

Unit 2 - Notes:

Sensor

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.

A sensor is a device used to measure a property, such as pressure, position, temperature, or acceleration, and respond with feedback.

Here are a few examples of the many different types of sensors:

In a mercury-based glass thermometer, the input is temperature. The liquid contained expands and contracts in response, causing the level to be higher or lower on the marked gauge, which is human-readable.

An oxygen sensor in a car's emission control system detects the gasoline/oxygen ratio, usually through a chemical reaction that generates a voltage. A computer in the engine reads the voltage and, if the mixture is not optimal, readjusts the balance.

Motion sensors in various systems including home security lights, automatic doors and bathroom fixtures typically send out some type of energy, such as microwaves, ultrasonic waves or light beams and detect when the flow of energy is interrupted by something entering its path.

A photosensor detects the presence of visible light, infrared transmission (IR), and/or ultraviolet (UV) energy.

Criteria to choose a Sensor

There are certain features which have to be considered when we choose a sensor. They are as given below:

1. Accuracy
2. Environmental condition – usually has limits for temperature/ humidity
3. Range – Measurement limit of sensor
4. Calibration – Essential for most of the measuring devices as the readings changes with time
5. Resolution – Smallest increment detected by the sensor

6. Cost
7. Repeatability – The reading that varies is repeatedly measured under the same environment

Classification of Sensors

The sensors are classified into the following criteria:

1. Primary Input quantity (Measurand)
2. Transduction principles (Using physical and chemical effects)
3. Material and Technology
4. Property
5. Application

Classification based on property is as given below:

- Temperature – Thermistors, thermocouples, RTD's, IC and many more.
- Pressure – Fibre optic, vacuum, elastic liquid based manometers, LVDT, electronic.
- Flow – Electromagnetic, differential pressure, positional displacement, thermal mass, etc.
- Level Sensors – Differential pressure, ultrasonic radio frequency, radar, thermal displacement, etc.
- Proximity and displacement – LVDT, photoelectric, capacitive, magnetic, ultrasonic.
- Biosensors – Resonant mirror, electrochemical, surface Plasmon resonance, Light addressable potentio-metric.
- Image – Charge coupled devices, CMOS
- Gas and chemical – Semiconductor, Infrared, Conductance, Electrochemical.

- Acceleration – Gyroscopes, Accelerometers.
- Others – Moisture, humidity sensor, Speed sensor, mass, Tilt sensor, force, viscosity.

Actuator

An actuator is a component of a machine that is responsible for moving and controlling a mechanism or system, for example by opening a valve. In simple terms, it is a "mover". An actuator requires a control signal and a source of energy.

Actuators are mechanical or electro-mechanical devices that provide controlled and sometimes limited movements or positioning which are operated electrically, manually, or by various fluids such as air, hydraulic, etc. Two basic motions are linear and rotary. Linear actuators convert energy into straight line motions, typically for positioning applications, and usually have a push and pull function. Some linear actuators are unpowered and manually operated by use of a rotating knob or handwheel. Rotary actuators convert energy to provide rotary motion. A typical use is the control of various valves such as ball valves or butterfly valves. Each actuator type has versions for various power configurations and come in many styles and sizes depending on the application. Linear chain actuators provide push and pull motions with rigid chains.

Types of Actuators

➤ Electric Linear

Electric Linear Actuators are electrically powered, mechanical linear actuators consisting of motors, linear guides, and drive mechanisms, which are used to convert electrical energy into linear displacement through mechanical transmission, electro-magnetism, or thermal expansion to provide straight line push/pull motion.

➤ Electric Rotary

Electric Rotary Actuators are electrically powered, mechanical devices consisting of motors and output shaft mechanisms with limited rotary travel which are used to convert electrical energy into rotational motion.

➤ Fluid Power Linear

Fluid Power Linear Actuators are mechanical devices consisting of cylinder and piston mechanisms that produce linear displacement by means of hydraulic fluid, gas, or differential air pressure. Key specifications include the intended application, fluid power type, mounting configuration, travel length, and force capacities, as well as physical dimensions as required

- Fluid Power Rotary

Fluid Power Rotary Actuators are fluid powered, mechanical devices consisting of cylinder and piston mechanisms, gearing, and output shafts giving limited rotational travel, which are used to convert hydraulic fluid, gas, or differential air pressure into rotational motion. Key specifications include the intended application, fluid power type, drive mechanism, mounting configuration, output configuration, rotation limits, and force capacities, as well as physical dimensions as required.

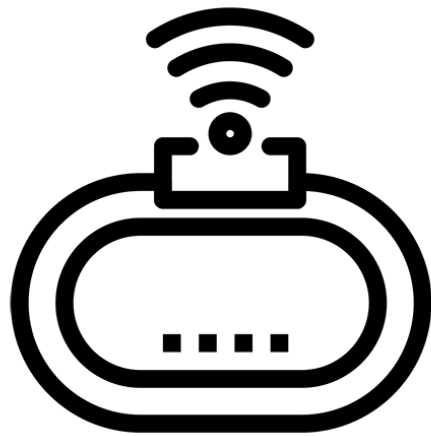
- Linear Chain Actuators

Linear Chain Actuators are mechanical devices consisting of sprockets and sections of chain which are used for providing linear motion via the free ends of the specially designed chains

- Manual Linear

- Manual Rotary

Role of microcontroller as gateway to interface sensor:



This post cover important topic of IoT devices and gateways. An IoT device is an embedded computer, incorporating one or more following functions:

- Computing capability;
- Sensors and actuators;
- Power supply;
- Wireless or wired communication interfaces;
- OS;

- User interface;
- Device management;
- Execution environment.

Gateways may also incorporate listed functions in order to simplify the system and to make it more cost effective. A RFC7228 (terminology for constrained-node networks) document gives a definition to small devices, constrained devices, constrained nodes, constrained networks, and constrained-node networks.

Constrained devices are those that have limited CPU, memory, power and create a network. Constrained devices are gather information about the surrounding environment, act as an information source, and can be connected to each other.

Constrained nodes are defined as ‘a node where some of the characteristics that are otherwise taken for granted for Internet nodes at the time of writing are not attainable, often due to cost constraints and/or physical constraints of characteristics like size, weight and available power and energy’.

Constrained networks are defined as ‘a network where some of the characteristics are taken for granted with link layers in common use in the internet at the time of writing and are not attainable’.

Constrained-Node Networks are defined as ‘a network whose characteristics are influenced by being composed of a significant portion of constrained nodes’.

Another classification of devices in IoT system is:

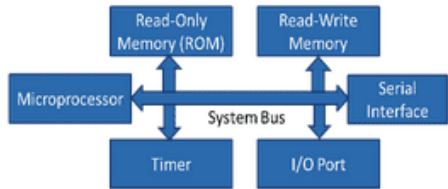
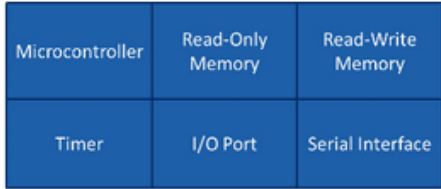
- Basic devices;
- Advanced devices.

Basic devices, microcontroller-class devices are those which can perform simple operations and usually can not communicate with each other without gateways. Advanced devices or general purpose-class devices are performing application level logic and support communication protocols. Basic and advanced IoT devices are different in terms of scenarios and processes. Basic IoT devices are good for performing simple processes like alarms, metering, standalone smart thermostats and others. Advanced IoT devices are designed for more complex processes, representing automated units, and processing multiple different actions at the same time. Basic IoT devices usually serve a single operation – measure temperature, wind force or others. The hardware requirements are relatively low for this type of devices. The components used for this type of devices are inexpensive, usually using an SoC inside, containing at least two microprocessors, and several wireless connectivity stacks.

The type of communication maybe different as there is a few of them available in the market. In terms of energy performance, these devices should perform a minimum consumption. Microcontrollers are equipped with several GPIO ports for interaction with external devices, supporting I2C, and ADCs, SPI protocols as a minimum.

UART, SPI, I2C or other serial interfaces are used to connect storage or displays, or communicate with another microcontroller. RFIC and SoC can also contain hardware security processors to provide encrypted secure communication between processors.

Difference between Microcontroller and Microprocessor

Microprocessor	Micro Controller
	
Microprocessor is heart of Computer system.	Micro Controller is a heart of embedded system.
It is just a processor. Memory and I/O components have to be connected externally	Micro controller has external processor along with internal memory and i/O components
Since memory and I/O has to be connected externally, the circuit becomes large.	Since memory and I/O are present internally, the circuit is small.
Cannot be used in compact systems and hence inefficient	Can be used in compact systems and hence it is an efficient technique
Cost of the entire system increases	Cost of the entire system is low
Due to external components, the entire power consumption is high. Hence it is not suitable to use with devices running on stored power like batteries.	Since external components are low, total power consumption is less and can be used with devices running on stored power like batteries.
Most of the microprocessors do not have power saving features.	Most of the micro controllers have power saving modes like idle mode and power saving mode. This helps to reduce power consumption even further.
Since memory and I/O components are all external, each instruction will need external operation, hence it is relatively slower.	Since components are internal, most of the operations are internal instruction, hence speed is fast.
Microprocessor have less number of registers, hence more operations are memory based.	Micro controller have more number of registers, hence the programs are easier to write.
Microprocessors are based on von Neumann model/architecture where program and data are stored in same memory module	Micro controllers are based on Harvard architecture where program memory and Data memory are separate
Mainly used in personal computers	Used mainly in washing machine, MP3 players

Difference between microprocessor and microcontroller

Microprocessor is an IC which has only the CPU inside them i.e. only the processing powers such as Intel's Pentium 1,2,3,4, core 2 duo, i3, i5 etc. These microprocessors don't have RAM, ROM, and other peripheral on the chip. A system designer has to add them externally to make them functional. Application of microprocessor includes Desktop PC's, Laptops, notepads etc.

But this is not the case with Microcontrollers. Microcontroller has a CPU, in addition with a fixed amount of RAM, ROM and other peripherals all embedded on a single chip. At times it is also termed as a mini computer or a computer on a single chip. Today different manufacturers produce microcontrollers with a wide range of features available in different versions. Some manufacturers are ATMEL, Microchip, TI, Freescale, Philips, Motorola etc.

Microcontrollers are designed to perform specific tasks. Specific means applications where the relationship of input and output is defined. Depending on the input, some processing needs to be done and output is delivered. For example, keyboards, mouse, washing machine, digicam, pendrive, remote, microwave, cars, bikes, telephone, mobiles, watches, etc. Since the applications are very specific, they need small resources like RAM, ROM, I/O ports etc and hence can be embedded on a single chip. This in turn reduces the size and the cost.

Microprocessor find applications where tasks are unspecific like developing software, games, websites, photo editing, creating documents etc. In such cases the relationship between input and output is not defined. They need high amount of resources like RAM, ROM, I/O ports etc.

The clock speed of the Microprocessor is quite high as compared to the microcontroller. Whereas the microcontrollers operate from a few MHz to 30 to 50 MHz, today's microprocessor operate above 1GHz as they perform complex tasks. Read more about what is microcontroller.

Comparing microcontroller and microprocessor in terms of cost is not justified. Undoubtedly a microcontroller is far cheaper than a microprocessor. However microcontroller cannot be used in place of microprocessor and using a microprocessor is not advised in place of a microcontroller as it makes the application quite costly. Microprocessor cannot be used stand alone. They need other peripherals like RAM, ROM, buffer, I/O ports etc and hence a system designed around a microprocessor is quite costly.

A MICROCONTROLLER BASICALLY HAS THESE COMPONENTS

CPU- central processing unit

RAM- Random access memory

ROM – Read only memory

Input-output ports

Timers and counters

Interrupt control

Analog to digital converter

Digital to analog converter

Interrupt controls

Oscillatory circuit

TYPES OF MICROCONTROLLER

8051 microcontroller

It is designed by Intel in 1981 and it is an 8 bit microcontroller it has 40 pins dual inline package 128 bytes of RAM 4k byte of ROM in 8051 there are 2 busses one for programming and other for data programming in microcontroller is complicated basically we write a program in C language and then it is converted to machine language understood by microcontroller two types of memory is present the program memory and data memory program memory stores the data being executed while data memory stores the result temporarily

Renesas microcontroller

It is in the automotive microcontroller family that offers high-performance features with low power consumption this microcontroller offers high security and embedded safety character for the automotive applications RX microcontroller is an example which has 32 bit

AVR microcontrollers

The AVR microcontrollers have modified Harvard RISC architecture with separate memories for data and program and speed of AVR is really high when compared to PIC and 8051

APPLICATIONS

Industrial automation

Communication application

Motor control applications

Test and measurement

Medical applications

Automobiles

Cameras

Security alarms

Mobile phones

Types of Microcontrollers

Microcontrollers are divided into various categories based on memory, architecture, bits and instruction sets. Following is the list of their types –

Bit

Based on bit configuration, the microcontroller is further divided into three categories.

- **8-bit microcontroller** – This type of microcontroller is used to execute arithmetic and logical operations like addition, subtraction, multiplication division, etc. For example, Intel 8031 and 8051 are 8 bits microcontroller.
- **16-bit microcontroller** – This type of microcontroller is used to perform arithmetic and logical operations where higher accuracy and performance is required. For example, Intel 8096 is a 16-bit microcontroller.
- **32-bit microcontroller** – This type of microcontroller is generally used in automatically controlled appliances like automatic operational machines, medical appliances, etc.

Memory

Based on the memory configuration, the microcontroller is further divided into two categories.

- **External memory microcontroller** – This type of microcontroller is designed in such a way that they do not have a program memory on the chip. Hence, it is named as external memory microcontroller. For example: Intel 8031 microcontroller.
- **Embedded memory microcontroller** – This type of microcontroller is designed in such a way that the microcontroller has all programs and data memory, counters and timers, interrupts, I/O ports are embedded on the chip. For example: Intel 8051 microcontroller.

Instruction Set

Based on the instruction set configuration, the microcontroller is further divided into two categories.

- **CISC** – CISC stands for complex instruction set computer. It allows the user to insert a single instruction as an alternative to many simple instructions.
- **RISC** – RISC stands for Reduced Instruction Set Computers. It reduces the operational time by shortening the clock cycle per instruction.

Applications of Microcontrollers

Microcontrollers are widely used in various different devices such as –

- Light sensing and controlling devices like LED.
- Temperature sensing and controlling devices like microwave oven, chimneys.
- Fire detection and safety devices like Fire alarm.
- Measuring devices like Volt Meter.

UNIT 2:

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. In the next section on open loop and closed loop control systems, we will study in detail about the blocks inside the control system and how to vary this input in order to get the desired response.

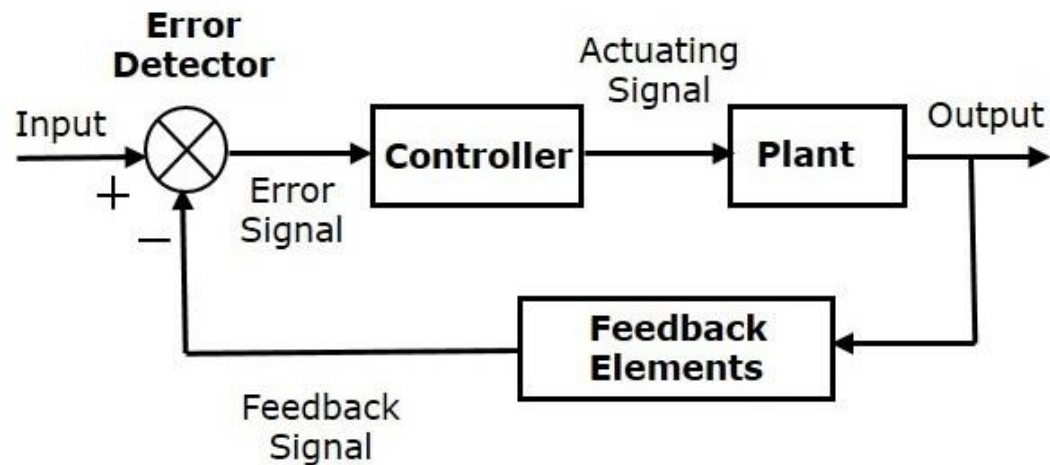
Examples – Traffic lights control system, washing machine

Classification of Control Systems

Based on some parameters, we can classify the control systems into the following ways.

In continuous time control systems, all the signals are continuous in time. But, in discrete time control systems, there exists one or more discrete time signals.

Real time system with feedback control:



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.

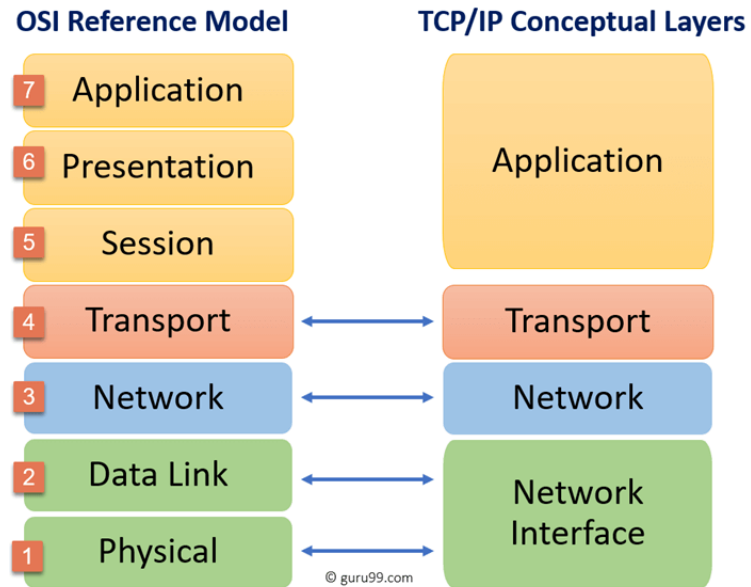
The error detector produces an error signal, which is the difference between the input and the feedback signal. This feedback signal is obtained from the block (feedback elements) by considering the output of the overall system as an input to this block. Instead of the direct input, the error signal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

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

Open Loop Control Systems	Closed Loop Control Systems
Control action is independent of the desired output.	Control action is dependent of the desired output.
Feedback path is not present.	Feedback path is present.
These are also called as non-feedback control systems .	These are also called as feedback control systems .
Easy to design.	Difficult to design.
These are economical.	These are costlier.
Inaccurate.	Accurate.

TCP/IP model versus OSI Model:



Difference between OSI Model and TCP/IP Model

OSI Model	TCP/IP Model
It is developed by ISO (International Standard Organization)	It is developed by ARPANET (Advanced Research Project Agency Network).
OSI model provides a clear distinction between interfaces, services, and protocols.	TCP/IP doesn't have any clear distinguishing points between services, interfaces, and protocols.
OSI refers to Open Systems Interconnection.	TCP refers to Transmission Control Protocol.
OSI uses the network layer to define routing standards and protocols.	TCP/IP uses only the Internet layer.
OSI follows a vertical approach.	TCP/IP follows a horizontal approach.
OSI layers have seven layers.	TCP/IP has four layers.
In the OSI model, the transport layer is only connection-oriented.	A layer of the TCP/IP model is both connection-oriented and connectionless.
In the OSI model, the data link layer and physical are separate layers.	In TCP, physical and data link are both combined as a single host-to-network layer.
Session and presentation layers are a part of the OSI model.	There is no session and presentation layer in the TCP model.

It is defined after the advent of the Internet.

It is defined before the advent of the internet.

The minimum size of the OSI header is 5 bytes.

The minimum header size is 20 bytes.

OSI(Open System Interconnection)	TCP/IP(Transmission Control Protocol / Internet Protocol)
1. OSI is a generic, protocol independent standard, acting as a communication gateway between the network and end user.	1. TCP/IP model is based on standard protocols around which the Internet has developed. It is a communication protocol, which allows connection of hosts over a network.
2. In OSI model the transport layer guarantees the delivery of packets.	2. In TCP/IP model the transport layer does not guarantees delivery of packets. Still the TCP/IP model is more reliable.
3. Follows vertical approach.	3. Follows horizontal approach.
4. OSI model has a separate Presentation layer and Session layer.	4. TCP/IP does not have a separate Presentation layer or Session layer.

5. Transport Layer is Connection Oriented.	5. Transport Layer is both Connection Oriented and Connection less.
6. Network Layer is both Connection Oriented and Connection less.	6. Network Layer is Connection less.
7. OSI is a reference model around which the networks are built. Generally it is used as a guidance tool.	7. TCP/IP model is, in a way implementation of the OSI model.
8. Network layer of OSI model provides both connection oriented and connectionless service.	8. The Network layer in TCP/IP model provides connectionless service.
9. OSI model has a problem of fitting the protocols into the model.	9. TCP/IP model does not fit any protocol
10. Protocols are hidden in OSI model and are easily replaced as the technology changes.	10. In TCP/IP replacing protocol is not easy.
11. OSI model defines services, interfaces and protocols very clearly and makes clear distinction between them. It is protocol independent.	11. In TCP/IP, services, interfaces and protocols are not clearly separated. It is also protocol dependent.

12. It has 7 layers

12. It has 4 layers

The Different Types of Communication Medium Used in Networks:

Communication medium refers to the physical channel through which data is sent and received. Data is sent in the form of voltage levels which make up the digital signal. A digital signal consists of 0s and 1s; essentially, a 1 corresponds to a high voltage, while a 0 corresponds to a low voltage.

The speed of data transmission or data rate depends upon the type of medium being used in the network. There are basically two types of networks:

- Wired network
- Wireless network

Wired Network

In a wired network, data is transmitted over a physical medium. There are three types of physical cables used in a wired network.

1. Twisted Pair

It consists of a pair of copper wires twisted around each other; the wires are around 1 to 2 mm thick and they are twisted to reduce the interference from the surrounding wires. Remember that a current carrying wire has a magnetic field around it that can interfere with that of another wire when in close proximity.

Invented by Alexander Graham Bell, this form of wire has been in use since the 19th century and is currently the cheapest mediums available. Twisted pairs are also used in telephone wires, but they only consist of four wires or two pairs. In computer networks, eight wires or four pairs are utilized. This is also known as the Ethernet cable or RJ-45 cable. The pairs of wires are bundled together and covered by a protective shield.

2. Coaxial Cable

Offering better data rates and less signal attenuation, a coaxial cable consist of a central copper conductor that is surrounded by a foil shield. The foil is covered by yet another shield known as a braided shield. Unlike twisted pairs, coaxial cables only have a single copper conductor. The conductor and the foil shield are separated by a dielectric.

3. Fiber Optic

It is the most expensive of wired mediums and offers the highest rates of data transmission. They are often used in long distance communications and are never affected by any electromagnetic fields. This is because it involves light.

A fiber optic cable is a thin, flexible, transparent medium made of very fine glass or plastic fibers. It utilizes the principle of total internal reflection. Unlike twisted pairs or coaxial cables, a fiber optic uses light pulses generated by laser or an injection diode to transmit data. Each pulse of light represents a single bit of data.

Wireless Network

A wireless network uses radio waves as the sole medium for transmitting and receiving data. There are no wires involved. An example is the wireless router in your home. Radio waves are electromagnetic waves which are transverse in nature and they have the longest wavelength on the electromagnetic spectrum.

They travel at the speed of light and have frequencies ranging from 3 kHz to 3 GHz. Radio waves can easily be absorbed by most materials and can bend around objects as well. However, they are susceptible to nearby electromagnetic fields which can cause losses in the data rate.