rely on a gear train, which is coupled directly from the motor to enhance the motor torque and dictate the output speed of the actuator.


THANK YOU