LEARNING MATERIAL OF

MECHATRONICS

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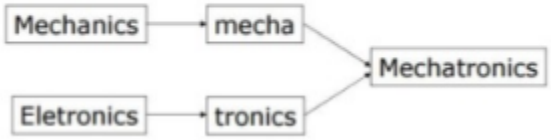
MECHATRONICS

Q /Define mechatronics ?

- The word, mechatronics is composed of **mecha** from mechanics and **tronics** from electronics.

Mechatronics is the combination of mechanical and electrical engineering, computer science, and information technology, which includes the use of control systems as well as numerical methods to design products with built-in intelligence.



- The term Mechatronics invented by Tetsuro Mori a senior japanese Engineer in 1969.
- Examples of mechatronic systems are robots, digitally controlled combustion engines, machine tools with self-adaptive tools, contact-free magnetic bearings, automated guided vehicles, etc.

Q/write <u>Advantages & disadvantages of Mechatronics ?</u>

Advantages of Mechatronics system

- It is cost effective and it can produce high quality products.
- Production of parts and products of international standards gives better reputation and return.
- It serves effectively for high dimensional accuracy requirements.
- It provides high degree of flexibility to modify or redesign the systems.
- It provides excellent performance characteristics.
- It Results in automation in production, assembly and quality control.
- Mechatronic systems provide the increased productivity in manufacturing organization.
- Reconfiguration feature by pre supplied programs facilitate the low volume production.
- It provides higher level of flexibility required for small product cycles.
- It provides the possibility of remote controlling as well as centralized monitoring and control. .
- It has greater extend of machine utilization.
- Higher life is expected by proper maintenance and timely diagnosis of the fault.

Disadvantages Of Mechatronics System

- The initial cost is high.
- Maintenance and repair may workout costly.
- Multi-disciplinary engineering background is required to design and implementation.
- It needs highly trained workers to operate.
- Techno-economic estimation has to be done carefully in the selection of mechatronic system.

It has complexity in identification and correction of problems in the systems.

Q/write Application of Mechatronics?

Mechatronics is widely used in your day-to-day life. It is used in appliances like washing machines and dishwashers. It's also used in measuring devices like testing of sensors, and calibration devices. Moreover, its uses in automatic air conditioning systems, automatic door systems, and security systems improve the quality of life as well as the security of secure facilities. Also Mechatronics is used in manufacturing, health care, space exploration, and in tools that make our lives easier on a day-to-day basis. Mechatronics is the broad term for integrating mechanical, telecommunication, and computer engineering, frequently using microcontrollers.

You might be wondering about how exactly mechatronics is applied in advanced manufacturing. Here are some good examples:

Production line automation: A manufacturing setting is designed as a chain process whereby one stage leads to the next. Most such systems use belts to move products and materials during the process. Mechatronics makes it possible to automate the process by incorporating devices like barcode readers, imaging and sound processors along the line.

For example, a packaged product can have its manufacture and expiry dates stamped in and recorded while on the belt.

Measuring devices: A manufacturing process is only good if the end products come out in the right shapes, sizes, weight, and quality. In that case, installing intelligent sensors, testing and calibration systems at the required points goes a long way in ensuring that. All this falls within the realm of mechatronics.

Control systems: In any effective manufacturing line, there must be measures put in place to ensure that the installation operates at its optimum level. That makes dealing with factors like pressure and temperature a priority. Thanks to mechatronics, this can be done very easily through sensors and response mechanisms that work to monitor and maintain the desired operating conditions. For example, a sensor can trigger the turn on of the cooling system when the temperature builds to a certain degree.

Q/write Scope of Mechatronics in Industrial Sector ?

The course aims to produce students who can design and develop smart machines and use their multidisciplinary skills to meet growing demands of an industry. Mechatronics Engineering is offered with an

integrated curriculum to provide a broad-based education in the basic principles of electrical, electronics, mechanical, control, instrumentation and computer engineering. Broad range of topic covered include: Design of machine elements, Analog and Digital system Design, Signal Processing, Measurements, Material Science,Mechanical Vibration, Kinematics of Machinery, PLC Programming, Control Systems,Microcontrollers, Hydraulic and Pneumatic Systems, Industrial Robotics, Embedded Systems,Nanotechnology and Computer Integrated Manufacturing.

Fig. 1: Top 5 industries hiring mechatronic professionals (Data Courtesy: TimesJobs.com)

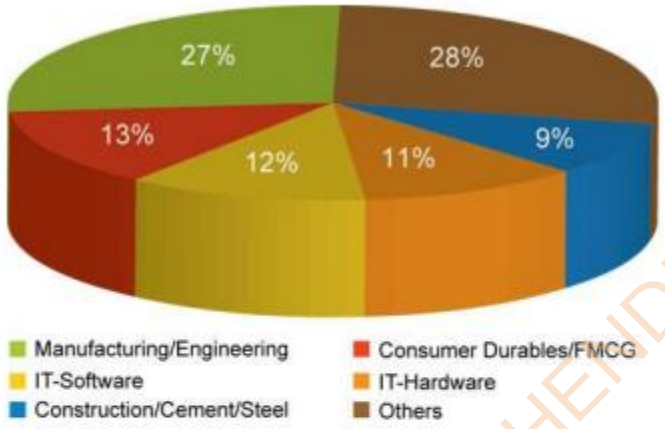
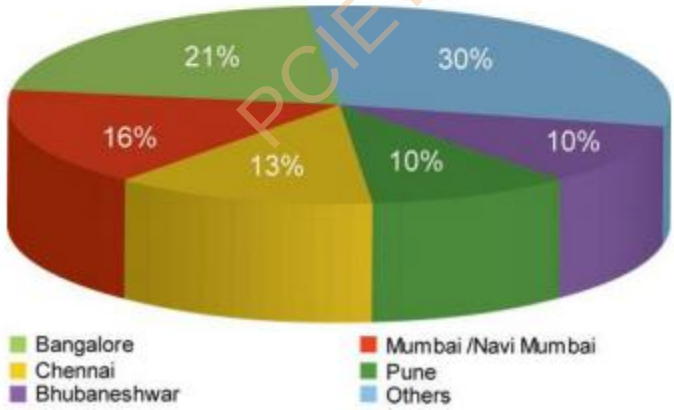


Fig. 2: Top 5 geographical locations hiring mechatronic professionals (Data Courtesy: TimesJobs.com)

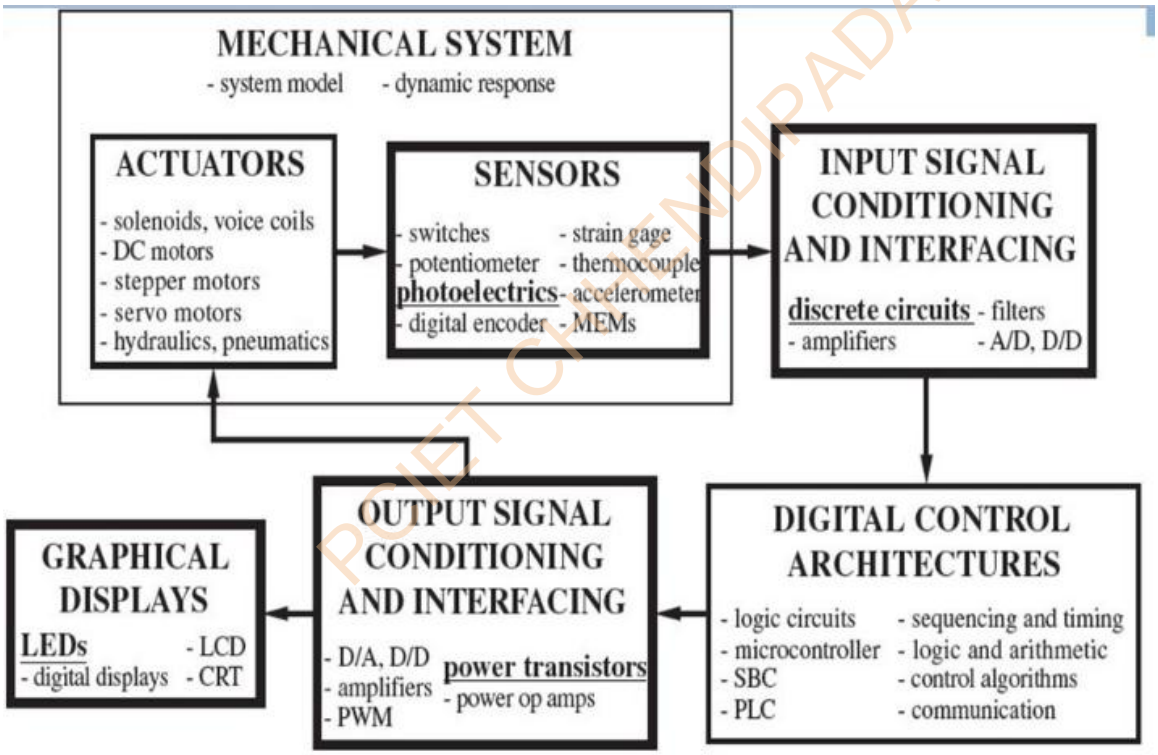


Q/what are the Components of a Mechatronics System?

Physically, a mechatronic system is composed of four prime components. They are sensors, actuators, controllers and mechanical components.

Basic Components :

- Sensors.
- Actuators (Hydraulics, Phnumetics)
- PLC, Micro controllers.
- Electrical Motors.
- Mechanical Couplings, Assembly & Gears.
- Control Panel.



Q/what is the Importance of mechatronics in automation ?

Automation is the technique of making an apparatus, a process, or a system operate automatically. Automation, in the machine tools has reduced the human involvement in the machine operation and improved the process efficiency and product quality. Therefore it is important to study the principles of mechatronics and to learn how to apply them in the automation of a manufacturing system.

2.0 SENSORS AND TRANSDUCERS

Q/Define Transducers ?

The device which converts the one form of energy into another is known as the transducer. The process of conversion is known as transduction. The conversion is done by sensing and transducing the physical quantities like temperature, pressure, sound, etc. The electrical transducer converts the mechanical energy into an electric signal.

Q/ Classify Transducers ?

There are many principles on which a transducer can work like resistive, inductive, capacitive etc. So Transducer can be categorized on the basis of four thoughts. On the basis of transduction form it`s used, we can go further.

1. Primary and secondary type
2. Analog and digital type
3. Active and passive type
4. Transducer and Inverse type

1.Primary and secondary type

Q/what is primary transducer?– The transducer consists the mechanical as well as the electrical devices. The mechanical devices of the transducer change the physical input quantities into a mechanical signal. This mechanical device is known as the primary transducers.

Q/What is Secondary Transducer? – The secondary transducer converts the mechanical signal into an electrical signal. The magnitude of the output signal depends on the input mechanical signal.

Q/what isAnalog Transducer ?– The Analog transducer changes the input quantity into a continuous function. The strain gauge, L.V.D.T, thermocouple, thermistor are the examples of the analogue transducer.

Q/what isDigital Transducer ? – These transducers convert an input quantity into a digital signal or in the form of the pulse. The digital signals work on high or low power.

Q/what is active andPassive Transducer ?– The transducer which requires the power from an external supply source is known as the passive transducer. They are also known as the external power transducer. The capacitive, resistive and inductive transducers are the example of the passive transducer.

Active Transducer – The transducer which does not require the external power source is known as the active transducer. Such type of transducer develops theirs owns voltage or

current, hence known as a self-generating transducer. The output signal is obtained from the physical input quantity.

Q/what is Inverse Transducer ?– The transducer which converts the electric quantity into a physical quantity, such type of transducers is known as the inverse transducer. The transducer has high electrical input and low non-electrical output.

Q/what is Electromechanical Transducers?

A transducer for receiving waves from an electric system and delivering waves to a mechanical system, or vice versa. Is known as electromagnetic transducer**.** Many of the transducers used in everyday life operate in both directions, such as the speakerphone .

Q/define Displacement &Positions 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.

A **displacement sensor** is used to measure travel range between where an object is and a reference position. **Displacement sensors** can be used for dimension measurement to determine an object's height, thickness, and width in addition to travel range.

Position Sensors detect the position of something which means that they are referenced either to or from some fixed point or position.

Q/define Velocity, motion, force and pressure sensors?

Velocity Sensors- A velocity or speed sensor measures consecutive position measurements at known intervals and computes the time rate of change in the position values.

Force Sensor- A Force Sensor is a sensor that helps in measuring the amount of force applied to an object

Motion Sensor- A motion detector is an electrical device that utilizes a sensor to detect nearby motion.

Pressure Sensor- A pressure sensor is a device for pressure measurement of gases or liquids.

Q/define Temperature and light sensors?

Temperature Sensors measure the amount of heat energy or even coldness that is generated by an

object or system, allowing us to "sense" or detect any physical change to that temperature producing either an analogue or digital output.

Light sensor is a passive device that converts the **light** energy into an electrical signal output. **Light sensors** are more commonly known as Photoelectric Devices or Photo **Sensors** because they convert **light** energy (photons) into electronic signal (electrons).

3.2 Electrical Actuator

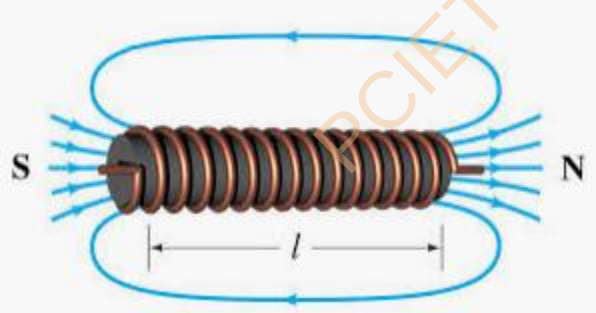
3.2.1 Switches and relay

The main difference between **Relay** and **Switch** is that the **Relay** is a electrically operated **switch** and **Switch** is a electrical component that can break an electrical circuit. Many **relays** use an electromagnet to mechanically operate a **switch.**

What is electromagnet - A coil of wire that becomes a temporary magnet when electricity flows through it. Because electromagnet is made up of insulated copper **wire** wrapped around soft iron, which allows **current** to **flow** in it and at that moment iron gains it **magnetic** properties and when the **current** is switched off, then there will be no **flow** of **current** and hence iron loses its property.

3.2.2 Solenoid

The **solenoid** simply **works** on the principle of "electromagnetism". When the current flow through the coil magnetic field is generated in it, if you place a metal core inside the coil the magnetic lines of flux is concentrated on the core which increases the induction of the coil as compared to the air core.



Like all magnets, the magnetic field of an activated solenoid has positive and negative poles that will attract or repel material sensitive to magnets. In a solenoid, the electromagnetic field causes the piston to either. Move backward or forward, which is how motion is created by a solenoid coil.

3.2.3 D.C Motors

A direct current (DC) motor is a type of electric machine that converts electrical energy into mechanical

energy. DC motors take electrical power through direct current, and convert this energy into mechanical rotation.

Whenever a current carrying conductor comes under a magnetic field, there will be a force acting on the conductor. The direction of this force can be found using Fleming's Left Hand Rule

Working Function-

A simple DC motor uses a stationary set of magnets in the stator, and a coil of wire with a current running through it to generate an electromagnetic field aligned with the center of the coil. One or more windings of insulated wire are wrapped around the core of the motor to concentrate the magnetic field.

The windings of insulated wire are connected to a commutator (a rotary electrical switch), that applies an electrical current to the windings. The commutator allows each armature coil to be energised in turn, creating a steady rotating force (known as torque).

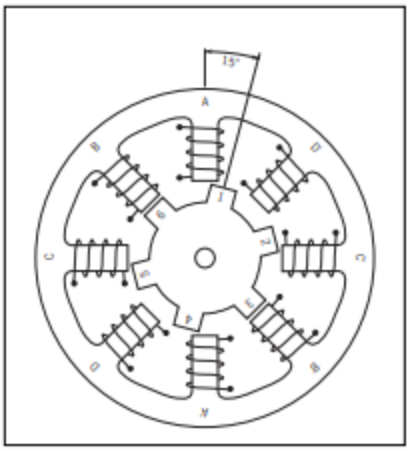
3.2.4 A.C Motors

An AC motor is an electric motor driven by an alternating current. The two basic parts of an AC motor are the stator (the stationary outer drum) and the rotor; the rotating inner portion of the motor which is attached to (and drives) the motor shaft. Both the stator and the rotor produce rotating magnetic fields. In the windings of the stator, this rotating field is provided inherently by the sinusoidal nature of alternating current. In the rotor, the magnetic field is created by permanent magnets, reluctance saliency, or by additional electrical windings.

3.2.5 Stepper Motors

A stepper motor is an electromechanical device it converts electrical power into mechanical power. Also, it is a brushless, synchronous electric motor that can divide a full rotation into an expansive number of steps.

The stepper motor uses the theory of operation for magnets to make the motor shaft turn a precise distance when a pulse of electricity is provided. The stator has eight poles, and the rotor has six poles. The rotor will require 24 pulses of electricity to move the 24 steps to make one complete revolution Another way to say this is that the rotor will move precisely 15° for each pulse of electricity that the motor receives.



3.2.6 Specification and control of stepper motors

Specification

Step angle:	1.8° full **step /** 0.9° half-**step**
Phase/Windings:	4/2
Voltage & Current:	12V at 400 mA
Resistance per Phase:	30 ohms

Stepper motors are **DC motors** that move in discrete steps. They have multiple coils that are organized in groups called "phases". By energizing each phase in sequence, the **motor** will rotate, one **step** at a time. With a computer controlled **stepping** you can achieve very precise positioning and/or speed **control**.

3.2.7 Servo Motors D.C & A.C

Servo Motor - Servo implies an error sensing feedback control which is utilized to correct the performance of a system.

Servo Motor consists of a DC Motor, a Gear system, a position sensor, and a control circuit. The DC motors get powered from a battery and run at high speed and low torque. The Gear and shaft assembly connected to the DC motors lower this speed into sufficient speed and higher torque. The position sensor senses the position of the shaft from its definite position and feeds the information to the control circuit. The control circuit accordingly decodes the signals from the position sensor and compares the actual position of the motors with the desired position and accordingly controls the direction of rotation of the DC motor to get the required position.

Advantages:

- If a heavy load is placed on the motor, the driver will increase the current to the motor coil as it attempts to rotate the motor. There is no out-of-step condition.
- High-speed operation is possible.
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DC Servo Motor

Generally, the DC servo motor includes a DC source separately in the field of the armature winding. The motor can be controlled either by managing the field current otherwise the armature current. The armature control has some benefits compare with field control. Similarly, field control has come benefits compare with armature control. The controlling of this motor can be done based on the application used. This motor offers a quick and accurate response to begin or end command signals because of the small armature inductive reactance. These motors are utilized in several devices and numerically controlled equipment.

AC Servo Motor

AC servo motor includes an encoder which is used by the controllers to give the feedback as well as closed loop control. AC motor can be located to high accuracy as well as controlled accurately as necessary for the applications. These motors have superior designs in order to achieve better torque. The AC servo motor applications mainly include in robotics, automation, CNC equipment, and many more applications**.**

4.0 PROGRAMMABLE LOGIC CONTROLLERS(PLC)

4.1 Introduction - A PROGRAMMABLE LOGIC CONTROLLER (**PLC**) is an industrial computer control system that continuously monitors the state of input devices and makes decisions based upon a custom program to control the state of output devices.

Now you are given a task that when you turn ON the switch, the light should glow only after 30 seconds. With this hard-wired setup – we're stuck. The only way to achieve this is to completely rewire our circuit to add a timing relay.

Here is where a PLC comes into the picture, which doesn't require any additional wiring and hardware to make sure of a change. Rather it requires a simple change in code, programming the PLC to only turn on the light 30 seconds after the switch is turned ON. So, by using a PLC, it is easy to incorporate multiple inputs and outputs.

4.2 Advantages of PLC

1. Very fast

2. Easy to change logic i.e. flexibility
3. Reliable due to absence of moving parts
4. Low power consumption
5. Easy maintenance due to modular assembly
6. Facilities in fault finding and diagnostic
7. Capable of handling of very complicated logic operations
8. Good documentation facilities
9. Easy to couple with the process computers
10. Analog signal handling and close loop control programming
11. Counter, timer and comparator can be programmed

4.3 Selection and uses of PLC

Choosing a PLC or Controller for your Process is very important as it helps in Cost optimization. To determine the most suitable PLC to be used in the automation task, there are several basic considerations to be made:

- Necessary input/output capacity
- Types of I/O required
- Size of memory required
- Speed and power required of the CPU and instruction set
- Manufacturer's support and backup
- They are user friendly and easy to operate
- They eliminate the need for hard-wired relay logic
- Its input and output modules can be extended depending upon the requirements

4.4 Architecture basic internal structures

A basic PLC system consists of the following sections:

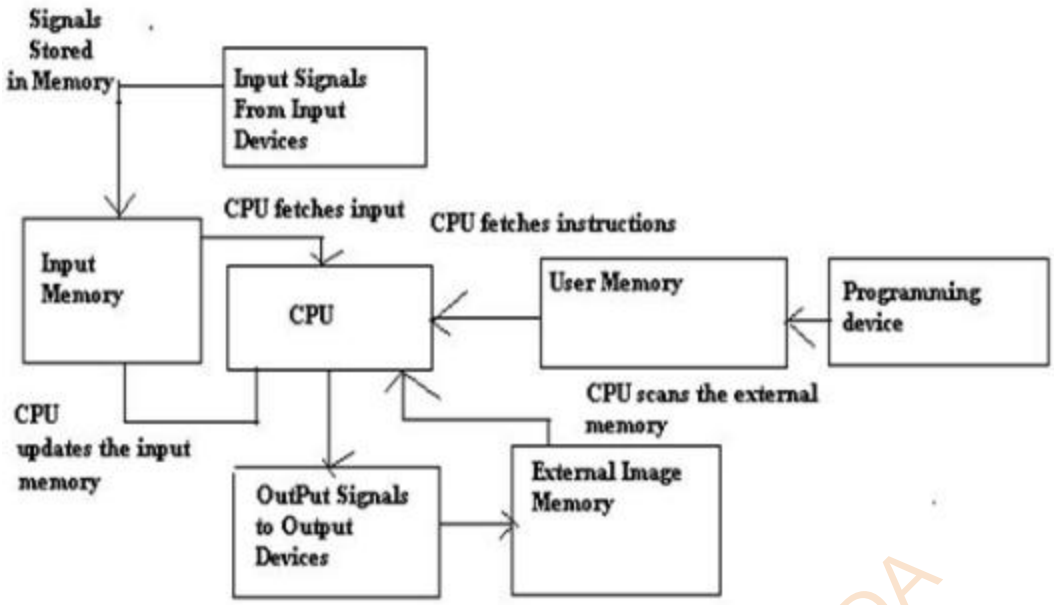
- **Input/ Output Section**: The input section or input module consists of devices like sensors, switches, and many other real-world input sources. The input from the sources is connected to the PLC through the input connector rails. The output section or output module can be a

motor or a solenoid or a lamp or a heater, whose functioning is controlled by varying the input signals.

- **CPU or Central Processing Unit**: It is the brain of the PLC. It can be a hexagonal or an octal microprocessor. It carries out all the processing related to the input signals in order to control the output signals based on the control program.
- **Programming Device**: It is the platform where the program or the control logic is written. It can be a handheld device or a laptop or a computer itself.
- **Power Supply**: It generally works on a power supply of about 24 V, used to power input and output devices.
- **Memory**: The memory is divided into two parts- The data memory and the program memory. The program information or the control logic is stored in the user memory or the program memory from where the CPU fetches the program instructions. The input and output signals and the timer and counter signals are stored in the input and output external image memory respectively.

Working of a PLC

- The input sources convert the real-time analog electric signals to suitable digital electric signals and these signals are applied to the PLC through the connector rails.
- These input signals are stored in the PLC external image memory in locations known as bits. This is done by the CPU
- The control logic or the program instructions are written onto the programming device through symbols or through mnemonics and stored in the user memory.
- The CPU fetches these instructions from the user memory and executes the input signals by manipulating, computing, processing them to control the output devices.
- The execution results are then stored in the external image memory which controls the output drives.
- The CPU also keeps a check on the output signals and keeps updating the contents of the input image memory according to the changes in the output memory.
- The CPU also performs internal programming functions like setting and resetting of the timer, checking the user memory.



4.5 Input/output Processing and Programming

Another portion of RAM is allocated for the storage of current I/O status. Every single input/output module has been assigned to it a particular location within the input/output image table. The location within the input and output image tables are identified by addresses, each location has its own unique address. During the execution of user program, the microprocessor scans the user program and interpret the user commands, the status of input modules used are read from the input image table (not directly from the input module itself). Various output device status generated during the execution of user program are stored in the output image table (not directly to output modules).

4.6 Mnemonics

A ladder diagram written in alphanumeric characters for easier understanding than the machine language program to be executed by CPU Unit. The **mnemonic** code can be converted to a ladder diagram in the **PLC**.

4.7 Master and Jump Controllers

A controller is basically a unit present in a control system that generates control signals to reduce the deviation of the actual value from the desired value to almost zero or lowest possible value. It is responsible for the control action of the system so as to get accurate output.

Before we introduce you to various controllers in detail, it is very essential to know the uses of controllers in the theory of control systems. The important uses of the controllers include:

1. Controllers improve the steady-state accuracy by decreasing the steady state error.
2. As the steady-state accuracy improves, the stability also improves.
3. Controllers also help in reducing the unwanted offsets produced by the system.
4. Controllers can control the maximum overshoot of the system.
5. Controllers can help in reducing the noise signals produced by the system.
6. Controllers can help to speed up the slow response of an overdamped system.

Master controller - A **controller**, which is used in a cascade **control** system. It provides an output which acts as a variable desired value for a slave **controller**.

Jump Controller