LAB MANUAL

MIT - SIEMENS

CENTRE OF EXCELLENCE

FOR

MECHATRONICS

G.S. MANDAL’S

MAHARASHTRA INSTITUTE OF TECHNOLOGY,

AURANGABAD

DEPARTMENT OF MECHANICAL ENGINEERING

INDEX

Vision and mission of the department

Vision: To be a center of excellence in the field of Mechanical Engineering where the best of teaching, learning and research synergize and serve the society through innovation and excellence in teaching.

Mission: To provide world-class under-graduate and graduate education in Mechanical Engineering by imparting quality techno-managerial education and training to meet current and emerging needs of the industry and society at large.

Program Education Objectives

PEO-I Graduates will apply the tools and skills acquired during their undergraduate studies either in advanced studies or as employees in engineering industries

PEO-2 Graduates of the program will have successful technical and professional career.

PEO-3 Graduates of the program will continue to learn to adopt constantly evolving technology.

PEO-4 Graduates will demonstrate sensitivity towards societal issues.

Program Outcomes

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems
2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. **Conduct investigations of complex problems:** Use research-based knowledge and search methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and teamwork:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. **Life-long learning:** Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes

PSO-I: Ability to design & analyse components & systems for mechanical performance

PSO-II: Ability to apply and solve the problems of heat power and thermal systems.

PSO-III: Ability to solve real life problems with the exposure to manufacturing industries

Course Outcomes

MED: Automation system design (Honor/Minor)		
CO No.	**Code**	**Statement**
CO 1	**MED 903.1**	List out the different sensors and their working principles.
CO 2	**MED 903.2**	Explain the uses and working of different actuators in the industrial automation.
CO 3	**MED 903.3**	Describe role of different mechanical components and their working in the automation system.
CO 4	**MED 903.4**	Relate the controllers used for automation with the PLC, for industrial applications.
CO 5	**MED 903.5**	Compare different sensors and actuators and select proper one for a typical industry application.
CO 6	**MED 903.6**	Apply the knowledge of sensors, actuators and PLC for the automation of given application/system.

Course Objectives

1. To give an idea about various sectors of manufacturing where automation can be implemented.
2. To aware students about different technologies practiced in different sections of manufacturing.

Lab Instructions

1. Respect the test equipment and be gentle with it.
2. **If you don't know something about a circuit or electronics hardware, ask before rushing ahead.**
3. Perform only those experiments authorized by your teacher.
4. Carefully follow all instructions, both written and oral.
5. Ensure that safety devices are adequate, appropriate and in good working condition.
6. You must not open the PC cases or install additional hardware or software on the Lab computers.
7. **Please report any problem, including damage to equipment, as soon as it occurs.**
8. It is your responsibility to keep the Lab neat and tidy.
9. Turn off all PC monitors and instruments when not in use.
10. Turn off the ceiling fans and lights if you are last person leaving the lab.

For EMERGENCY

In the case of an electrical emergency, such as electrocution or fire, all 240V and 415V, general purpose power outlets in the lab can be isolated/turned off.

Practical No. 01

Aim: - Study and demonstration of mechatronics system and its components.

Introduction to Mechatronics:

Mechatronics is the synergistic integration of sensors, actuators, signal conditioning, power electronics, decision and control algorithms, and computer hardware and software to manage complexity, uncertainty, and communication in engineered systems.

Typical knowledgebase for optimal design and operation of mechatronic systems comprises of:

– Dynamic system modeling and analysis

-- Thermo-fluid, structural, hydraulic, electrical, chemical, biological, etc.

– Decision and control theory

– Sensors and signal conditioning

– Actuators and power electronics

– Data acquisition

-- A2D, D2A, digital I/O, counters, timers, etc.

– Hardware interfacing

– Rapid control prototyping

– Embedded computing

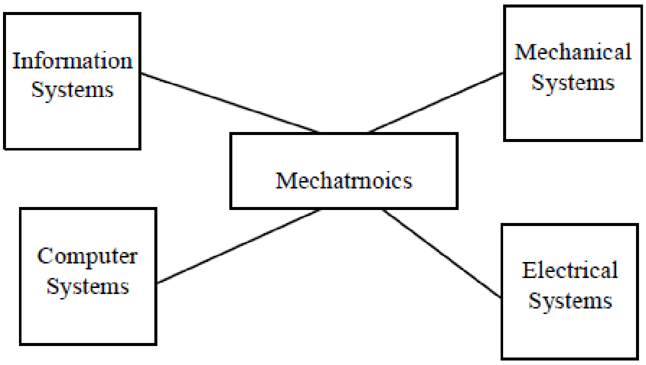

Fig.: - Disciplinary Foundations of Mechatronics

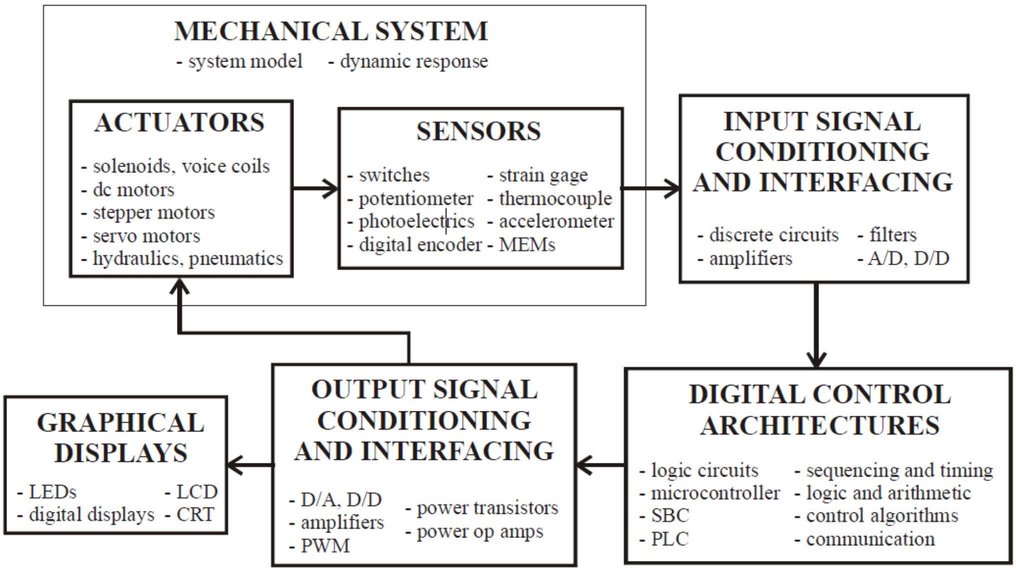

Fig.: - Elements of Mechatronics System

Elements of Mechatronics System

Mechatronics system comprise of various elements of Mechanical, Electrical, Electronics domains.

Mechanical elements refer to

• Mechanical structure, mechanism, thermo-fluid, and hydraulic aspects of a mechatronics system.

• Mechanical elements require physical power to produce motion, force, heat, etc.

Electromechanical elements refer to:

Sensors

A variety of physical variables can be measured using sensors, e.g., light using photo-resistor, level and displacement using potentiometer, direction/tilt using magnetic sensor, sound using microphone, stress and pressure using strain gauge, touch using micro-switch, temperature using thermistor, and humidity using conductivity sensor.

Actuators

DC servomotor, stepper motor, relay, solenoid, speaker, light emitting diode (LED), shape memory alloy, electromagnet, and pump apply commanded action on the physical process.

Electrical elements refer to:

Electrical components (e.g., resistor (R), capacitor (C), inductor (L), transformer, etc.), circuits, and analog signals.

• Electronic elements refer to:

analog/digital electronics, transistors, thyristors, opto-isolators, operational amplifiers, power electronics, and signal conditioning

• The electrical/electronic elements are used to interface electromechanical sensors and actuators to the control interface/computing hardware elements.

Control interface/computing hardware elements refer to:

Analog-to-digital (A2D) converter, digital-to-analog (D2A) converter, digital input/output (I/O), counters, timers, microprocessor, microcontroller, data acquisition and control (DAC) board, and digital signal processing (DSP) board.

• Control interface hardware allows analog/digital interfacing

– communication of sensor signal to the control computer and communication of control signal from the control computer to the actuator.

• Control computing hardware implements a control algorithm, which uses sensor measurements, to compute control actions to be applied by the actuator.

Mechatronics Applications

• Smart consumer products: home security, camera, microwave oven, toaster, dish washer, laundry washer-dryer, climate control units, etc.

• Medical: implant-devices, assisted surgery, haptic, etc.

• Defense: unmanned air, ground, and underwater vehicles, smart munitions, jet engines, etc.

• Manufacturing: robotics, machines, processes, etc.

• Automotive: climate control, antilock brake, active suspension, cruise control, air bags, engine management, safety, etc.

Conclusion:

Thus, we have studied the Mechatronics system, its components and applications.

Practical No. 02

Aim: - Study and Demonstration of Sensors.

Introduction to Sensors

A sensor is a device that receives a stimulus and responds with an electrical signal.

Sensors are almost always **transducers,** but **transducers** are not necessarily **sensors**. A **transducer** is a device which converts signals from one form to another. This can include loudspeakers and linear positioners are well as physical quantity to electrical signal devices.

Sensor is a device that when exposed to a physical phenomenon (temperature, displacement, force, etc.) produces a proportional output signal (electrical, mechanical, magnetic, etc.).

The term transducer is often used synonymously with sensors. However, ideally, a sensor is a device that responds to a change in the physical phenomenon. On the other hand, a transducer is a device that converts one form of energy into another form of energy. Sensors are transducers when they sense one form of energy input and output in a different form of energy. For example, a thermocouple responds to a temperature change (thermal energy) and outputs a proportional change in electromotive force (electrical energy). Therefore, a thermocouple can be called a sensor and or transducer.

Normally, the output from a sensor requires post processing of the signals before they can be fed to the controller. The sensor output may have to be demodulated, amplified, filtered, linearized, range quantized, and isolated so that the signal can be accepted by a typical analog-to-digital converter of the controller. Some sensors are available with integrated signal conditioners, such as the microsensors. All the electronics are integrated into one microcircuit and can be directly interfaced with the controllers.

Classification of Sensor:

Sensors are classified as **passive or active**. In passive sensors, the power required to produce the output is provided by the sensed physical phenomenon itself (such as a thermometer) whereas the active sensors require external power source (such as a strain gage).

Furthermore, sensors are classified as **analog or digital** based on the type of output signal. Analog sensors produce continuous signals that are proportional to the sensed parameter and typically require analog-to-digital conversion before feeding to the digital controller.

Digital sensors on the other hand produce digital outputs that can be directly interfaced with the digital controller. If many sensors are required, it is more economical to choose simple analog sensors and interface them to the digital controller equipped with a multi-channel analog-to-digital converter.

Sensor	Features
	Linear/Rotational sensors
Linear/Rotational variable differential transducer (LVDT/RVDT)	High resolution with wide range capability Very stable in static and quasi-static applications
Optical encoder	Simple, reliable, and low-cost solution Good for both absolute and incremental measurements
Electrical tachometer	Resolution depends on type such as generator or magnetic pickups
Hall effect sensor	High accuracy over a small to medium range
Capacitive transducer	Very high resolution with high sensitivity Low power requirements Good for high frequency dynamic measurements
Strain gauge elements	Very high accuracy in small ranges Provides high resolution at low noise levels
Interferometer	Laser systems provide extremely high resolution in large ranges Very reliable and expensive
Magnetic pickup	Output is sinusoidal
Gyroscope	
Inductosyn	Very high resolution over small ranges
	Acceleration sensors
Seismic accelerometer	Good for measuring frequencies up to 40% of its natural frequency
Piezoelectric accelerometer	High sensitivity, compact, and rugged Very high natural frequency (100 kHz typical)

Force, torque, and pressure sensor

Strain gauge	Good for both static and dynamic measurements
Dynamometers/load cells	They are also available as micro- and nanosensors
Piezoelectric load cells	Good for high precision dynamic force measurements
Tactile sensor	Compact, has wide dynamic range, and high
Ultrasonic stress sensor	Good for small force measurements

Flow sensors

Pitot tube	Widely used as a flow rate sensor to determine speed in aircrafts
Orifice plate	Least expensive with limited range
Flow nozzle, venturi tubes	Accurate on wide range of flow
	More complex and expensive
Rotameter	Good for upstream flow measurements
	Used in conjunction with variable inductance sensor
Ultrasonic type	Good for very high flow rates
	Can be used for both upstream and downstream flow measurements
Turbine flow meter	Not suited for fluids containing abrasive particles
	Relationship between flow rate and angular velocity is linear
Electromagnetic flow meter	Least intrusive as it is noncontact type
	Can be used with fluids that are corrosive, contaminated, etc.
	The fluid has to be electrically conductive

Temperature sensors

Thermocouples	This is the cheapest and the most versatile sensor
	Applicable over wide temperature ranges (-200∞C to 1200∞C typical)
Thermistors	Very high sensitivity in medium ranges (up to 100∞C typical)
	Compact but nonlinear in nature
Thermodiodes, thermo transistors	Ideally suited for chip temperature measurements
	Minimized self heating
RTD—resistance temperature detector	More stable over a long period of time compared to thermocouple
	Linear over a wide range

Infrared type	Noncontact point sensor with resolution limited by wavelength
Infrared thermography	Measures whole-field temperature distribution
	Proximity sensors
Inductance, eddy current, hall effect, photoelectric, capacitance, etc.	Robust noncontact switching action The digital outputs are often directly fed to the digital controller
	Light sensors
Photoresistors, photodiodes, photo transistors, photo conductors, etc.	Measure light intensity with high sensitivity Inexpensive, reliable, and noncontact sensor
Charge-coupled diode	Captures digital image of a field of vision
	Smart material sensors
Optical fiber	
As strain sensor	Alternate to strain gages with very high accuracy and bandwidth Sensitive to the reflecting surface's orientation and status
As level sensor	Reliable and accurate
As force sensor	High resolution in wide ranges
As temperature sensor	High resolution and range (up to 2000∞C)
Piezoelectric	
As strain sensor	Distributed sensing with high resolution and bandwidth
As force sensor	Most suitable for dynamic applications
As accelerometer	Least hysteresis and good setpoint accuracy
Magnetostrictive	
As force sensors	Compact force sensor with high resolution and bandwidth Good for distributed and noncontact sensing applications
As torque sensor	Accurate, high bandwidth, and noncontact sensor
	Micro- and nano-sensors
Micro CCD image sensor	Small size, full field image sensor
Fiberscope	Small (0.2 mm diameter) field vision scope using SMA coil actuators
Micro-ultrasonic sensor	Detects flaws in small pipes
Micro-tactile sensor	Detects proximity between the end of catheter and blood vessels

Conclusion:

Thus, we have studied various sensors, their types and their applications.

Practical No. 03

Aim: - Study and Demonstration of Actuators.

Introduction to Actuators:

Actuators are basically the muscle behind a mechatronics system that accepts a control command (mostly in the form of an electrical signal) and produces a change in the physical system by generating force, motion, heat, flow, etc. Normally, the actuators are used in conjunction with the power supply and a coupling mechanism as shown in Fig. below. The power unit provides either AC or DC power at the rated voltage and current. The coupling mechanism acts as the interface between the actuator and the physical system. Typical mechanisms include rack and pinion, gear drive, belt drive, lead screw and nut, piston, and linkages.

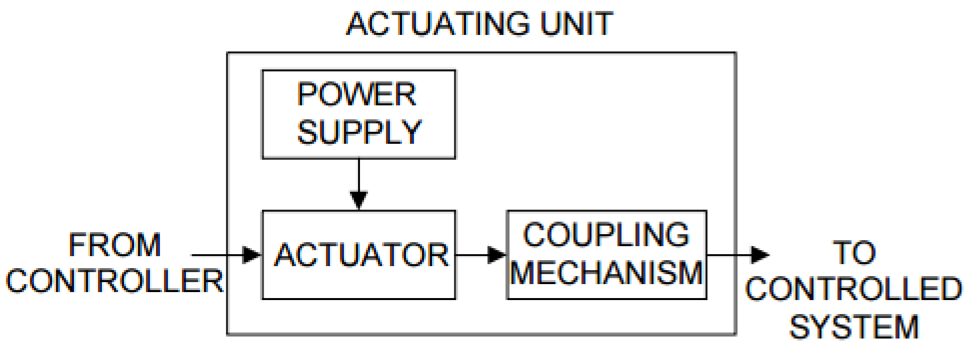

Fig.: - Typical Actuating unit

Classification Actuators can be classified based on the type of energy. They are essentially of electrical, electromechanical, electromagnetic, hydraulic, or pneumatic type. The new generations of actuators include smart material actuators, microactuators, and Nanoactuators. Actuators can also be classified as binary and continuous based on the number of stable-state outputs. A relay with two stable states is a good example of a binary actuator. Similarly, a stepper motor is a good example of continuous actuator. When used for a position control, the stepper motor can provide stable outputs with very small incremental motion.

Principle of Operation

Electrical Actuators

Electrical switches are the choice of actuators for most of the on-off type control action. Switching devices such as diodes, transistors, triacs, MOSFET, and relays accept a low energy level command signal from the controller and switch on or off electrical devices such as motors, valves, and heating elements. The gate terminal receives the low energy control signal from the controller that makes or breaks the connection between the power supply and the actuator load. When switches are used, the designer must make sure that switch bounce problem is eliminated either by hardware or software.

Electromechanical Actuators

The most common electromechanical actuator is a motor that converts electrical energy to mechanical motion. Motors are the principal means of converting electrical energy into mechanical energy in industry. Broadly they can be classified as DC motors, AC motors, and stepper motors. DC motors operate on DC

Electromagnetic Actuators

The solenoid is the most common electromagnetic actuator. A DC solenoid actuator consists of a soft iron core enclosed within a current carrying coil. When the coil is energized, a magnetic field is established that provides the force to push or pull the iron core. AC solenoid devices are also encountered, such as AC excitation relay. A solenoid operated directional control valve is shown in Fig. Normally, due to the spring force, the soft iron core is pushed to the extreme left position as shown. When the solenoid is excited, the soft iron core will move to the right extreme position thus providing the electromagnetic actuation. Another important type is the electromagnet. The electromagnets are used extensively in applications that require large forces.

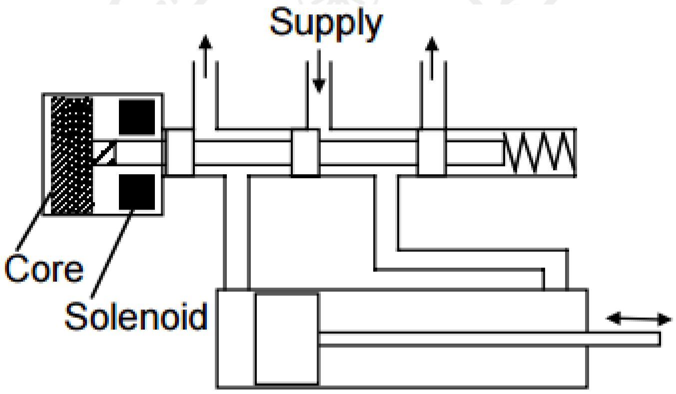

Fig.: Solenoid Operated Direction Control Valve

Hydraulic and Pneumatic Actuators

Hydraulic and pneumatic actuators are normally either rotary motors or linear piston/cylinder or control valves. They are ideally suited for generating very large forces coupled with large motion. Pneumatic actuators use air under pressure that is most suitable for low to medium force, short stroke, and high speed applications. Hydraulic actuators use pressurized oil that is incompressible.

They can produce very large forces coupled with large motion in a cost-effective manner. The disadvantage with the hydraulic actuators is that they are more complex and need more maintenance. The rotary motors are usually used in applications where low speed and high torque are required. The cylinder/piston actuators are suited for application of linear motion such as aircraft flap control. Control valves in the form of directional control valves are used in conjunction with rotary motors and cylinders to control the fluid flow direction as shown in Fig. above. In this solenoid operated directional control valve, the valve position dictates the direction motion of the cylinder/piston arrangement.

Actuator			Features
		Electrical	
Diodes, thyristor, bipolar transistor, triacs, diacs, power MOSFET, solid state relay, etc.			Electronic type Very high frequency response Low power consumption
		Electromechanical	
DC motor	Wound field	Separately excited	Speed can be controlled either by the voltage across the armature winding or by varying the field current
		Shunt	Constant-speed application
		Series	High starting torque, high acceleration torque, high speed with light load
		Compound	Low starting torque, good speed regulation Instability at heavy loads
	Permanent magnet	Conventional PM motor	High efficiency, high peak power, and fast response
		Moving-coil PM motor	Higher efficiency and lower inductance than conventional DC motor
		Torque motor	Designed to run for a long periods in a stalled or a low rpm condition
	Electronic commutation (brushless motor)		Fast response High efficiency, often exceeding 75% Long life, high reliability, no maintenance needed Low radio frequency interference and noise production
AC motor	AC induction motor		The most commonly used motor in industry Simple, rugged, and inexpensive
	AC synchronous motor		Rotor rotates at synchronous speed Very high efficiency over a wide range of speeds and loads Need an additional system to start
	Universal motor		Can operate in DC or AC Very high horsepower per pound ratio Relatively short operating life
Stepper motor	Hybrid		Change electrical pulses into mechanical movement Provide accurate positioning without feedback
	Variable reluctance		Low maintenance

	Electromagnetic	
Solenoid type devices		Large force, short duration
Electromagnets, relay		On/off control
	Hydraulic and Pneumatic	
Cylinder		Suitable for liner movement
Hydraulic motor	Gear type	Wide speed range
	Vane type	High horsepower output
	Piston type	High degree of reliability
Air motor	Rotary type	No electric shock hazard
	Reciprocating	Low maintenance
Valves	Directional control valves	
	Pressure control valves	
	Process control valves	
	Smart Material actuators	
Piezoelectric & Electrostrictive		High frequency with small motion High voltage with low current excitation High resolution
Magnetostrictive		High frequency with small motion Low voltage with high current excitation
Shape Memory Alloy		Low voltage with high current excitation Low frequency with large motion
Electrorheological fluids		Very high voltage excitation Good resistance to mechanical shock and vibration Low frequency with large force
	Micro- and Nanoactuators	
Micromotors		Suitable for micromechanical system
Microvalves		Can use available silicon processing technology, such as electrostatic motor
Micropumps		Can use any smart material

Conclusion:

Thus, we have studied the actuators, their types and applications.

Practical No. 04

Aim: - Study and Demonstration of PLC Hardware and Software.

Introduction to PLC

A Programmable Logic Controller, PLC or Programmable Controller is a digital computer used for automation of electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures.

The word "Programmable" differs it from the conventional hard-wired relay logic control. PLC can be easily Programmed or changed as per the application's requirement.

What are **PLC Capabilities**?

-Logic Control

-Timer

-Counter

-Arithmetic Function

-PID Control

-Analog Signal

-Communication

-Signals & Listing

-Real time function

-HMI Panels

Advantages of PLC

Reduced Space

Energy Saving

Ease of Maintenance

Economical

Greater Life & Reliability

Tremendous Flexibility

Shorter Project Time

Archiving & Documentation

Advantages of PLC

- Reduced space – Compact construction compared to Hard wired controller, Less wiring
- Energy saving – 1/10th of power consumed by equivalent Relay logic control
- Ease of Maintenance – Modular replacement / Easy troubleshooting / Error diagnostic by Software
- Economical – Low payback period
- Greater Life & Reliability – Lesser moving parts, Reduced wear & tear
- Tremendous flexibility – Control logic can be changed without rewiring / Supports Complex functions like Time delays, Counting, Comparing, Arithmetic operations
- Online / Offline programming possible
- High processing speed & great flexibility in processing both Analog & Digital signal

Components of PLC

There are 5 basic components in a PLC system

- PLC processor or controller cpu
- Input / Output module
- Chassis or Backplane
- Power supply
- Programming Software that runs in a PC

PLC CPU

Stores the control program and data in its memory. Performs logic operation with the data.

Performs calculations. CPU has 3 types of Memories.

1) System Memory – OS, PII, PIQ, Timers, Counters etc.

2) Load Memory – Used to store the user program. e.g. Memory Card

3) Work Memory – Used to store the parts of user program required for program processing.

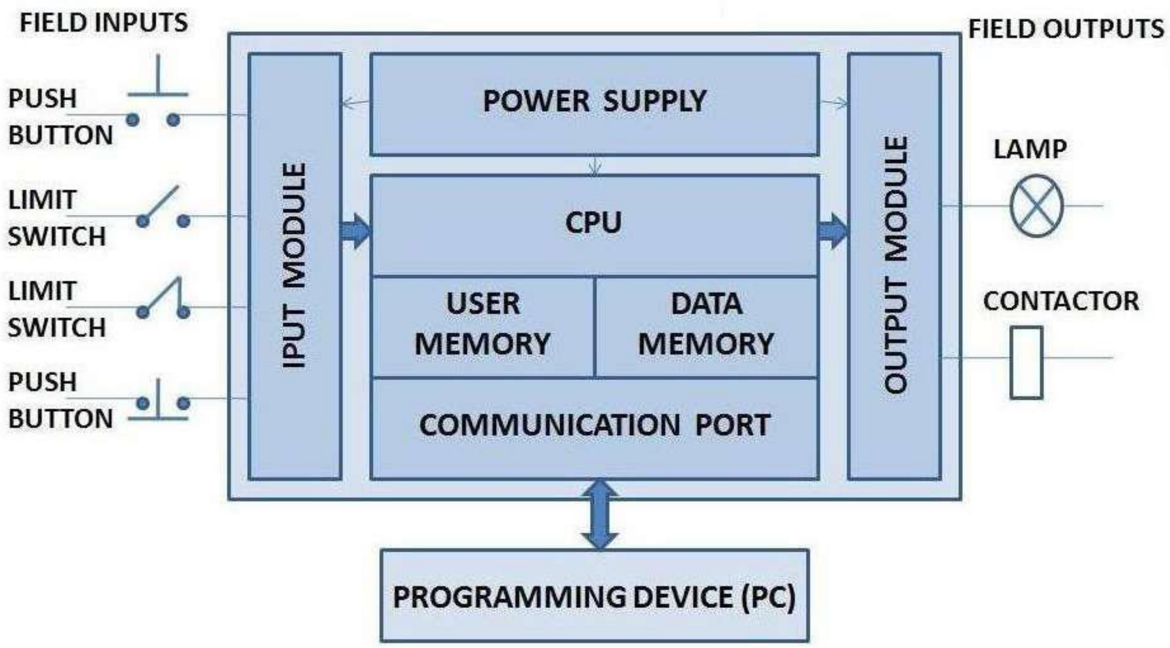

Fig.: PLC Block Diagram

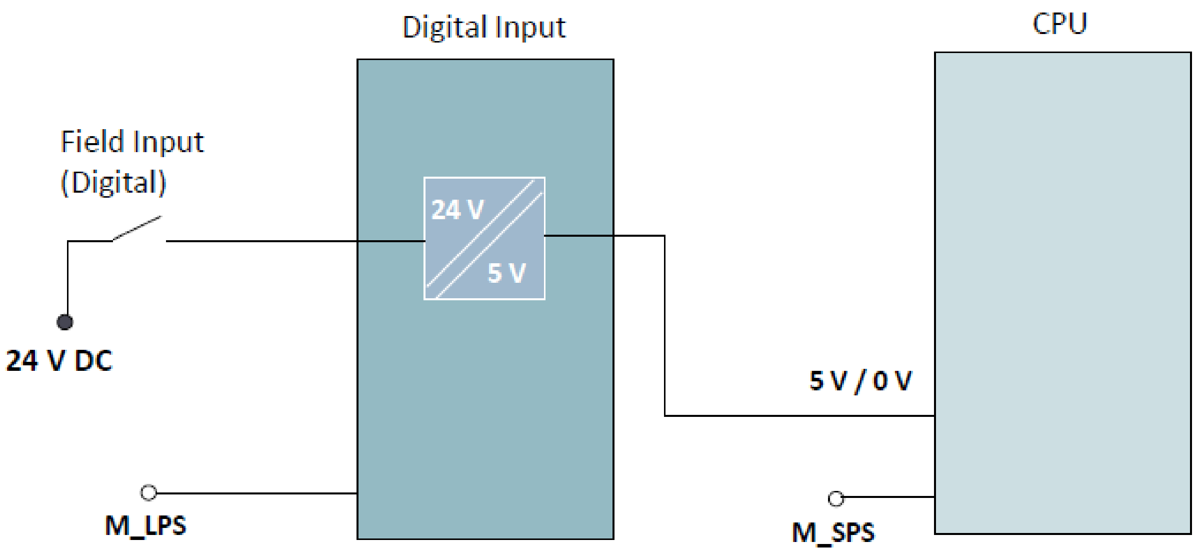

Fig.: Digital Input Module

Purpose of Digital Input/output Module

The digital input module is used for signal conversion to 5V DC, which is required for working of the controller.

Also, it is used for the signal isolation and for serial communication with CPU. Input module acts as Interface between field control Inputs and CPU. The voltage/ current signals generated by Sensors, Transducers, Limit switches, Push buttons etc. are applied to the terminals of Input module.

Input module converts the field signal into standard control signal for processing by PLC. receives 24 V DC or 230 V AC & delivers 5V DC. Sends one signal at a time to CPU by multiplexing action. Analog input module or digital input module are there for input and output of PLC. Analog Current Input module – 4 to ± 20mA or 0 to ± 20 mA. Analog Voltage Input module – 0 to ± 50mV or 0 to ± 500 mV or 0 to ± 10 V. Digital Input module – 24 V DC, 230 V AC.

PLC Programing

PLC Scan Cycle

- Sense the Input
- Process the Logic
- Give Output

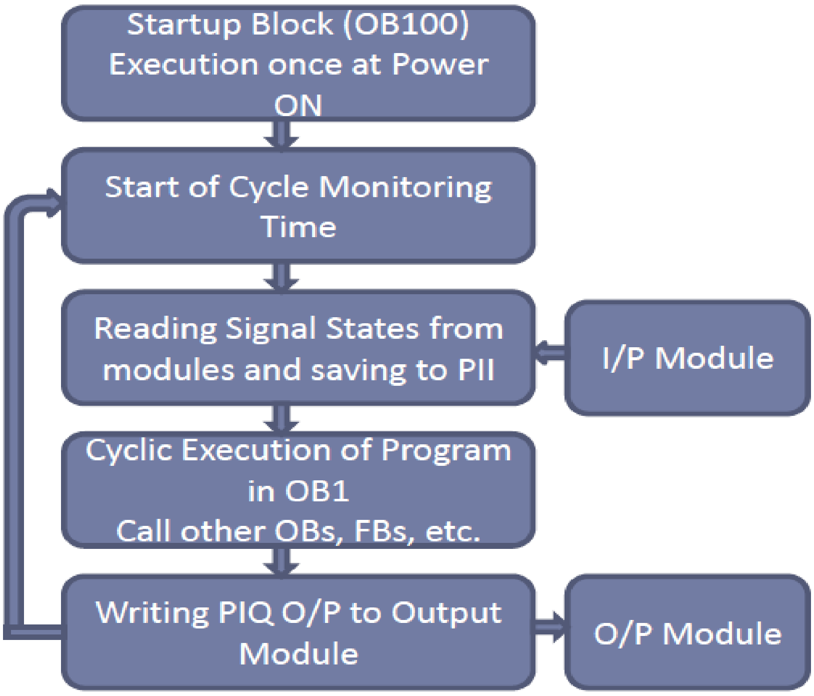

Fig.: PLC Program Scan Cycle

Programming Languages

A program loaded into PLC systems in machine code, a sequence of binary code numbers to represent the program instructions. Assembly language based on the use of mnemonics can be used, and a computer program called an assembler is used to translate the mnemonics into machine code. High level Languages (C, BASIC, etc.) can be used.

Programming Devices

PLC can be reprogrammed through an appropriate programming device:

Programming Console, Computer, Hand Programmer etc.

Introduction to Ladder Logic

Ladder logic uses graphic symbols like relay schematic circuit diagrams. Ladder diagram consists of two vertical lines representing the power rails. Circuits are connected as horizontal lines between these two verticals.

Ladder diagram features

Power flows from left to right.

Output on right side cannot be connected directly with left side.

Contact cannot be placed on the right of output.

Each rung contains one output at least.

Each output can be used only once in the program.

A particular input a/o output can appear in more than one rung of a ladder.

The inputs a/o outputs are all identified by their addresses, the notation used depending on the PLC manufacturer.

Introduction to Statement list

Statement list is a programming language using mnemonic abbreviations of Boolean logic operations. Boolean operations work on combination of variables that are true or false.

A statement is an instruction or directive for the PLC.

Statement List Operations

* Load (LD) instruction.

* And (A) instruction.

* Or (O) instruction.

* Output (=) instruction.

Function Block Diagrams

Function block is represented as a box with the function name written in.

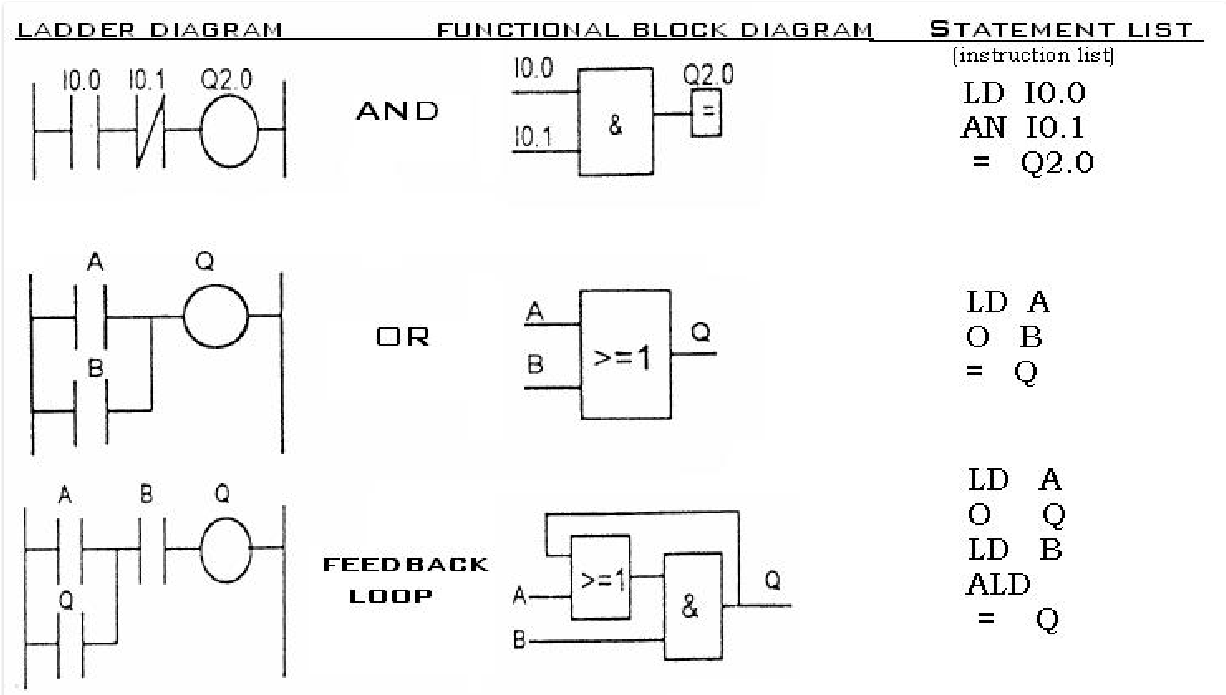

Fig.: PLC Programming Languages

Conclusion:

Thus, we have studied the PLC construction working and basics of PLC programming.

Practical No. 05

Title: - PLC Programing Exercises – NO NC.

(Students have to develop and test the PLC ladder program for at least two basic examples)

Practical No. 06

Title: - PLC Programing Exercises – SR RS Block.

(Students have to develop and test the PLC ladder program for at least two basic examples)

Practical No. 07

Title: - PLC Programing Exercises – Latching circuit.

(Students have to develop and test the PLC ladder program for at least two basic examples)

Practical No. 08

Title: - Mechatronics System Case Study.

(Student have to prepare report on case study of at least one mechatronics system application)