VTU MECHATRONICS QUESTION PAPER SOLUTION- JAN 21'

17ME753

1a. Mechatronics may be defined as" the complete integration of mechanical system with electronics, electrical and computer system into a single system".

- Mechatronics is the synergistic (Together) combination of mechanical engineering, electronic engineering, control engineering and systems thinking in the design of products and manufacturing processes".
- Multi-disciplinary products are not new; they have been successfully designed and used for many years. Most common is the electromechanical system.
- It employs a sequential design-by-discipline approach. For example in the design of electromechanical system three stages of design are adopted.
- They are design of mechanical system, design of microelectronic system and control system.
- Each design application follows the completion of the previous one.
- to overcome drawbacks Mechatronics uses concurrent engineering.

Applications of Mechatronic systems:
The areas are:
1. Automotive machines.
2. Fax and photocopier mechanics
3. Dishwashers.
4. Automatic washing machine
5. Air conditioners, elevator controls.
6. Documents scanners
7. IC manufacturing systems.
8. Robotics employed in welding, nuclear inspection, painting etc.,
9. VCRs and CD Players.

1b. Advantages and disadvantages of Mechatronics:
Advantages:
1. The products produced are cost effective and very good quality.
2. High degree of flexibility
3. Greater extent of machine utilization
4. Greater productivity
5. High life expected by proper maintenance.
6. The integration of sensor and control system in a complex system reduces capital expenses.

Disadvantages:

1. Higher initial cost of the system.
2. Imperative to have Knowledge of different engineering fields for design and implementation.
3. It is expenses to incorporate Mechatronics approaches to existing/old systems.
4. Specific problem of various systems will have to be addressed separately and properly.

2a. A Transducer is a device which transforms one form of physical phenomenon or energy to another form for varies purposes including measurement, control and information transfer.

Sensor may be define as an element or device which can respond directly to different physical attributes such as heat, light, force related quantities etc.

Difference between Sensor and Transducers

Basis For Comparison	Sensor	Transducer
Definition	Senses the physical changes occurs in the surrounding and converting it into a readable quantity.	The transducer is a device which, when actuates transforms the energy from one form to another.
Components	Sensor itself	Sensor and signal conditioning
Function	Detects the changes and induces the corresponding electrical signals.	Conversion of one form of energy into another.
Examples	Proximity sensor, Magnetic sensor, Accelerometer sensor, Light sensor, Barometer, Gyroscope etc.	Thermistor, Potentiometer, Thermocouple, etc.

2b.

Light sensors:

Principle of Working and Applications of Light Sensors:

A light sensor is a device that is used to detect light. There are different types of light sensors such as photocell/ photo resistor and photo diodes being used in manufacturing and other industrial applications.

Photo resistor is also called as light dependent resistor (LDR). It has a resistor whose resistance decreases with increasing incident light intensity. It is made of a high resistance semiconductor material, cadmium sulfide (CdS). The resistance of a CdS photo resistor varies inversely to the amount of light incident upon it. Photo resistor follows the principle of photoconductivity which results from the generation of mobile carriers when photons are absorbed by the semiconductor material.

Figure shows the construction of a photo resistor. The CdS resistor coil is mounted on a ceramic substrate. This assembly is encapsulated by a resin material. The sensitive coil electrodes are connected to the control system though lead wires. On incidence of high intensity light on the electrodes, the resistance of resistor coil decreases which will be used further to generate the appropriate signal by the microprocessor via lead wires.

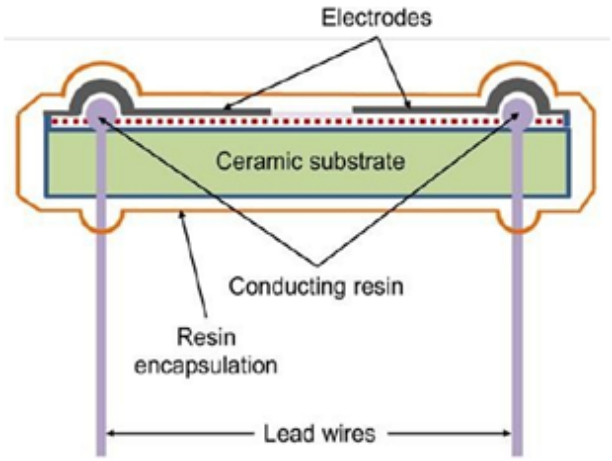
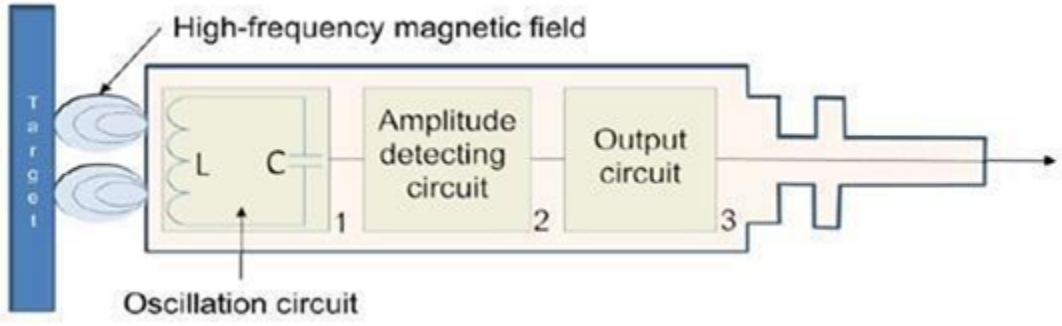


Photo resistors are used in science and in almost any branch of industry for control, safety, amusement, sound reproduction, inspection and measurement.

Eddy current proximity sensors are used to detect non-magnetic but conductive materials. They comprise of a coil, an oscillator, a detector and a triggering circuit. Figure shows the construction of eddy current proximity switch. When an alternating current is passed thru this coil, an alternative magnetic field is generated. If a metal object comes in the close

proximity of the coil, then eddy currents are induced in the object due to the magnetic field. These eddy currents create their own magnetic field which distorts the magnetic field responsible for their generation. As a result, impedance of the coil changes and so the amplitude of alternating current. This can be used to trigger a switch at some pre-determined level of change in current.

Eddy current sensors are relatively inexpensive, available in small in size, highly reliable and have high sensitivity for small displacements.



Hall Effect Sensors:

Hall Effect sensors work on the principle that when a beam of charge particles passes through a magnetic field, forces act on the particles and the current beam is deflected from its straight line path. Thus one side of the disc will become negatively charged and the other side will be of positive charge. This charge separation generates a potential difference which is the measure of distance of magnetic field from the disc carrying current.

The typical application of Hall Effect sensor is the measurement of fluid level in a container. The container comprises of a float with a permanent magnet attached at its top. An electric circuit with a current carrying disc is mounted in the casing. When the fluid level increases, the magnet will come close to the disc and a potential difference generates. This voltage triggers a switch to stop the fluid to come inside the container.

3a.

Microcontroller	Microprocessor
Micro Controller is a heart of the embedded system	The microprocessor is the heart of Computer system
Microcontroller has an external processor along with internal memory and input/output components	It is just a processor. Memory and I/O components have to be connected externally
Since memory and I/O are present internally, the circuit is small.	Since memory and I/O has to be connected externally, the circuit becomes large
The cost of the entire system is low	Cost of the entire system increases
The microcontroller has a number of registers, hence the programs are easier to write	Microprocessor has less number of registers, hence more operations are memory based
Used mainly in the washing machine, MP3 players	Mainly used in personal computers

Different Microcontrollers used in an automobile can communicate with one another through a multiplexing. These microcontrollers can manage related systems separately by using a BUS to communicate with other networks when they are required to perform a function. The combination of several linked networks includes the CAN (controller area networks). Present

controller area networks permit complex interactions, that involve sensory systems, car speed, outdoor rain ffall interactions, in car temperatures with performance controls for air conditioning maintenance, the audio visual multimedia systems and braking mechanisms.

The communication in the automobiles, which is established by different mictrocontrollers has control over both fail safe systems and automotive fault tolerant systems wherein the microcontrollers can not only serve to respond mishaps and faults that occur to the car (anti lock brake interference, accelerator and broken lights), but also to duplicate as secondary units that continuously check the primary microcontroller in the event of microcontroller itself failing. An example of fault tolerance is, when the car tires slip on a snow filled road. The incident not only activated a response from the car driver, but the incident is also sensed by a sensor microcontroller, which will then activate the anti clock braking system when the car driver bangs on the brakes.

Infineon Tri-core Microcontroller

Tri-core is a 32- bit microcontroller, which is developed by Infineon.These microcontrollers are assembled in over 50 automotive brands which means, every second vehicle designed today includes a Tri-core based microcontroller. It is responsible for keeping the exhaust emissions and fuel consumption as low as possible. Tri-core microcontrollers are used in the gear boxes to control the injection, central control units for combustion engines' ignition: Progressively, they are also being used in electrical and hybrid vehicle drives.

3b.

Microcontroller	Microprocessor
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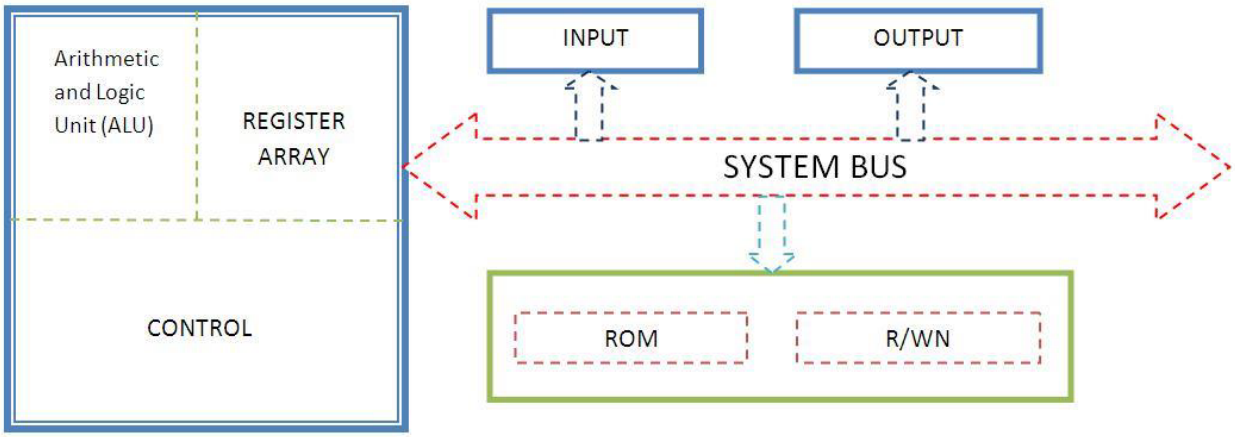
4a.



Microprocessor works or operates in binary digits i.e. 0 and 1, bits. These bits are nothing but electrical voltages in the machine, generally 0 - low voltage level, and 1 - high voltage level. A group of bits form a ‘word’. In general, the word length is about 8 bits. This is called as a ‘byte’. A word with a length of 4 bits is called as a ‘Nibble

Microprocessor processes the 'commands in binary form' to accomplish a task. These are called as '*instructions*'. Instructions are generally entered through input devices and can be stored in a storage device called *memory*.

Figure 2 and 3 show the configuration and basic blocks of a microprocessor.
The functions of each element are as follows.

- ALU: ALU stands for Arithmetical Logical Unit. As name indicates it has two parts:

Arithmetical unit which is responsible for mathematical operations like addition, subtraction, multiplication and division,
Logical unit which is dedicated to take logical decisions like greater than, less than, equal to, not equal to etc. (Basically AND/OR/NOT Operations)

- Register Array: Registers are small storage devices that are available to CPU or processors. They act as temporary storage for processing of intermediate data by mathematical or logical operations.

- Control: This part of CPU is dedicated to coordinate data flow and signal flow through various types of buses i.e. Data Bus, Control Bus, and Address Bus etc. It directs data flow between CPU and storage and I/O devices.

- Memory: There are two different types of memory segments being used by the CPU. First is the ROM which stands for Read Only Memory while other is R/W which stands for Read and Write Memory or Random Access Memory (RAM).

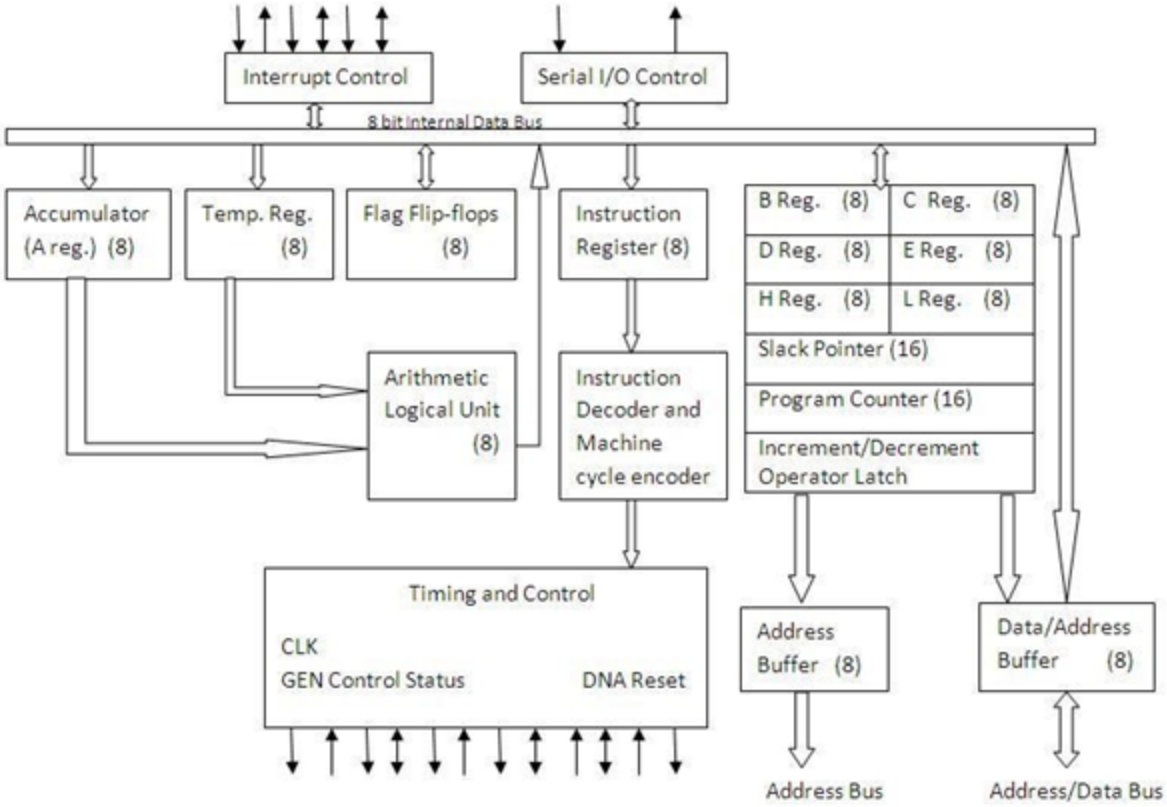
ROM: From this memory unit, CPU can only read the stored data. No writing operations can be done in this part of memory. Thus it is used to store the programs that need no alteration or changes like Monitor Program or Keyboard driver etc.

R/W: As name indicates it is opposite to ROM and used for both reading and writing operations. In general User's program and instruction are stored in this segment of memory unit.

- Input Devices: Input devices are used to enter input data to microprocessor from Keyboard or from ADC which receives data from sensors/signal conditioning systems.

- Output Devices: These devices display the results/conclusions coming out from ALUs either in soft copy (Monitor) or in Hard Copy (Printer).

4b.



1. Internal Architecture of 8085 Microprocessor

Register Array

8085 Microprocessor consists of six registers, one accumulator and a flag register. The typical architecture is shown in figure 6. There are six general-purpose registers B, C, D, E, H, and L, each having capacity to store 8 bit data. They are combined as BC, DE, HL to perform 16 bit operations. In addition to this Register array, two 16 bit registers viz. stack register and program counter are provided. As discussed in the earlier lecture, the 'program counter' is employed to sequence the execution of instructions. It always points to the memory address from which the next byte is to be fetched. Stack Pointer points to the memory location in R/W (Read and/or write) memory. It is also termed as a 'stack'.

Accumulator

The accumulator is 8-bit register (can store 8 bit data). It is a part of arithmetic/logic unit (ALU). In general, after performing logical or arithmetical operations, result is stored in accumulator. Accumulator is also identified as Register A.

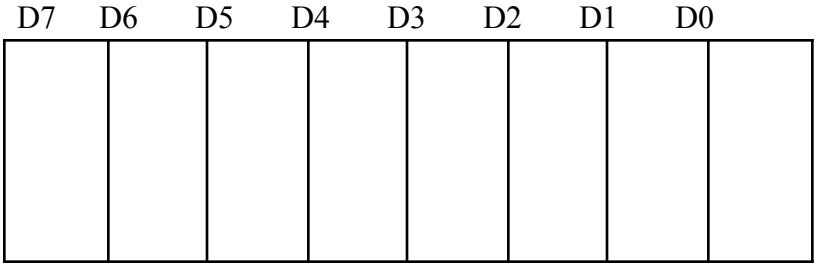
Flags

ALU of 8085 have five flip flops whose states (set/reset) are determined by the result data of other registers and accumulator. They are called as Zero, Carry, Sign, Parity and Auxiliary-Carry flags.

A Zero Flag (Z): When an arithmetic operation results in *zero*, the flip-flop called the Zero flag - which is set to one.

B Carry flag (CY): After an addition of two numbers, if the sum in the accumulator is larger than eight bits, then the flip-flop uses to indicate a *carry* called the Carry flag – which is set to one.

C S-Sign (S): It is set to 1, if bit D7 of the result = 1; otherwise reset. D7 is the first digit of a binary number.



A P-Parity (P): If the result has an even number of 1s, the flag is set to 1; for an odd number of 1s the flag is reset.

B AC-Auxiliary Carry (AC): In an arithmetic operation, when a carry is generated by digit D3 and passed to digit D4, the AC flag is set. Generally this flag is used internally for Binary Coded Decimals (BCD).

Figure 3.2.2 shows a 8-bit flag register, adjacent to the accumulator. It is not used as a register. Out of eight bit-positions, five positions are used to store the outputs of five flip- flops. These flags play an important role in decision-making process of the microprocessor.

Instruction Register/Decoder

Before execution of an instruction, it is sent to the Instruction Register. Instruction register stores current instruction of any program. Decoder takes the instruction from memory, decodes it and then passes it to the next stage.

Memory Address Register

Memory Address Register (MAR) holds the address of next instruction to be executed.

Control Generator

In microprocessor, the Control Generator generates a signal that executes the operations in accordance to the decoded instructions. In fact it creates a signal (information) which have details about connections between different blocks of the microprocessor so that data reaches to the respective place.

Register Selector

Register selector is basically a logical controller which directs switching between different registers of microprocessor.

General Purpose Registers

Microprocessor has few extra registers which can be used to store additional data during a program.

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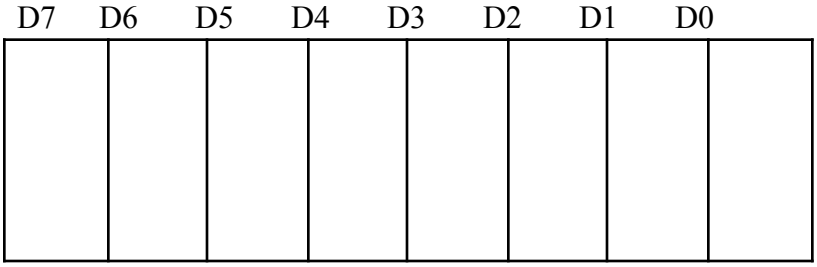

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D7 D6 D5 D4 D3 D2 D1 D0

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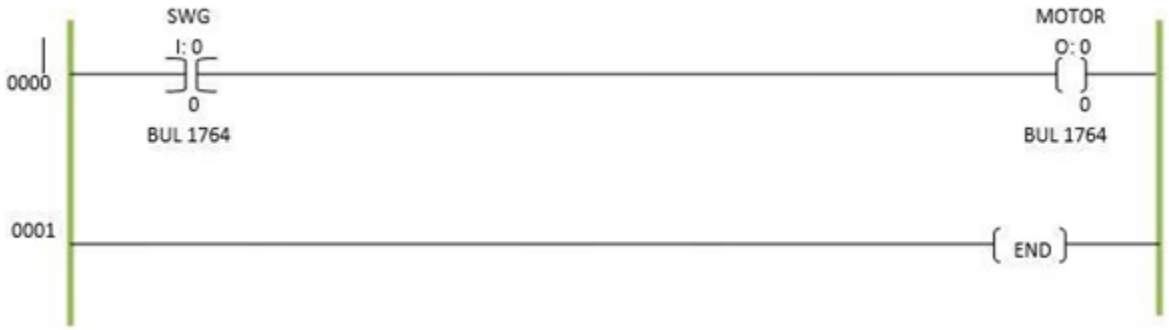
5a. the basic elements of a PLC. It is basically a microprocessor based control system. Microprocessor communicates with the outside world with input/output derives via a circuitry. This circuitry protects the microprocessor and other elements of PLC from the high voltages and currents coming to the PLC. Microprocessor does its basic functions of taking decisions according to the instructions written in the programs which are stored in the memory. PLC scans a set of sensor inputs rapidly and repeatedly. Then it evaluates their logic relationships to defined outputs according to a logic program. At last it sets the outputs according to the programmed logic. Figure 3.2.2 shows an industrial PLC with input and output ports.

Principle of operation

PLCs are programmed through concept of ladder logic. In general there exists a graphical user interface (GUI) to program a PLC that makes it different from other processers. Ladder logic comprises of two columns. Left column shows input devices like switches, sensors while in output column is at right side which shows actuators like cylinders, motors.

5b.



PLCs are controlled through Ladder Logic. In input section of the ladder, name of the input device must be mentioned on the top of symbol, followed by primary input port. Secondary input port is mentioned just below symbol. In similar way, output symbol should be mentioned with name and output ports as shown.

In industrial applications, it is required to use various sensors to control the operations of systems and processes using PLCs. Figure 3.3.7 shows a typical

program to operate an electric motor and a pneumatic cylinder with the help of some sensors such pneumatic proximity switch.

To control a mechatronics system we need to combine various mechanical and electrical input and output devices and to operate them in a sequential manner. Consider a prototype of industrial assembly line with 3 stations.

6a. (a) Polar configuration

It consists of a sliding arm L-joint, actuated relative to the body, which rotates around both a vertical axis (T-joint), and horizontal axis (R-joint).

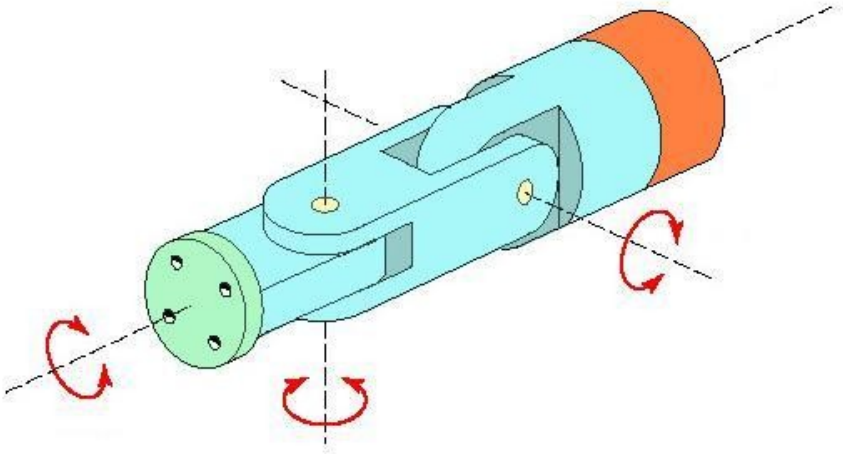
- Cylindrical configuration

It consists of a vertical column. An arm assembly is moved up or down relative to the vertical column. The arm can be moved in and out relative to the axis of the column. Common configuration is to use a T-joint to rotate the column about its axis. An L-joint is used to move the arm assembly vertically along the column, while an O-joint is used to achieve radial movement of the arm.

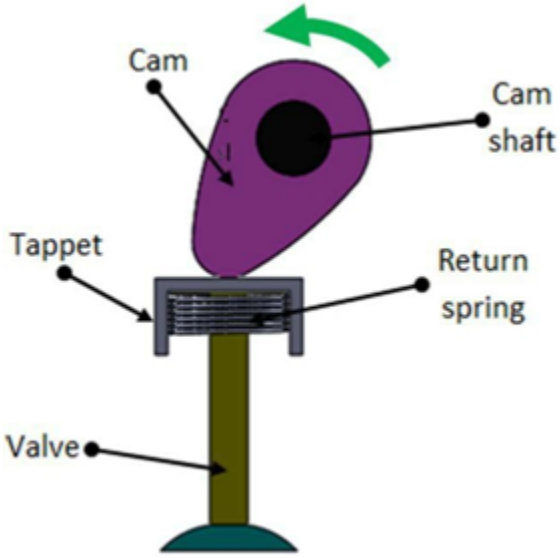
- Cartesian co-ordinate robot

It is also known as rectilinear robot and x-y-z robot. It consists of three sliding joints, two of which are orthogonal O-joints.

Robot wrist assemblies consist of either two or three degrees-of-freedom. A typical three-degree-of-freedom wrist joint is depicted in Figure 3.5.4. The roll joint is accomplished by use of a T-joint. The pitch joint is achieved by recourse to an R- joint. And the yaw joint, a right-and-left motion, is gained by deploying a second R- joint. The SCARA body-and-arm configuration typically does not use a separate wrist assembly. Its usual operative environment is for insertion-type assembly operations where wrist joints are unnecessary. The other four body-and-arm configurations more-or-less follow the wrist-joint configuration by deploying various combinations of rotary joints viz. type R and T.



7b.



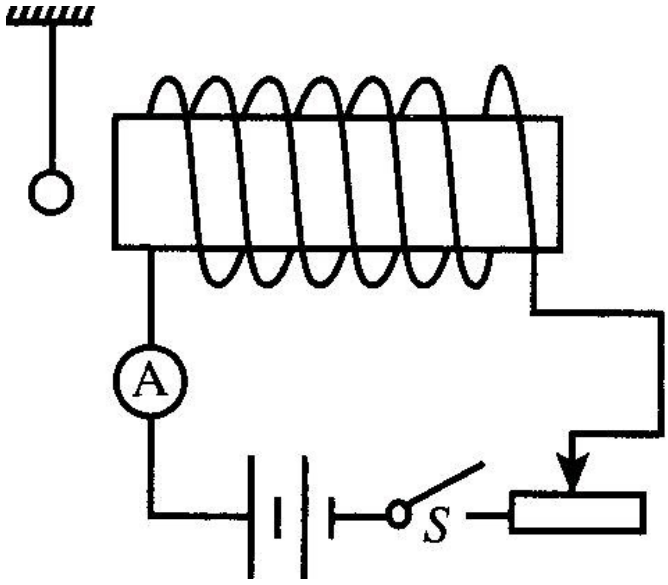
Cam in I.C engine

The cam shaft is driven by a motor. The cutting tool mounted on the transverse slide travels to desired depth and at desired feed rate by a set of plate cams mounted on the cam shaft. The bar feeding through headstock at desired feed rate is carried out by a set of plate cams mounted on the camshaft.

7c. A DC motor is a device that converts direct current (electrical energy) into rotation of an element (mechanical energy). These motors can further be classified into brushed DC motor and brushless DC motors.

Criteria:
Driving cycles
configuration (electric, hybrid)
Maximal speed
Maximal torque
Maximal power

8a.



Solenoids are basically coils of wire. These generate a magnetic field which strives a force over a metallic element. This happens when we apply the electric current to the solenoid.e. It is in the shape of a corkscrew and wraps around a piston. On the other hand, it is made up of iron. Likely in all the electromagnets. When an electric current passes through the wire, a magnetic field generates.

More importantly, electromagnets are better as compared to the permanent magnets because they can be switched on and off by the removal of the electric current or by the application.

This makes them more useful like switches and valves and also allows them automated entirely. Likewise, all other magnets and activated solenoid's magnetic field has both positive and negative poles that result in attracting or repelling material sensitive to magnets.

8b. A DC servo motor is an assembly of four major components, DC motor

- Position sensing device

- Gear assembly
- Control circuit

In digital control, micro controller used for generating the PWM pluses in terms of duty cycles to produce more accurate control signals.The position sensor provide a feedback signal corresponding to the present position of the load. This sensor is normally a potentiometer that produces the voltage corresponding to the absolute angle of the motor shaft through gear mechanism. Then the feedback voltage value applies on the input of error amplifier.

The error amplifier is a negative feedback amplifier and it reduces the difference between its inputs. It compares the voltage related to current position of the motor with desired voltage related to desired position of the motor. And it produces the error either a positive or negative voltage.

This error voltage applied to the armature of the motor. If the error is more then motor armature gets more output.

The amplifier amplifies the error voltage and powers the armature. The motor rotates till the error becomes zero. If the error is negative, the armature voltage reverses and hence the armature rotates in the opposite direction.

9a.

The pressure reducing valve (PRV)

17.1 Introduction

The pressure reducing valve may be used for water hammer protection under properly defined conditions. The water hammer events are so fast that the relief of pressure by this means requires very special rapid response valves designed for the particular system.

Pressure relief valves may also be used as an added precaution where some other method is in place as the basic protection device, such as an air vessel.

There are also by-pass valves which are required to operate when a pump stops due to a power failure or normal trip, anticipating the eventual return flow, and then being required to be closed to prevent the excessive waste of the return flow.

Spring-Loaded Pressure-Reducing Valves

The spring-loaded pressure-reducing valve (Figure 7-15) is commonly used in pneumatic systems. It is often referred to as a pressure regulator. The valve simply uses spring pressure against a diaphragm to open the valve. On the bottom of the diaphragm, the outlet pressure of the valve forces the diaphragm upward to shut the valve. When the outlet pressure drops below the set point of the valve, the spring pressure overcomes the outlet pressure and forces the valve stem downward, opening the valve. As the outlet pressure increases, approaching the desired pressure, the pressure under the diaphragm begins to overcome spring pressure, forcing the valve stem upward and closing the valve. You can adjust the downstream pressure by turning the adjusting screw, which varies the spring pressure against the diaphragm. This particular spring-loaded valve will fail in the open position if a diaphragm rupture occurs.

9b. In a rotary actuator the force is applied a distance away from the axis of rotation, causing a turning movement. There are two basic constructions of a rotary actuator; rotary vane actuators, and rack and pinion actuators, which operate as follows:

In a rotary vane actuator, compressed air pushes against a vane, which is attached to a central spindle. This acts to turn the spindle, with the air 'behind' the vane released through a port. When the vane reaches a stop at the specified angle of rotation, the air flow is reversed and the spindle rotates back to its original position for the process to repeat. Rotary vane actuators are more limited in rotation and in torque than the rack and pinion version, and are therefore more commonly used for lighter loads.

A rack and pinion actuator offers greater torque range and range of rotation than its rotary vane counterpart, and are generally bigger and longer lasting. In a rack and pinion actuator, the rack is machined as part of the piston rod of a double acting linear cylinder. A pinion gear meshes with the rack and turns a spindle as the piston moves due to an applied pressure. The spindle sits at right angles to the piston and rotates clockwise, then anti-clockwise as the linear cylinder completes its double action. Rack and pinion rotary actuators are useful for applications requiring more speed and less wear.

10a. The solenoid valve is industrial equipment controlled by electromagnetism. It is an automatic basic element to control the fluid. It belongs to the actuator, but not limits to the

hydraulic pressure and pneumatic control. In the industrial control system, the solenoid valve is used to regulate the direction, flow rate, speed and other parameters of the medium. The solenoid valve can coordinate with different circuits to realize the anticipated control, with both control precision and flexibility being guaranteed.

The solenoid valve has an enclosed chamber inside and ventilated holes in different positions. Every hole is connected with different oil pipes. The chamber has a piston in the middle. The two sides are two pieces of electromagnets. The electrifying magnetic coil will attract the valve body to its side, so that different oil outlets will be opened or closed through controlling the movement of the valve body. However, the oil inlet is constantly open. The hydraulic oil will enter into different draw-off pipes. The oil pressure will be used to drive the piston of the oil cylinder, which will drive the piston rod and then the mechanical device. In this way, through controlling the current of the solenoid valve, the mechanical movement will be controlled. Furthermore, let's briefly learn about the working principle of two main types of solenoid valve.

Direct-acting solenoid valve

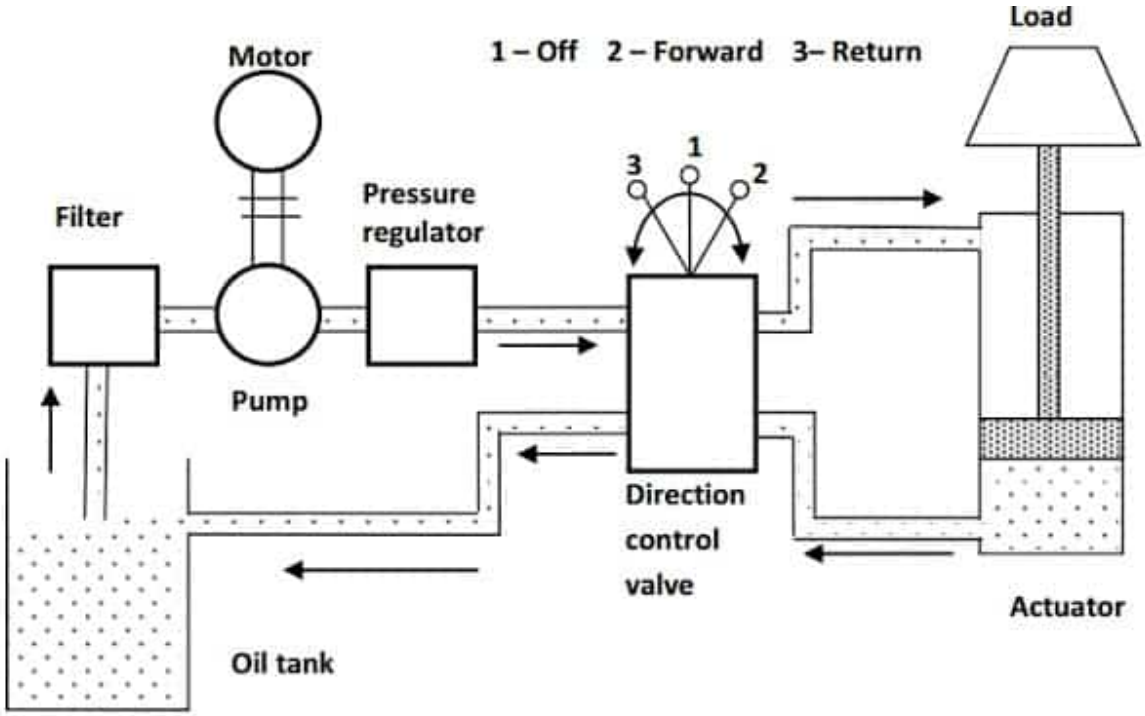
- Working principle
  When the power is on, the solenoid coil generates the electromagnetic force to lift the closure member from the valve seat to open the valve. When the power is cut off, the electromagnetic force disappears and the spring presses the closure member on the valve seat to close the valve.
- Characteristics
  It can work normally in the vacuum, negative pressure and zero pressure. However, the diameter normally doesn’t exceed 25mm.

2. Pilot-operated solenoid valve

- Working principle
  When the power is on, the electromagnetic force opens the pilot hole and the pressure of the upper chamber decreases rapidly, forming a pressure difference which is low in the upside and high in the bottom around the closure element. The fluid pressure promotes the closure element to move upwards to open the valve. When the power is off, the spring force closes the pilot hole. The pressure through the bypass port rapidly forms a pressure difference which is high in the upside and low in the bottom around the closure element. The fluid pressure drives the closure element to move downwards and close the valve.

Hydraulic systems are power-transmitting assemblies employing pressurized liquid as a fluid for transmitting energy from an energy-generating source to an energy-using point to accomplish useful work. The figure shows a simple circuit of a hydraulic system with basic components. Hydraulic systems are used for transmission of power through the medium of hydraulic oil. The hydraulic system works on the principle of Pascal's law which says that " the pressure in a fluid at rest is transmitted uniformly in all directions".

The fluid medium used is hydraulic oil, which may be mineral oil or water or combinations. This area is also known as oil hydraulics.



Components of a hydraulic system

The working of a power pack commences when the pump is initialized with the help of an electric motor coupled to it. The oil is pumped from the reservoir along the suction line through a suction strainer with a capability to retain the foreign particles up to 149 microns.

From the suction line the oil is forced into the pressure line through the pump at 35 bars. There is provision to measure the pressure, with the help of a pressure gauge. An isolator is used to measure the pressure immediately in any line.

When the set of pressure is reached, the fluid moves to the cylinder present at the fixture (clamp). The hydraulic energy of the fluid is converted back to the mechanical energy by the cylinder.

According to the direction of the energizing of the solenoid valve, the linear movement of the clamps (clamping and unclamping) is controlled. When the solenoid valve is energized in

reverse, the unclamping of the workpiece occurs. There is a return line provided so that the used fluid may be utilized again. Due to the friction losses, the total energy is not converted into useful work so a part is converted into the heat. So, a heat exchanger is incorporated. The return line filter has a return capacity of 10 microns.