2015 BATCH MECHATRONIC SYSTEMS

KARPAGAM ACADEMY OF HIGHER EDUCATION

(Deemed to be University)
(Established Under Section 3 of UGC Act 1956)
Pollachi Main Road, Eachanari (Po),
COIMBATORE – 21

FACULTY OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

SUBJECT NAME: MECHATRONIC SYSTEMS **SUBJECT CODE : 15BEME703** **L T P C** **3 20 4**

INTENDED OUTCOMES:

To impart knowledge about the elements and techniques involved in Mechatronics systems which are very much essential to understand the emerging field of automation.

UNIT I MECHATRONICS SENSORS AND TRANSDUCERS 9
Introduction to Mechatronics – Systems – Measurement Systems – Control Systems –Traditional design – Microprocessor based Controllers. Introduction to sensors – Performance Terminology – Static and Dynamic characteristics – Displacement – Position and Proximity – Velocity and Motion – Fluid Pressure – Temperature Sensors – Light Sensors – Selection of Sensors – Signal processing – Servo systems.

UNIT II ACTUATORS AND SYSTEM MODELS 9
Pneumatic and Hydraulic Systems – Directional Control Valves – Rotary Actuators. Mechanical Actuation Systems – Cams – Gear Trains – Ratchet and pawl – Belt and Chain Drives – Bearings. Electrical Actuation Systems – Mechanical Switches – Solid State Switches – Solenoids – D.C Motors – A.C Motors – Stepper Motors. Introduction to system models– Building block of Mechanical, Electrical, Fluid and Thermal Systems.

UNIT III MICROPROCESSORS IN MECHATRONICS 9
Introduction – Architecture – pin configuration Instruction set – Programming of Microprocessors using 8085 instructions – Interfacing. Input and output devices – interfacing D/A converters and A/D converters – Application – Temperature control – Stepper motor control.

UNIT IV CONTROLLERS 9
Introduction –Continuous and discrete process Controllers – Control Mode – Two – Step mode – Proportional Mode –Derivative Mode – Integral Mode – PID Controllers –Digital Controllers – Adaptive Control – Digital Logic Control – Micro Processors Control. Introduction to PLC – Basic Structure – Input / Output Processing – Programming – Mnemonics – Timers, Internal relays and counters – Data Handling – Analog Input / Output – Selection of a PLC.

UNIT V DESIGN OF MECHATRONIC SYSTEMS 9
Stages in designing Mechatronics Systems – Traditional and Mechatronic Design – Possible Design Solutions – Case Studies of Mechatronics Systems, Pick and place robot – automatic Car Park Systems – Engine Management Systems – Introduction to MEMS.

TOTAL 45 PERIODS

TEXT BOOKS

S. No.	Author(s) Name	Title of the book	Publisher	Year of Publication
1	Bolton W	Mechatronics	Pearson Education, Delhi	2008

15BEME 703 – MECHATRONICS SYSTEM
FOE/KAHE
REFERENCES

S. No.	Author(s) Name	Title of the book	Publisher	Year of Publication
1	Michael B. Histand David G. Alciatore	Introduction to Mechatronics and Measurement Systems	McGraw–Hill International Editions, New York	2012
2	Bradley D, Buru N.C and Loader A.J	Mechatronics	Chapman and Hall, Pearson Education Asia, New Delhi	2000
3	Ghosh P.K and Sridhar P.R	Introduction to Microprocessors for Engineers and Scientist	Prentice Hall of India, New Delhi	2009

WEB REFERENCE
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LESSON PLAN / 2015 BATCH

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DEPARTMENT OF MECHANICAL ENGINEERING

LESSON PLAN

Subject Name : MECHATRONICS SYSTEM Subject Code : 15BEME703

Sl. No.	Lecture Duration (Hr)	Topics to be Covered	Support Materials
UNIT I MECHATRONICS SENSORS AND TRANSDUCERS			
1.	1	Introduction to Mechatronics – Systems	T_1
2.	1	Measurement Systems – Control Systems	T_1
3.	1	Traditional design – Microprocessor based Controllers.	T_1
4.	1	Introduction to sensors – Performance Terminology	T_1
5.	1	Static and Dynamic characteristics.	T_1
6.	1	Displacement – Position and Proximity	T_1
7.	1	Velocity and Motion – Fluid Pressure	T_1
8.	1	Temperature Sensors	T_1
9.	1	Light Sensors	T_1
10.	1	Selection of Sensors	T_1
11.	1	Signal processing	T_1
12.	1	Servo system	T_1
Total no. of Hours planned for unit - I			**12**
Sl. No.	**Lecture Duration (Hr)**	**UNIT- II ACTUATORS AND SYSTEM MODELS**	**Support Materials**
13.	1	Pneumatic and Hydraulic Systems	T_1
14.	1	Directional Control Valves – Rotary Actuators. Mechanical Actuation Systems	T_1

15.	1	Cams – Gear Trains – Ratchet and pawl	T_1
16.	1	Belt and Chain Drives – Bearings.	T_1
17.	1	Electrical Actuation Systems – Mechanical Switches	T_1
18.	1	Solid State Switches – Solenoids	T_1
19.	1	D.C Motors – A.C Motors	T_1
20.	1	Stepper Motors.	T_1
21.	1	Introduction to system models– Building block of Mechanical	T_1
22.	1	Electrical, Fluid Systems	T_1
23.	1	Thermal Systems	T_1
Total no. of Hours planned for unit – II			**11 hrs**
Sl. No.	**Lecture Duration (Hr)**	**UNIT III MICROPROCESSORS IN MECHATRONICS**	**Support Materials**
24.	1	Introduction – Architecture	T_1
25.	1	pin configuration Instruction set	T_1
26.	1	Programming of Microprocessors using 8085 instructions	T_1
27.	1	Interfacing.	T_1
28.	1	Input and output devices	T_1
29.	1	interfacing	T_1
30.	1	D/A converters	T_1
31.	1	A/D converters	T_1
32.	1	Application	T_1
33.	1	Temperature control – Stepper motor control	T_1
Total no. of Hours planned for unit – III			**11hrs**
Sl. No.	**Lecture Duration (Hr)**	**UNIT IV CONTROLLERS**	**Total no. of Hours planned for unit – II**
34.	1	Introduction –Continuous and discrete process Controllers	T_1
35.	1	Control Mode – Two – Step mode	T_1
36.	1	Proportional Mode –Derivative Mode	T_1

37.	1	Integral Mode – PID Controllers	T_1
38.	1	Digital Controllers – Adaptive Control	T_1
39.	1	Digital Logic Control	T_1
40.	1	Micro Processors Control.	T_1
41.	1	Introduction to PLC – Basic Structure	T_1
42.	1	Input / Output Processing – Programming	T_1
43.	1	Mnemonics – Timers,	T_1
44.		Internal relays and counters	T_1
45.		Data Handling – Analog Input / Output – Selection of a PLC	T_1
TOTAL NO. OF HOURS PLANNED FOR UNIT – IV			**10 hrs**
Sl. No.	**Lecture Duration (Hr)**	**UNIT V DESIGN OF MECHATRONIC SYSTEMS**	**Support Materials**
46.	1	Stages in designing Mechatronics Systems –	T_1
47.	1	Traditional and Mechatronic	T_1
48.	1	Design – Possible Design Solutions	T_1
49.	1	Case Studies of Mechatronics Systems,	T_1
50.	1	Pick and place robot – automatic Car Park Systems	T_1
51.	1	Engine Management Systems	T_1
52.	1	Introduction to MEMS and previous year university question discussion	T_1,QB

TEXT BOOKS

S. No.	Author(s) Name	Title of the book	Publisher	Year of Publication
1	Bolton W	Mechatronics	Pearson Education, Delhi	2008

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MECHATRONICS

Unit – I

INTRODUCTION TO MECHATRONICS:

ϖ Consider the modern auto-focus, auto-exposure camera. To use the camera all you need to do is point it at the subject and press the button to take the picture. The camera automatically adjusts the focus so that the subject is in focus and automatically adjusts the aperture and shutter speed so that the correct exposure is given.

ϖ Consider a truck smart suspension. Such suspension adjusts to uneven loading to maintain a level platform, adjusts to cornering, moving across rough ground. etc. to maintain smooth ride.

ϖ Consider an automated production line. Such a line may involve a number of production processes which are all automatically carried out in the correct sequence and in the correct way.

ϖ The automatic camera, the truck suspension and the automatic production line are examples of a marriage between electronic control systems and mechanical engineering. Such control systems
generally use microprocessors as controllers arid have electrical sensors extracting information from the mechanical inputs and outputs via electrical actuators to mechanical systems.

ϖ The term mechatronics is used for this integration of microprocessor control systems, electrical systems and mechanical system. A mechatronics system is not just a marriage of electrical and mechanical systems and is more than just a control system; it is a complete integration of all of them.

ϖ In the design now of cars, robots, machine tools, washing machines, cameras, and very many other machines, such an integrated and interdisciplinary approach to engineering design is increasingly being adopted Mechatronics has to involve a developing, say, a mechanical system then designing the electrical part and the microprocessor part.

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Definition:

"Mechatronics is the synergetic integration of mechanical engineering with electronics and intelligent computer control in the design and manufacturing of industrial products and processes".

SYSTEMS:

Mechatronics involves what are termed as *systems*. A system can be thought of as a box which has an input, and an output and where we are not concerned with what goes on inside the box but only the relationship between the output and the input. Thus for example, a motor may be thought of as a system which has as input electric power and as output the rotation of a shaft.

Example: A Motor.

A motor has input as electric power as input and rotation as output. The following figure shows the representation.

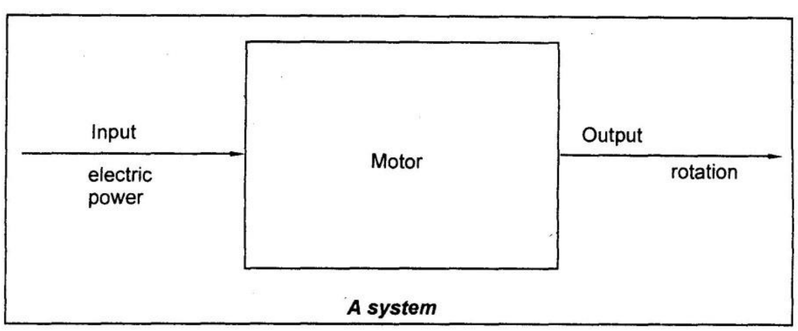


Fig:

System

Basically in mechatronics we divide the systems in to 2 types

1. Measurement System.
2. Control System.

Now we will discuss in detail about these 2 systems.

MEASUREMENT SYSTEM:

A Measurement system can be defined as a black box which is used for making measurements. It has an input the quantity being measured and its output the value of that quantity.

Example: A temperature measurement system. i.e. Thermometer

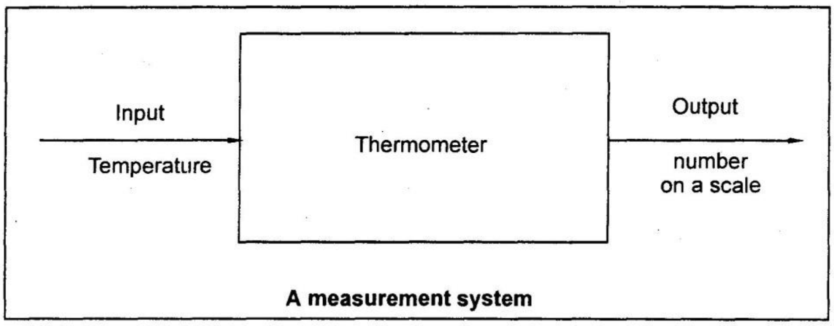
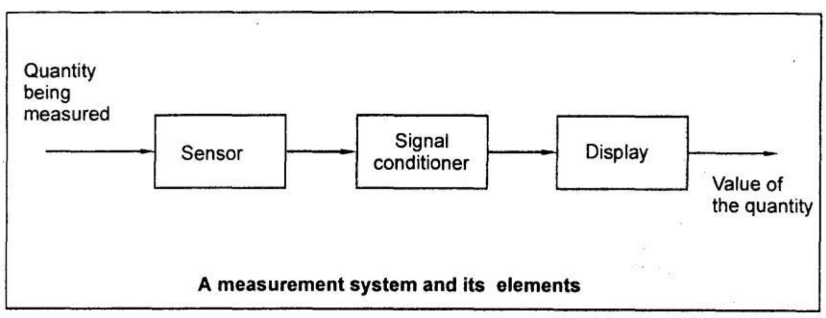


Fig: Measurement system

Elements of Measurement system

Measurement System can be considered to be made up of three elements as shown in figure.



1. A sensor which responds to the quantity being measured by giving as its output a signal which is related to the quantity.

Ex.

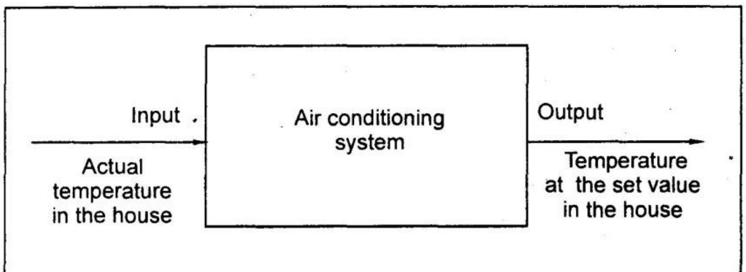
a thermocouple is a temperature sensor.

2. A signal conditioner takes the signal from the sensor and manipulates it into a condition which is suitable for either display or in the case of a control system, for use to exercise control. Thus for example the output from a thermocouple is a rather small e.m.f and might be fed through an amplifier to obtain a bigger signal. The amplifier is the

CONTROL SYSTEM:

A control system can be defined as a block box which can be used to control its output to some particular value. Example: a domestic central heating control system.

We can set the required temperature on the thermostat or controller and the pump can be adjusted to supply water through radiators. So the required temperature can be maintained in the house.



A Control system

In a system when the output quantity is controlled by varying the input quantity then the system is called as Control system.

The output quantity is called as controlled variable or response and the input quantity is called as command signal or excitation.

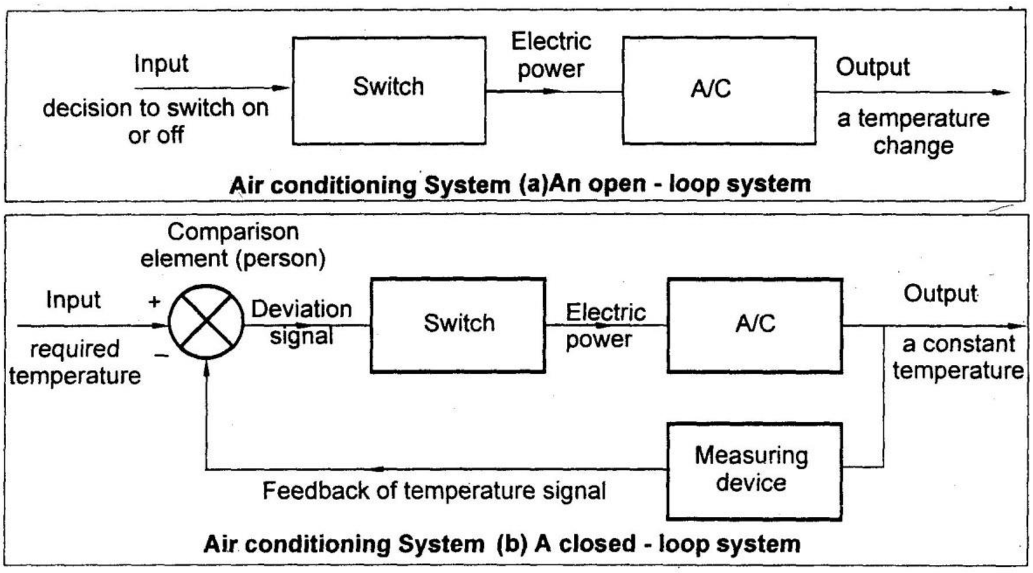
In Control system, we have two types

1. Open loop control system.
2. Closed loop system.

OPEN AND CLOSED-LOOP SYSTEMS:

There are two basic forms of control system one being called and Open loop and other closed-loop systems. The difference between these can be illustrated by a simple example.

Consider an electric fire which has a selection switch which allows a 1 KW or a 2 kW heating element to be selected. If a person used the
heating element to heat a room, he or she might just switch on the 1 kW element if the room is not required to be at too high a temperature.



The heating system with the heating element could be made a ***closed loop*** **system** if the person has a thermometer and switches the 1 kW and 2 kW elements on or off, according to the difference between the actual temperature and the required temperature, to maintain the temperature of the room constant.

Illustration of a motor:

To illustrate further the differences between open and closed-loop systems, consider a motor.

With an ***open-loop system*** the speed of rotation of the shaft might be determined solely by the initial setting of a knob which affects the voltage applied to the motor.

Any changes in the supply voltage, the characteristics of the motor as a result of temperature changes, or the shaft load will change the shaft speed but not be compensated for.

There is no feedback loop. With a ***closed-loop system***, however, the initial setting of the control knob will be for a particular shaft speed and this will be maintained by feedback, regardless of any changes in supply voltage, motor characteristics or load.

In an open-loop control system the output from the system has no effect on the input signal. In a closed-loop control system the output does have an effect on the input signal, modifying it to maintain an output signal at the required value.

OPEN-LOOP SYSTEMS have **the advantage** of being

ϖ Relatively simple and

ϖ Consequently low cost with generally good reliability.

However, there are **disadvantages** like,

ϖ Inaccurate since there is no correction for error.

CLOSED-LOOP SYSTEMS have the **advantage** of being

ϖ Relatively accurate in matching the actual to the required values.

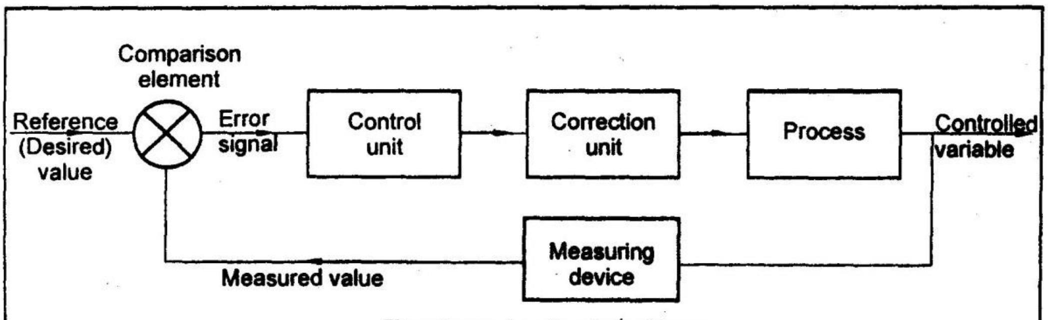
However, there are **disadvantages** like,

ϖ More complex

ϖ Somore costly and

ϖ A greater chance of breakdown as a consequence of the greater number of components.

BASIC ELEMENTS OF A CLOSED-LOOP SYSTEM:



The elements of a closed loop control system

Generally the closed loop system consists of the following elements

1. Comparison element.
2. Control element.
3. Correction element.
4. Processdement
5. 5. Measurement element.

Comparison element

- This compares the required or reference value of the variable condition being controlled with the measured value of what is
- being achieved and produces an error signal.

 It can be regarded as adding the reference signal, which is positive, to the measured value signal, which is negative in this case:

- Error signal = reference value signal - measured value signal.

- The symbol used, in, general, for an element at which signals are summed is a segmented circle, inputs going into segments.
- The inputs are all added; hence the feedback input is marked as negative and the reference signal positive so that the sum gives the difference between the signals.

Control element

- This decides what action to take when it receives an error signal.

- It may be for example, a signal to operate a switch or open a valve.

- The control plan being used by the element may be just to supply a signal which switches on or off when here is an error, as in a room thermostat or perhaps a signal which proportionally opens or closes a valve according to the size of the error.

Correction element

- The correction element produces a change in the process to correct or change the controlled condition.
- Thus it might be a switch which switches on a heater and so increases the temperature of the process or a valve which opens and allows more liquid to enter the process.

- The term actuator is used for the element of a correction unit that provides the power to carry out the control action.

Process element

The process is what is being controlled. It could be a room in a house with its temperature being controlled or a tank of water with its level being controlled.

Measurement element

ϖ The measurement element produces a signal related to the variable condition of the process that is being controlled.

ϖ For example, a switch which is switched on when a particular position is reached or a thermocouple which gives an e.m.f related to the temperature.

FOR TEMPERATURE CONTROLLEDCLOSEDLOOP SYSTEM

With the closed-loop system illustrated in Fig. above, for a person controlling the temperature of a room, the various elements are:

Controlled variable	- the room temperature
Reference value	- the required room temperature
Comparison element	- the person comparing the measured value with the required value of temperature
Error signal	- the difference between the measured and required temperatures.
Control unit	- the person
Correction unit	- the switch on the fire
Process	- the heating by the fire
Measuring device	- a thermometer

AUTOMATICWATER LEVELCONTROLLER:

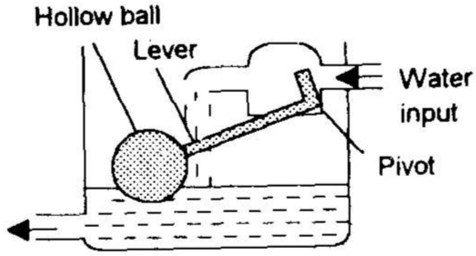


Fig. The automatic control of water level

An automatic control system for the control of the room temperature could involve a temperature sensor, after Suitable signal conditioning, feeding an electrical signal to the input of a computer where it is compared with the set value and an error signal generated. This is then acted on by the computer to give at its output a signal, which, after suitable signal conditioning, might be used to control a heater and hence the room temperature. Such a system can readily be programmed to give different temperatures al different times of the day.

The above figure shows an example of a simple control system used to maintain a constant water level in a tank. The reference value is the initial setting of the lever arm arrangement so that it just cuts off the water supply at the required level. When water is drawn from the tank the float moves downwards with the water level. This causes the lever arrangement to rotate and so allows water to enter the tank. This flow continues until the ball has risen to such a height that it has moved the lever arrangement to cut off the water supply. It is closed loop control system with the elements being:

Controlled variable	- the water level in the tank
Reference value	- initial setting of the float and lever position
Comparison clement	- the lever
Error signal	- the difference between the actual and initial settings of the lever positions
Control unit	- the pivoted lever
Correction unit	- the flap opening or closing the water supply
Process	- the water level in the tank
Measuring device	- the floating ball and lever

SEQUENTIAL CONTROLLERS:

When a controller operates in a sequence way i.e. Step by step, then that type of controllers is called as sequence controllers.

In sequential controllers, step 2 is started only after completing step 1 and after completing step 2 step 3 will be started. In sequential controllers, the control .actions are ordered in time, which is obtained by an electrical circuit with sets, of relays or cam operated switches which are wired up in such a way as to give the required sequence.
Now-a-days hardwired circuits and relays are replaced by a microprocessor controlled system, the sequencing are controlled by software program

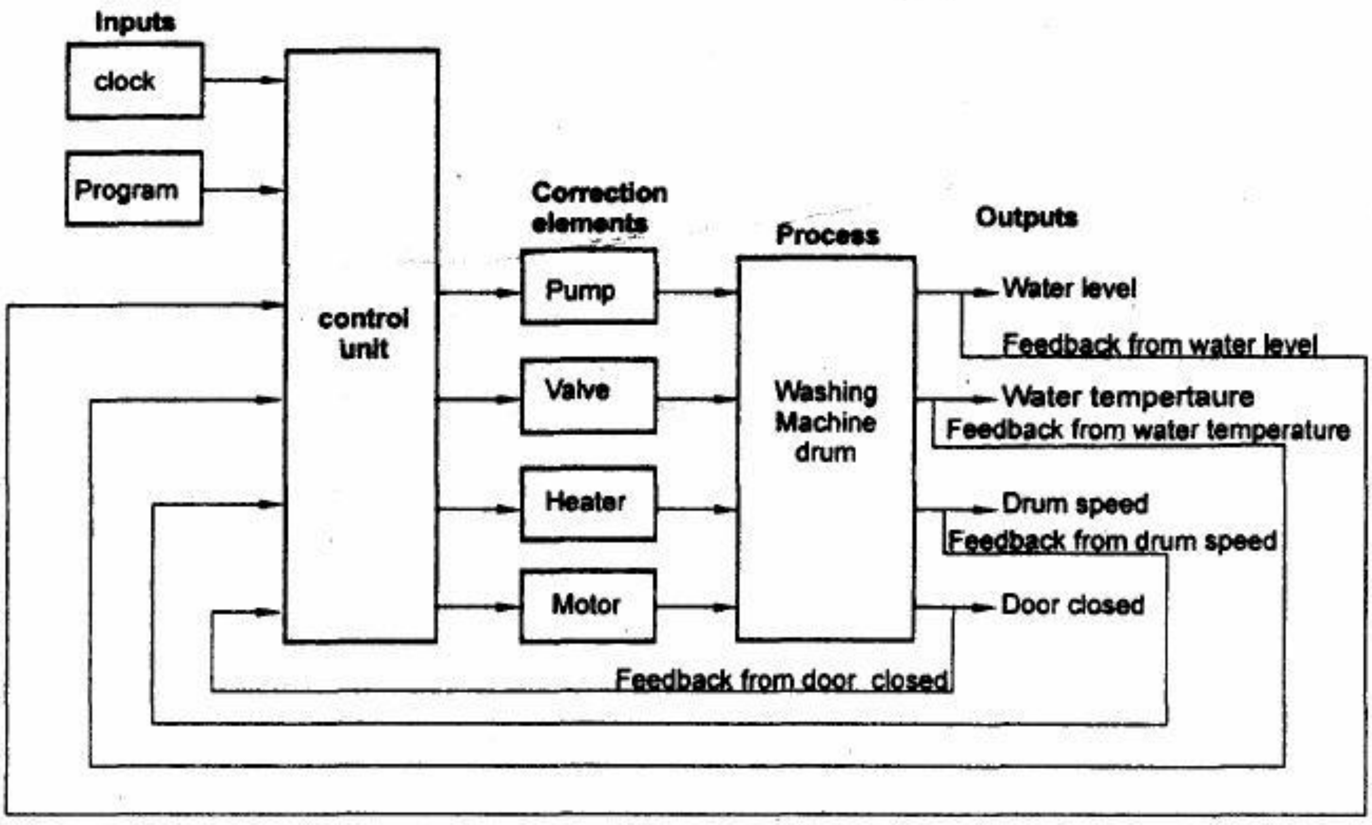
Example: Washing machine.

Consider a washing machine; the numbers of sequential operations carried out are,

1. Pre wash cycle -the clothes in the drum are washed with cold water.

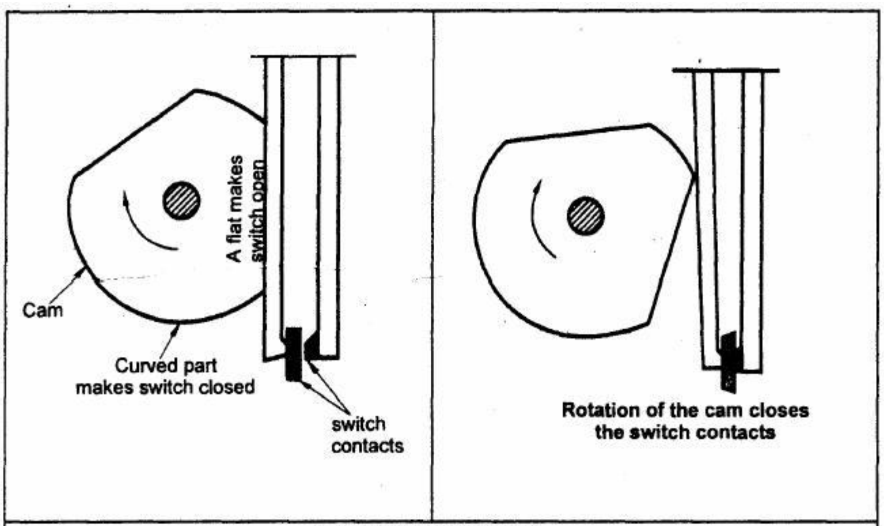
2. Main wash cycle - the clothes are washed with hot water.
3. Rinse cycle - the washed clothes are rinsed with cold water number of times.

4. Spinning - the rinsed clothes are spinned to remove water.



Feedback from outputs of water level, water temperature, drum speed and door closed

The above figure shows the basic washing machine system and gives a rough idea of its constituent elements.



Cam- operated switch

The system that is used for the washing machine controller was a mechanical system which involved a set of cam-operated switches, i.e mechanical switches. Figure below show the basic principle of one such switch.

When the machine is switched on, a signal electric motor slowly rotates its shaft, giving an amount of rotation proportional no tune. The rotation turns the controller cams so that each in turn operates electrical switches and so switches on circuits in the correct sequence. The contour of a cam determines the time at which it operates a switch.

The contours of the cams and the means by which the program is specified and stored in the machine. The sequence of instructions and the instructions used in a particular washing program are determined by the set of cams chosen.

With modern washing machines the controller is a microprocessor and the program is not supplied by the mechanical arrangement of cams but by a software program.

For the pre-wash cycle an electrically operated valve is opened when a current is supplied and switched off when it ceases. This valve allows cold water into the drum for a period of time determined by the profile of the cam or the output from the microprocessor used to operate its switch.

However, since the requirement is a specific level of water in the washing machine drum, there needs to be another mechanism which will stop the water going into the tank, during the permitted time,

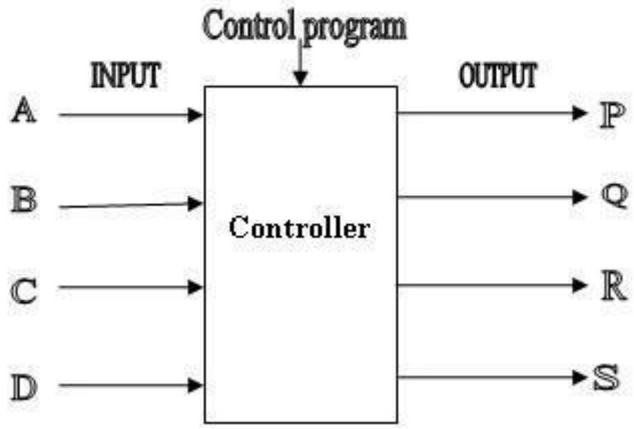
Microprocessor or a cam switches on the current to a discharge pump to empty the water from the drum.

The rinse part of the operation is now switched as a sequence of signals to open valves which allow cold water into the machine. Switch it off, operate the motor to rotate the drum, operate a pump to empty the water from the drum, and repeat this sequence a number of times.

MICROPROCESSOR BASED CONTROLLERS:

Microprocessors are rapidly replacing the mechanical cam operated controllers. These microprocessors are used to control the function. In many simple systems, an embedded micro controller is used to control or perform the particular task.

A more adaptable form of controller is the programmable logic controller. The programmable logic controller is defined as a sequential logic device that generates output signals according to logic
operations performed on the input signals. The PLC is a microprocessor based controller which uses programmable memory to
store instructions and to implement functions such as logic sequence, timing counting and arithmetic to control events. This PLC can be easily reprogrammed for different tasks. The PLC is shown below.



The example for input devices are switches relays and limit switches. The examples for output devices are motor to be controlled, Lamp, relay and solenoid. The controller monitors the inputs and outputs according to the program stored in the PLC by the operator. PLC are similar to computers but have certain features which are specific to their use of controllers. These are,

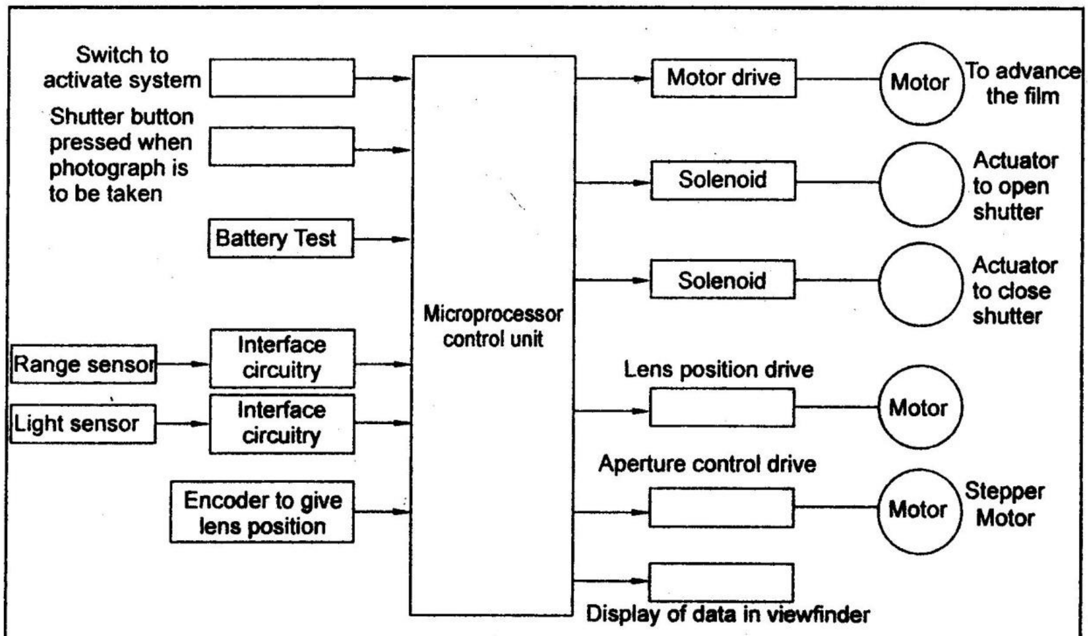
1. They are rugged and designed to withstand vibrations, temperature, humidity and noise.

2. The interfacing for inputs and outputs is inside the controllers.
3. They are easily programmed and have an easily understood programming language. The Programming is primari1y concerned with logic and switching operations.

Note:
Micro controller: - Microprocessor with integrated peripherals is called as micro controller

Some of the microprocessor based control system is discussed below.

AUTOMATIC CAMERA:



Basic elements of the control system for an automatic camera

- The modern camera is likely to have automatic focusing and
- exposure. Figure 1.10 illustrates the basic aspects of
- a microprocessor-based system that can' t be used to control the focusing and exposure.
- When the switch is operated to activate the system and the camera pointed at the object being photographed, the microprocessor takes the input from the range sensor and sends an output to the lens position drive to move the lens to achieve focusing. The lens position is fed back to the microprocessor so that the feedback signal can' t be used to modify the lens position according to the inputs from the range sensor.

- The light sensor gives an input to the microprocessor which then

gives an output to determine, if the photographer has selected the shutter controlled rather than aperture controlled mode, the time for which the shutter will be opened. When the photograph has been taken, the microprocessor gives an output to the motor drive to advance the film ready for the next photograph.

- The program for the microprocessor is a number of steps high to give on-off states.

A few steps of the program for the automatic camera might be of the form:

begin

if battery check input

OKthen continue

otherwise stop

loop

read input from range sensor calculate lens

movement output signal to lens position drive

input data from lens position encoder

compare calculated output with actual output stop output when lens in correct position send in-focus signal to viewfinder display etc.

THE ENGINE MANAGEMENT SYSTEM:

ϖ The engine management system of a car is responsible for managing the ignition and fuelling requirements of the engine.

ϖ With a four-stroke internal combustion engine there are several cylinders, each of which has a piston connected to a common crankshaft and each of which carries out a four-stroke sequence of operations.

ϖ When the piston moves down a valve opens and the air-fuel mixture is drawn into the cylinder.

ϖ When the piston moves up again the valve closes and the air-fuel mixture is compressed.

ϖ When the piston is near the top of the cylinder the spark plug ignites the mixture with a resulting expansion of the hot gases. This expansion causes the piston to move back down again and so the cycle is repeated.

ϖ The pistons of cacti cylinder are connected to a common crankshaft and their power strokes occur at different times so that here is continuous power for rotating the crankshaft.

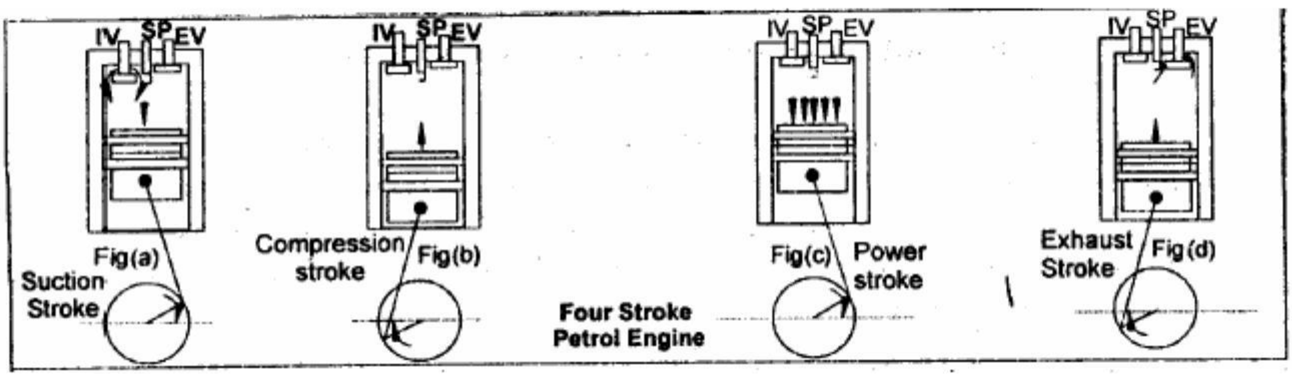
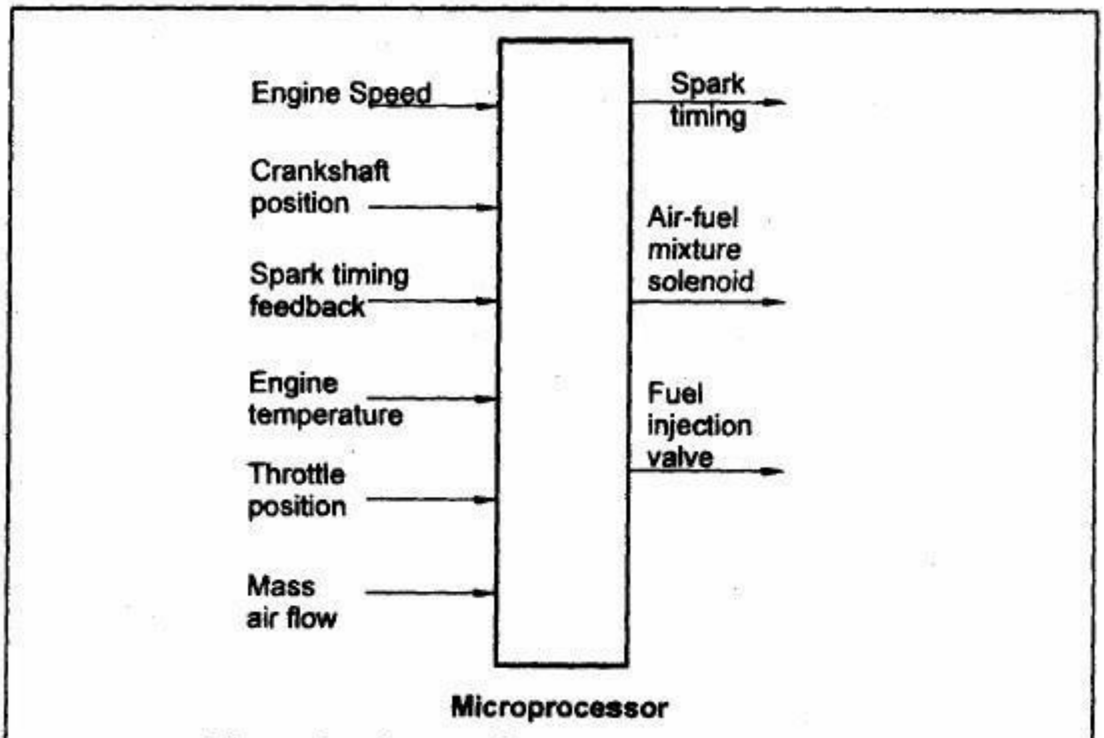


Fig. Four Stroke Sequence

ϖ The power and speed of the engine are controlled by varying the ignition timing and the air - fuel mixture.

ϖ With modem car engines this is done by a microprocessor. Figure shows the basic elements of a microprocessor control system.



Elements of an engine management system

ϖ For ignition timing, the crankshaft drives a distributor which makes electrical contact for each spark plug in turn and a timing wheel. This timing wheel generates pulses to indicate he crankshaft position.

ϖ The microprocessor then adjusts the timing at which high voltage pulses are sent to the distributor so they occur at the right moments of time.

ϖ To control the amount of air fuel mixture entering a cylinder during the intake strokes, the microprocessor varies the time for which a solenoid is activated to open the intake on the basis of inputs received of the engine temperature and the throttle position.

ϖ The amount of fuel to be injected into the air stream can be determined by an input from a sensor of the mass rate of air flow, or computed from other measurements, and the microprocessor then gives an output to control a fuel injection valve.

MECHATRONICS APPROACH:

The domestic washing machine that used cam operated switches in order to control the washing cycle is out of date. Such mechanical switches are being replaced by microprocessor. A microprocessor may be considered as being essentially a collection of logic gates and memory elements that are not wired up is individual components but whose logical functions are implemented by means of software.

The microprocessor- controlled washing machine can be considered an example of a mechatronics approach in that a mechanical system has become integrated with electronic controls. As a consequence, a bulky mechanical system is replaced by much more compact microprocessor system which is readily adjustable to give a greater variety of programs.

Mechatronics brings together a number of technologies like, mechanical engineering, Electronic Engineering, electrical engineering, information technology, computer technology and control engineering. This can be considered as the application of Computer based digital control techniques, through electronic and electric interfaces to mechanical engineering problems.

There are many applications of mechatronics in the mass produced products used in home. Microprocessor based controllers are to be found in and video recorder systems, central heating controls, sewing machines, etc.. They are to be found in cars in the active suspension, antiskid brakes, engine control, speedometer display, transmission etc. A large scale application of mechatronics is a flexible manufacturing engineering system (FMS) involving computer controlled machines, robots, automatic material conveying and overall supervisory control.

PART – A –TWO MARK QUESTIONS

1. Write about Mechatronics?
2. What are the components in a Mechatronics system?
3. What is the use of actuators and sensors?
4. What is the use of digital devices?
5. What is the function of conditioning and interfacing Circuits and graphical displays?
6. Give some examples of Mechatronics systems?
7. What are the important sub-systems involved in Mechatronic system?
8. What is the use of control system?
9. What are the important elements of measurement system?
10. What is the function of sensor?
11. What is the function of signal conditioner?
12. What is the use of Display system?
13. How the control system is classified?
14. What is meant by open loop control system?
15. What is meant by closed loop control system in CNC machine?
16. What are the import elements of a closed loop control system?
17. What is the use of comparison element?
18. What is meant by error signal?
19. What is the use of control element?
20. What is the function of the correction element?
21. What is meant by process element?
22. What is meant by sequence control?
23. Why mechatronic systems are also known as smart devices?

PART – B QUESTIONS

15BEME 703 – MECHATRONICS SYSTEM FOE/KAHE

1. Explain the closed loop system with example.
2. What are the basic components of closed loop system? Explain.
3. Describe the sequential controllers.
4. Explain the microprocessor controlled automatic camera.
5. Explain the microprocessor controlled engine management system.
6. Explain the mechatronics approach with its advantages.

15BEME 703 – MECHATRONICS SYSTEM (UNIT – II)
ACTUATORS

ACTUATIONSYSTEM:

The actuation systems are the elements of the control system and they are responsible for transforming the output of a microprocessor into a controlling action on a machine or device. Actuators produce physical changes such as linear and angular displacement.

There are four types of actuators.

1. Mechanical actuators.
2. Electrical actuators.
3. Hydraulic actuators.
4. Pneumatic actuators.

Example:

In a CNC milling machine, there may be an electrical signal output from the CNC controller to move the milling table in the x direction for a certain length. There you need an actuation system.

PNEUMATIC AND HYDRAULIC SYSTEMS:

Power from one point to another point can also be transmitted using air as medium called pneumatic transmission or liquid as medium called hydraulic transmission. In case of hydraulic system, liquid, which may be water or hydraulic oil is pressurized to 20 to 250 atm pressures and transmitted through pipe line. The pressurized liquid is made to actuate rotary or linear actuator through control valves to get required function. Hydraulic system of power transmission is preferred over mechanical or electrical system on the following grounds.

1. Compact size.
2. Less moving parts.
3. Less wear and tear & self lubricating.
4. Controlled motion.
5. Adaptability for automatic control.

However, the initial cost of hydraulic transmission will be high. Improperly filled hydraulic system will give maintenance problem and cost of spares will be high. Some of the applications of hydraulic system are hydraulic presses, fork lifts, hydraulic jacks and hydraulic shaper etc.

In hydraulic actuation system, the hydraulic signals are used to control device but are more expensive than pneumatic system. Oil leak is another problem in hydraulic system.

Basic components of hydraulic system are

1. Reservoir to hold oil,
2. Hydraulic pump normally positive displacement type,
3. Electric motor to drive the pump,
4. Actuator, which may be rotary or linear,
5. Control valves for controlling flow, direction and pressure, and
6. Pipe lines and fittings to transmit oil power.

In pneumatic control system, the moister should be separated, to avoid presence of free moisture during expansion. Besides, this moisture will pose problems in line especially in pilot operator solenoid valves. Pneumatic system is fast comparable to hydraulic system. But positioning and speed control is difficult because of compressibility of air.

large valves and other high power control device and so it can be used to move heavy loads. Pneumatic system consists of a compressor, control valves and actuators. Since air is used as medium, reservoir is not required.

Power supplies:

Hydraulic power supply:

Hydraulic systems are design to move large loads by controlling a high pressure fluid in distribution lines and piston with mechanical or electromechanical valves.

The basic components of a hydraulic system are,

In a hydraulic system, pressurized oil is provided by a hydraulic pump driven by an electric motor.

The hydraulic pump pumps the oil from a sump through a non-return valve and an accumulator to the system.

A pressure relief valve is circulated to release the pressure when it rises above the safe level.

The non return valve is to prevent the oil returning back to the pump.

The accumulator is a reservoir in which the oil is held under pressure.

The accumulator is used to store the oil and provides a smooth drive during any short term fluctuation in the output oil pressure.

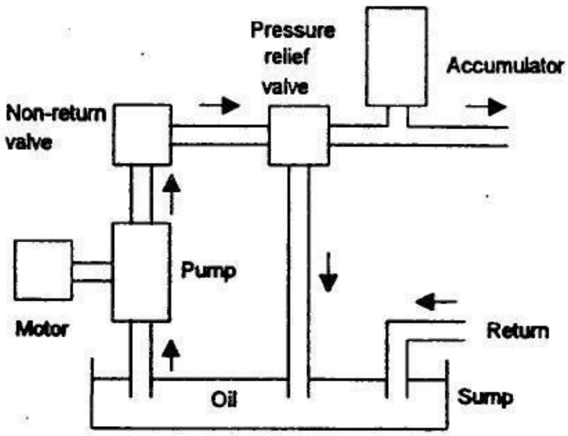


Fig. Hydraulic Power Supply

Pneumatic System:

The basic components of a pneumatic system are,

In a pneumatic power supply an electric motor drives an air compressor.

Before the air enters the compressor, it passes through a filter and a silencer.

In the filter all the dust particles present in the inlet air is removed.

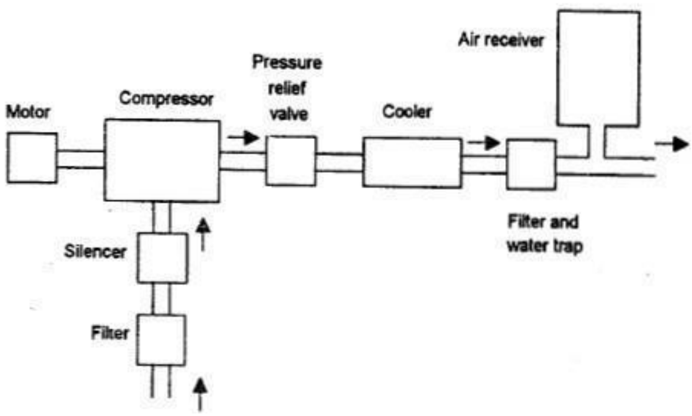


Fig. Pneumatic power supply

In the silencer the noise level is reduced.

A pressure relief valve is provided to protect the system in case of pressure rises above the safe level.

Since the air compressor increases the temperature of the air, a cooler is provided to reduce the temperature of air.

In the filter and water trap, the water from the air and other unwanted particles in air are removed.

An air receiver increases the volume of air in the system and smoothens out any short term pressure fluctuation.

DIRECTION CONTROL VALVES:

The direction control valves are used in the pneumatic and hydraulic system to direct the flow of liquid through a system. They are used for varying the rate of flow of liquid. They are either completely open or closed.

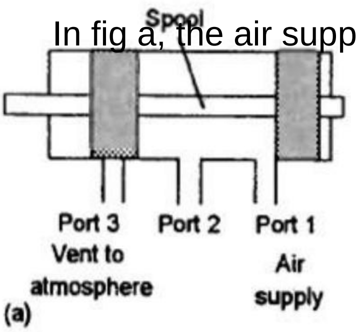
There are two types of direction control valves. They are.

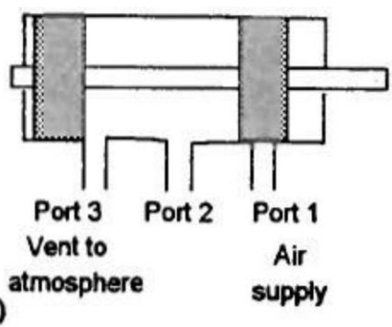
1. Spool valve.
2. Poppet valve.

Spool Valve:

A spool moves horizontally within the valve body to control the flow.

In fig a, the air supply is connected to port 1. The port 3 is closed.





The device is connected to port 2, and device is pressurized.

In fig. b when the spool is moved to the left, the air supply is cut off.

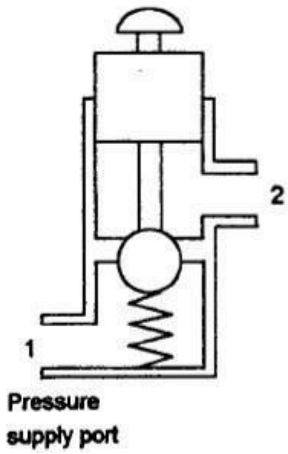
Port 2 and port 3 are connected.

So the air in the system connected to port 2 is allowed to go out to the atmosphere through port 3.

In fig. a air is allowed to flow into the system.

In fig. the air is allowed to flow out of the system.

Poppet Valve:



This valve is normally in the closed condition.

The port 1 is connected to pressure supply.

The Port 2 is connected to the system. Initially there is no connection between port 1 and port 2.

Here balls, discs, or cones are used as a valve to be seated in the valve seat to control the flow.

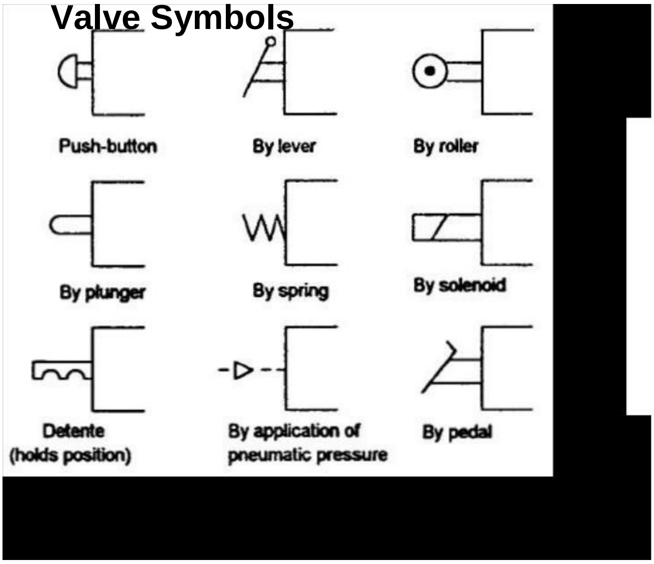
Here a ball is used as shown in fig.

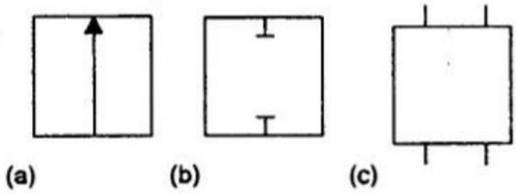
When the push button is depressed, the ball is pushed out of its seat.

This allows the flow from port 1 connected to port 2.

When the button is released, the spring forces the ball back to its seat and so closes off the flow.

Valve Symbols





(a) Flow path, (b) flow shut-off, (c) initial connections

The symbol used for control valves consists of a square for each of its switching positions.

A two position valve will have two squares; a three position valve will have three squares.

The arrow headed lines are used to indicate the direction of flow in each of the position.

The blocked-off lines indicate the flow is closed.

In the fig the valve has four ports.

The ports are labeled by a number or a letter according to their function.

The ports are labeled 1 (or P) for pressure supply.

The ports are labeled 3 (or T) for hydraulic return port, 3 or 5 (or R or S) for pneumatic exhaust port and 2 or 5 (or B or A**)** for Output ports.

Example

The following are some of the illustrations of how these various symbols can be combined to describe how a valve operates. The Fig. is a 2/2 valve, because it has 2 ports and 2 positions. The first number (numerator) indicates the number of ports. The second number (denominator) indicates the number of .positions. The valve symbol in Fig. is 2/2, solenoid operated, push button valve.

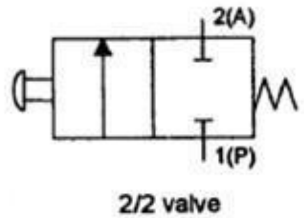


Fig. 2/2 Valve

The valve symbol in Fig. , is 3/2 because it has 3 ports and 2 positions.

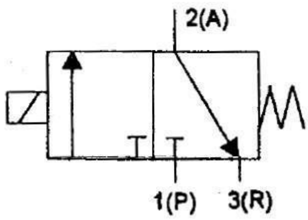


Fig. 3/2 Valve

The valve symbol in Fig. is 4/2 valve because it has 4 port and 2 positions.

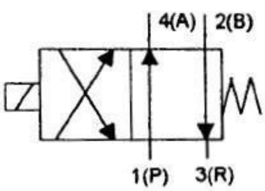
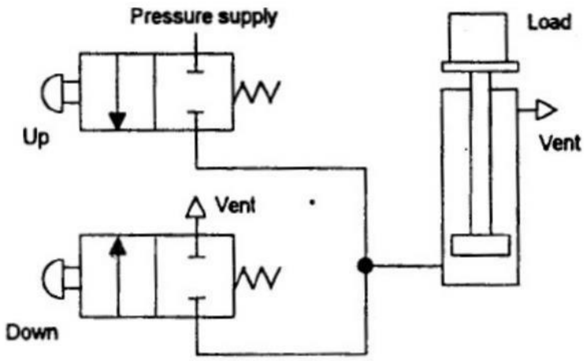


Fig. 4/2 Valve

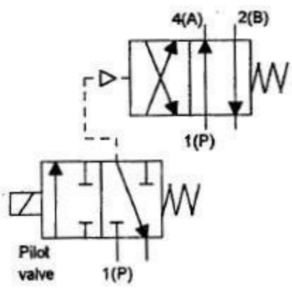
The following is an example for the application of valves in a pneumatic lift system.



The push button 2/2 valves are used. When the up valve is pressed the load is lifted. When the bottom valve is pressed the load is lowered. An open arrow is used to indicate a vent to the atmosphere.

Pilot Operated Valve:

The force required to move the ball or shuttle in a valve can often be too large for manual or solenoid operation. To overcome this problem a pilot operated system is used. Where one valve is used to control second valve. Figure illustrates this. The pilot valve is small capacity and can be operated manually or by a solenoid. It is used to allow the main valve to be operated by the system pressure. The pilot pressure line is indicated by dashes. The pilot and main valve can be operated by two separate valves but they are often combined in a single housing.



Direction Valves

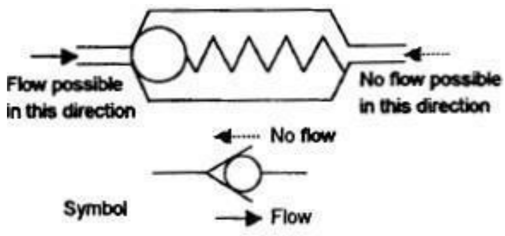


Figure shows a simple direction control valve and its symbol. Free flow can occur in one direction through the valve, that which results in the ball being pressed against the spring. Flow in the other direction is blocked by the spring forcing the ball against its seat.

PRESSURE CONTROL VALVE:

There are three types of pressure control valve.

1. Pressure regulating valves.
2. Pressure limiting valves.
3. Pressure sequence valves.

1. Pressure regulating valves:

This is used to control the operating pressure in a circuit and maintain it at a constant value. The compressed air produced by the compressor may fluctuate. Changes in the pressure may affect. The switching characteristics of the cylinder the running times of the cylinders. The timing characteristics of flow control valve. Thus the constant pressure level is required for the trouble free operation of a pneumatic control. A pressure regulator is fitted downstream of the compressed air filter. It provides a constant set pressure at the outlet of the regulator. The pressure regulator is also called as pressure reducing valve or pressure regulating valve. There are two types of Pressure regulators. They are

1. Diaphragm type pressure regulator (with or without vent holes).
2. Piston spool type pressure regulator.

1. Diaphragm type pressure regulator:

Two types of pressure regulators with diaphragm are available.

(a)With vent holes and

(b) Without vent holes.

(a)Diaphragm type pressure regulator (with vent holes):

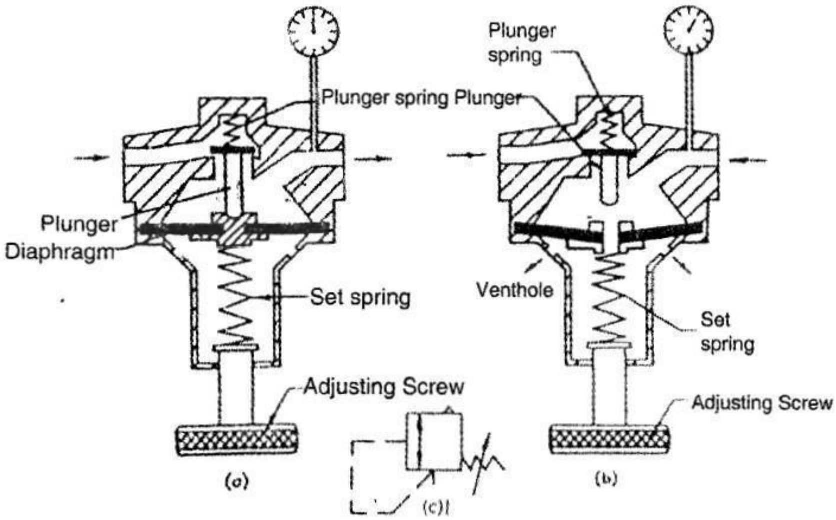
A diaphragm type pressure regulator is shown in figure (a) & (b).In this type pressure is regulated by a diaphragm. The output pressure acts on one side of the diaphragm. On the other side of the diaphragm, a spring (set spring) force acts. The spring force can be adjusted by an adjusting screw provided at the bottom of the regulator.

When the pressure output increases:

The diaphragm moves against the spring force. Due to this, the outlet area of cross-section at the valve seat reduces or closes entirely. Thus the quantity of air flowing is regulated.

When the air drawn off on the outlet side:

The operation pressure drops. The spring force opens the valve. Thus, the continual opening and closing of the valve seat regulates the preset output pressure. a damper spring is provided above the valve disc to avoid fluttering. A pressure gauge is fitted to the outlet of the regulator for monitoring and setting of the circuit pressure.



If the pressure on the outlet side increases considerably:

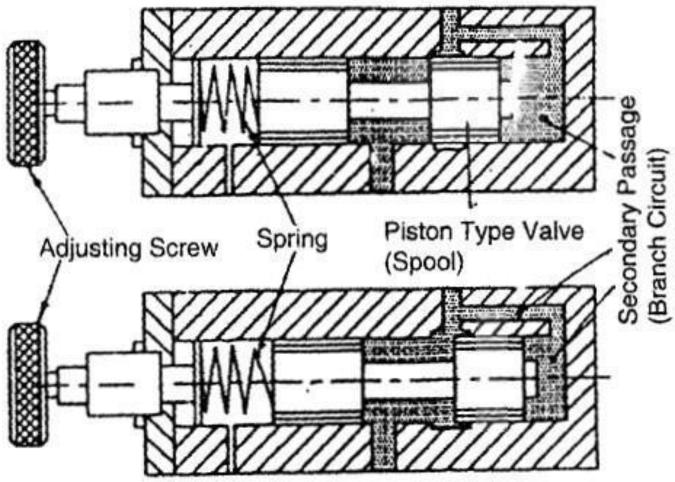
The diaphragm is pushed down against the spring force. The center piece of the diaphragm opens. The compressed air flows to the atmosphere through the vent holes in the housing.

(b) Diaphragm type pressure regulator (without vent holes):

A diaphragm pressure gauge without vent holes is shown in the fig. With these valves, it is not possible to exhaust the compressed air. The spring is pre-stressed by means of adjusting screw. Thus the diaphragm is also pre-stressed. The plunger is raised with the diaphragm to a greater or lesser extent from the seat. Therefore, the flow from the primary to the secondary side increases or decreases depending on the setting of the spring. If no air is drawn off on the outlet side, the diaphragm moves down against the compression spring. The damper spring moves the plunger downward to its seat. Thus the flow of air is closed off at the sealing seat. The compressed air can continue to flow only when the air is drawn off on the outlet side.

Piston - spool type pressure regulator:

A piston type pressure regulator is shown in fig.



The valve is of piston type. It is kept on its seat by a spring force. The spring force can be adjusted screw provided at the bottom. In the normal piston, the valve is open and the compressed. Air freely flows from inlet A and outlet B. The valve spool is kept in equilibrium by the spring force on one side and air pressure on the other side through secondary circuit. When the pressure in the secondary side rises, the pressure on the spool face increases. The spool moves and partly closes the outlet side. This reduces the volume of air going to the secondary side and hence pressure is reduced. If the pressure in the secondary side increases considerably, the outlet port is completely closed. The flow is completely closed.

2. Pressure limiting valves:

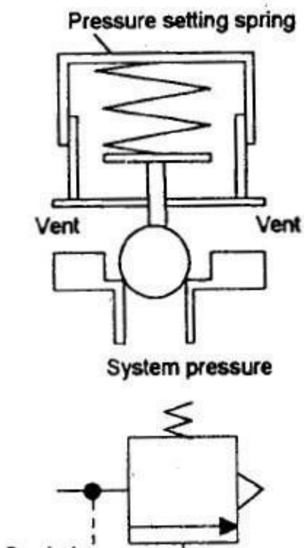
These are used as safety devices to limit the pressure in a circuit to below some safe value. The valve opens and vents to the atmosphere or back to the sump, if the pressure rises above the set safe value. A simple pressure relief valve is shown in the fig. it consists of conical poppet valve, spring, adjusting screw. The force exerted by the spring on the poppet can be varied by the pressure adjusting screw.

Under normal conditions:

The spring presses the conical poppet valve in its seat. The oil flow path is closed.

When the system pressure exceeds the set value:

The increased pressure presses the poppet against the spring force. Oil flow through the exhaust port T to the reservoir. Thus the excessive pressure is released. When the pressure drops below the set value, the poppet again closes.



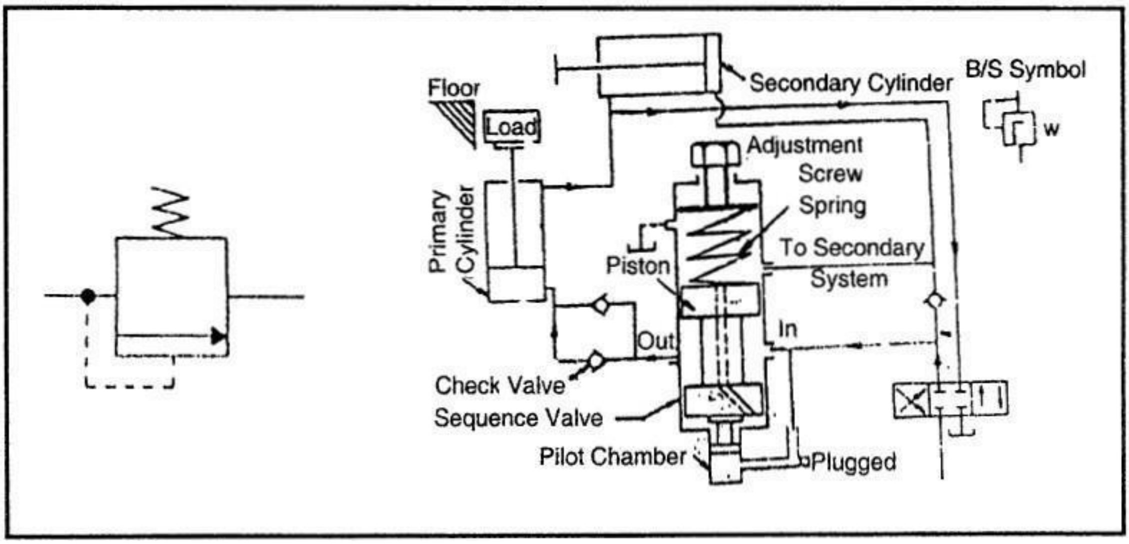
3. Pressure Sequence Valves:

The sequence valve helps two or more cylinders to work in a particular sequence. It makes sure that the operation of one cylinder is completed before the start of the operation of another cylinder. For example, consider two hydraulic cylinders which operate in sequence. The sequences of operations to be performed are

(i) Lifting the weight up to the floor level by the first cylinder

(ii) Pushing the weight into the floor by the Second Cylinder

The sequence valve is connected in the hydraulic circuit as shown in the fig.



DCV is shifted in one extreme position

The fluid from the pump enters into the inlet of the sequence valve and comes out and enters into the first cylinder through a check valve and causes the piston to rise up.

Now the load is lifted up to the floor level. During this operation fluid on its top is going back to the reservoir. After lifting the load, the piston comes to rest. Thus the first operation is over. As soon as the piston has come to rest, the oil does not find any passage for its flow.

Thus the pressure in the sequence valve increases. The increase in pressure lifts the valve piston and the oil is now entering to the second cylinder. The piston of the second cylinder pushes the load into the floor.

During this operation the fluid on the left side is discharged to the reservoir. Thus the secondary operation is completed.

DCV is shifted in another extreme position

Now the outlet port in sequence valve is closed as the piston of the sequence valve move down. The fluid now entering into the second cylinder causes the piston to move from the left to right while the fluid on the other side is connected to the reservoir through the check valve After the second cylinder piston has come to rest, the pump supply enters into the top of the first cylinder. The piston in the first cylinder lower down while fluid at its bottom is flowing to the reservoir through the check valve and sequence valve. The pressure setting of the sequence valve is adjusted by adjustment screw.

CYLINDERS

The hydraulic or pneumatic cylinder is an example of a linear actuator. The principles for both hydraulic and pneumatic versions are the same. Only difference is big size cylinder are used in hydraulic due to high pressure.

Construction

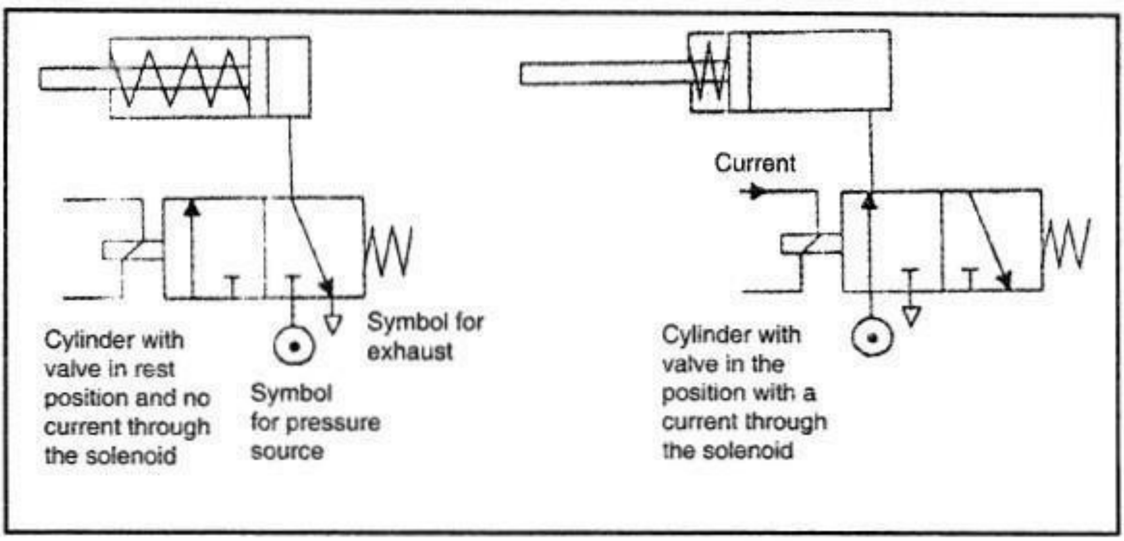
A cylinder consists of a cylindrical type along which a piston/ ram can slide. There are two types of cylinder. They are.

1. Single acting cylinder.

2. Double acting cylinder.

1. Single acting cylinder:

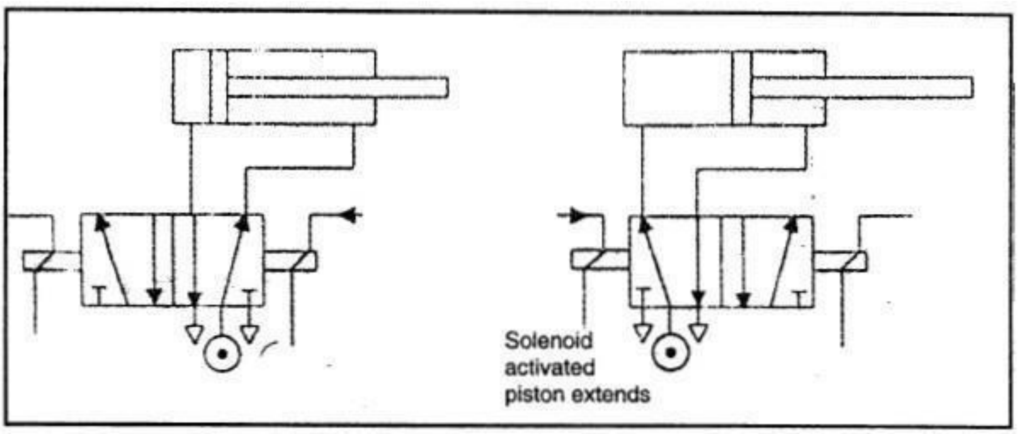
The simple level of control for the single acting cylinder involves direct control signals. Direct control is used when. The flow rate required to operate the cylinder is relatively small. The size of the control valve is small with low actuating forces. The circuit for the direct control of single acting cylinder is shown in the fig.



A 3/2 directional control valve is used. The cylinder is of small capacity and the air consumption is low. Hence the operation can be directly controlled by a push button 3/2 direction control valve with spring return. When the push button is pressed, the air passes through the valve from pressure port (P) the cylinder port (A). The piston rod extends against the force of the cylinder return spring. Thus the work piece is clamped. When the push button is released, the valve spring returns the 3/2 D.C.V. to its initial position. The cylinder retracts by the return spring force. The air form the cylinder returns through the exhaust port (R).Cylinder is the only working element or actuator.

2. Double acting cylinder:

They are used when the control pressures are applied to each side of the piston.



A difference in pressure between the two sides, result in motion of the piston. The circuit includes a double acting cylinder with 5/2 D.C.V.

When the spool of the DCV is at extreme left:

Air flows from pressure port (P) to the working port (B).Then air is allowed to enter the right end of the cylinder. The piston moves from right to left. At the same time air in the left end of the cylinder flows into the valve through port 'A' and exhausted through exhaust port 'R'. The other exhaust port 'S' is blocked.

When the spool of DCV is at extreme right:

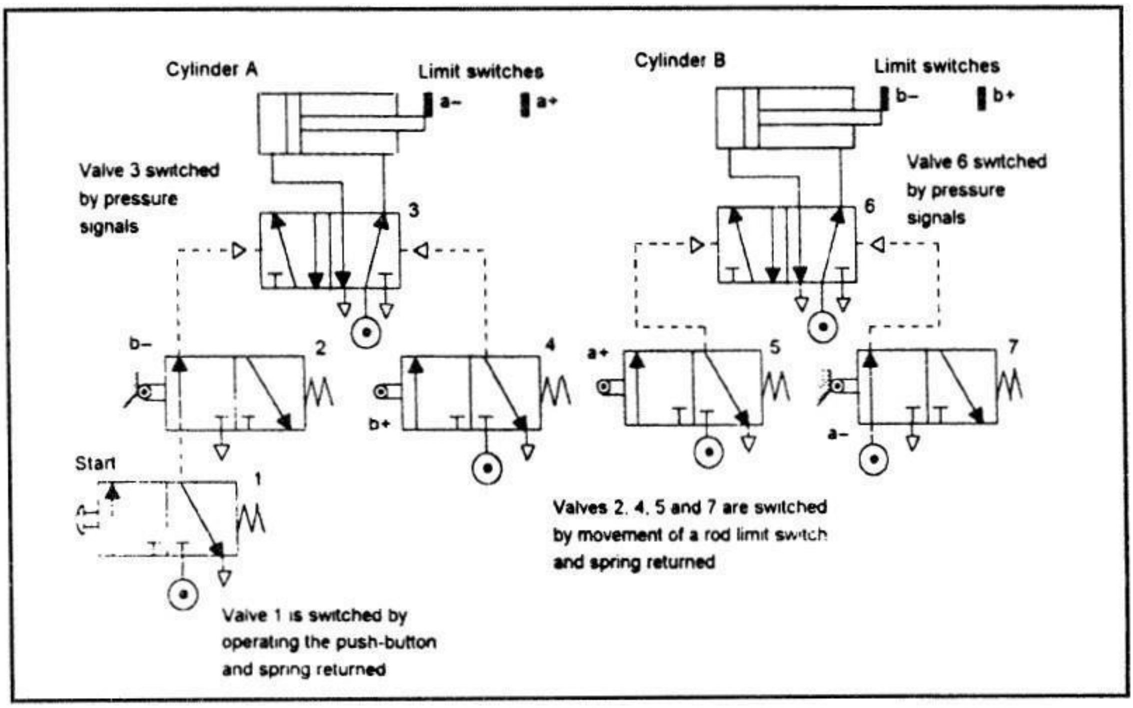
Air flows from inlet pressure port (P) to the working port (A). Air is allowed to enter the left end of the cylinder. The piston moves from left to right .At the same time the air in the right end of the cylinder flows into the valve through the exhaust port 'S'. The other exhaust port 'R' is blocked. This is the principle of working of the double acting cylinder.

CYLINDER SEQUENCING:

Many control system employ pneumatic (or) hydraulic cylinders as actually elements and require a sequence of extensions and retraction of the cylinder to occur.

For example,

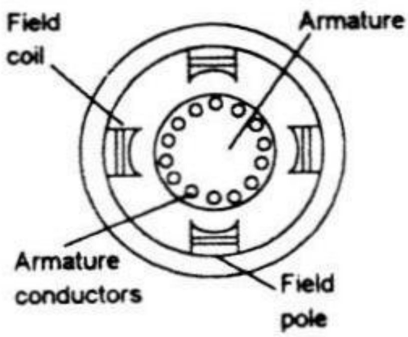
There are two cylinders A & B. When the start button is pressed, the piston of cylinder A extends. When it is fully extended, the piston of cylinder B extends. The sequence of operation of these two cylinders is explained.



Each cylinder is given a reference letter A & B. To indicate the extension of the piston in cylinder. A, a+ sign is used. To indicate the retraction of the piston in cylinder A a - sign is used. Similarly for cylinder B, b+ (for extension) and b - (for retraction) are used.

D.C Motor

Electric motors are frequently used as the final control element in positional or speed-control systems. Motors can be classified into two main categories: d.c. motors and a.c. motors. Most motors used in modern control systems being d.c. motors Construction.



* YOKE:

1. It is the outermost covering of the machine. 2. It provides mechanical support for the poles. 3. It is a stationary part. 4. It carries magnetic flux produced by the poles. 5. It is made of cast iron.

* FIELD SYSTEM:

(a) Pole core

(b) Pole shoe

(c) Field coil.

(a) Pole core:

1. They are fabricated by laminations of steel.
2. They are laminated so as to avoid eddy current loss.

(b) Pole shoe:

1. They act as a mechanical support to the field coil.
2. They reduce the reluctance of the magnetic flux.
3. They spread out the flux in the air gap uniformly.

(c) Field coil:

1. These coils are wound on the pole core. 2. When current is passed through this coil, they electromagnetic.

* **Inter poles:**

1. They are fixed between the main poles.
2. They are in-line with the neutral axis.
3. They are smaller in size than main poles.
4. They are used for spark less commutation.

* **Armature:**

1. It is the rotating part of the machine.
2. It is cylindrical in shape.
3. It is fabricated by means of steel laminations.
4. It is laminated to avoid the eddy current loss.
5. The periphery of the armature is cut into slots and teeth's.
6. The conductors are placed in the slots.
7. Due to loss, heat is developed in the armature.
8. Therefore to dissipate heat a fan is provided at one end of the armature.

* **Commutator:**

1. It is made up of copper segments insulated from each other by mica sheets.
2. The armature conductors are soldered to Commutator.

3. It is used to convert bidirectional current to unidirectional current.

* **Brushes:**

1. These are made of carbon. It is rectangular in shape.
2. The brush holders are kept passed against the Commutator.
3. It collects current from the line to the Commutator.

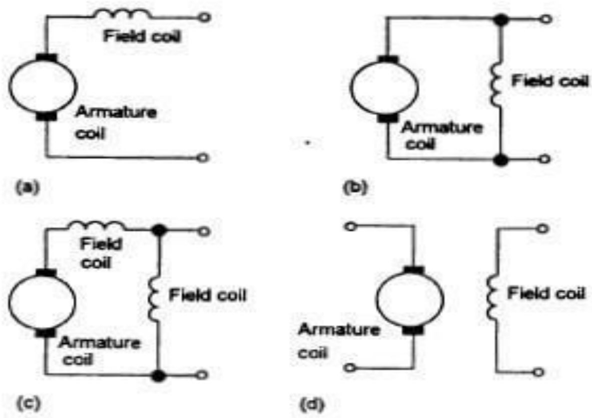
Principle of Working:

The armature is made up of magnetic material with coils of core wound on it. The armature is mounted on bearings and is free to rotate. They are field coils wound and permanent magnet W electromagnets fixed to the carrying [w] starter. The ends of the armature coil are connected to Commutator. When the current is applied to the field coil it cuts the magnetic flux near to armature, and armature start rotating. The direction of rotation of the D.C motor can be changed by reversing either the armature current (or) the field current.

TypesofD.C. motor

1. Series wound motor (fig. a)

With the series wound motor the armature and fields coils are in series. Such a motor exerts the highest starting toque and has the greatest no-load speed. With light loads there is a danger that a series wound motor might run at too high a speed. Reversing the polarity of the supply to the coils has no effect on the direction of rotation of the motor. It will continue rotating in the same direction since both the field and armature currents have been reversed.


Field coil
Armature coil
(a)
Field coil
Armature coil
(b)
Field coil
Field coil
Armature coil
(c)
Field coil
Armature coil
(d)

2. Shunt wound motor (fig.b)

With the shunt wound motor the armature and field coils are in parallel. It provides the lowest starling toque, a much lower no-load speed and has good speed regulation. Because of this almost constant speed regardless of load, shunt wound motors are very widely .used. To reversed the direction of rotation. either the armature or field supplied must be reversed. For this reason, the separately excited windings are preferable for such a situation.

3. Compound motor (fig. c)

The compound motor has two field windings. One in series with the armature and one in parallel. Compound wound motors aim to get the best features of the series and shunt wound motors, namely a high starting torque and good sped regulation.

4. Separately excited motor (fig. d)

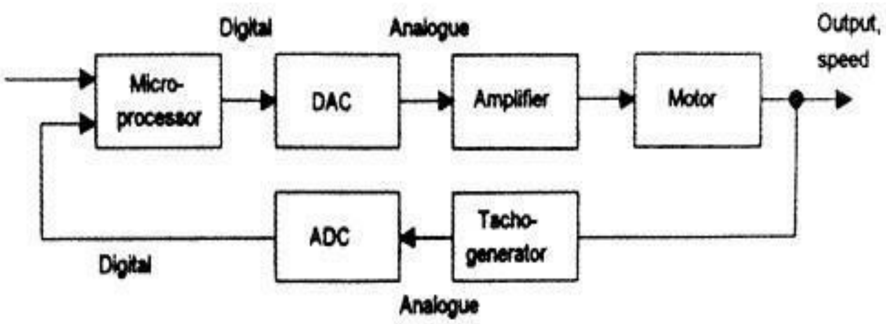
The separately excited motor has separate control of the armature and field currents and can be considered to be a special case of the Shunt bound motor.

Control of D.C. Motor:

1. The speed of the permanent magnet motor depends upon the current through the armature coil.
2. In a field coil D.C motor, the speed can be changed by varying the armature current or the field current.
3. Generally it is the armature current that is varied.
4. To obtain a variable voltage at the armature an electric circuit is used.
5. Usually the D.C motors are controlled by the signals coming from microprocessors.
6. In such cases the technique knows as pulse width modulation (PWM) is used, to obtain a variable voltage.
7. This PWM can be obtained by means of a basic transistor circuit.
8. This technique can be used to drive the motor in one direction only.
9. By involving four transistors which is know as H - circuit, the direction change in rotation of motor can be obtained

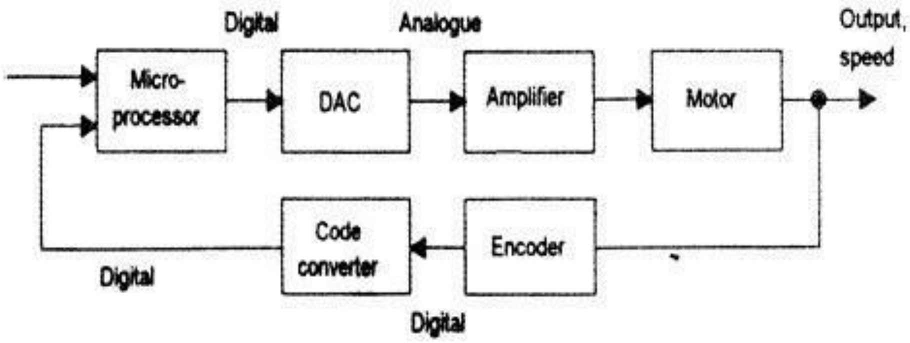
In a closed loop control system, the feed back signals are used to modify the motor speed. There are three methods for doing it.

<u>Method -I</u>



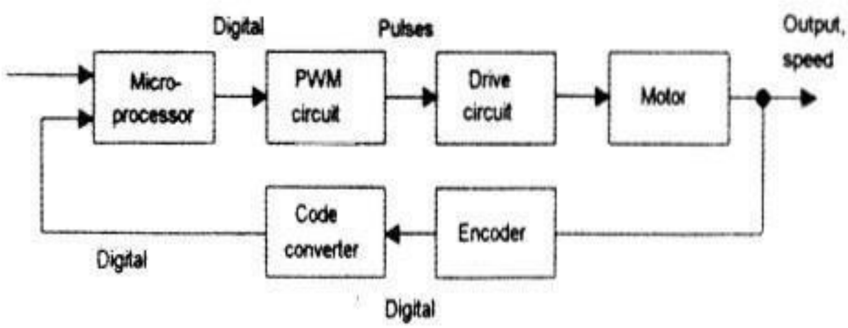
1. Here the feed back signal is provided by a tachometer.
2. The analogue signal from the tachometer is converted into digital signal by using ADC.
3. This digital signal is given as input to the microprocessor is converted into analogue by using DAC.
4. This signal is used to vary the voltage applied to the armature of the D.C. motor.

Method –II



1. The feed back signal is coded using a encoder.
2. In the code converter, the digital output is obtained.
3. This digital signal is given as an input to the microprocessor.

Method –III



1. The system is completely digital.
2. PWM is used to control the average voltage applied to the armature.

A.C MOTOR

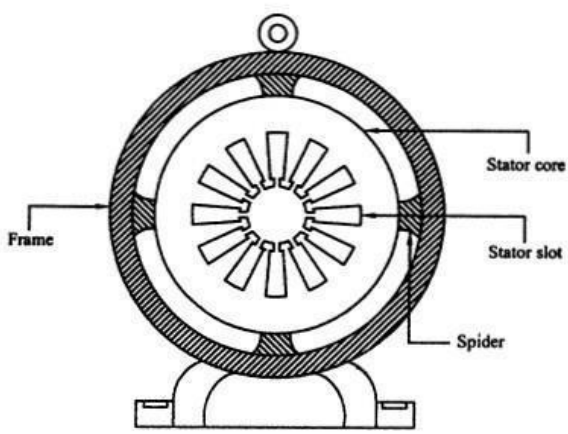
Types of A.C motor:

1. Squirrel cage induction rotor.
2. Slip ring (or) wound rotor.

Construction of A.C Motor

STATOR:

1. It is the stationary part of the machine.
2. It is made of high grade silicon steel laminations.
3. it is laminated so as to avoid eddy current loss.



Stator

4. The stator windings are placed in the slots on the inner surface of stator core.
5. The windings are wound for a particular number of poles.
6. The three phase stator windings are fed from three phase supply.
7. The stator windings are sometimes known as primary windings.

ROTOR:

Squirrel cage rotor:

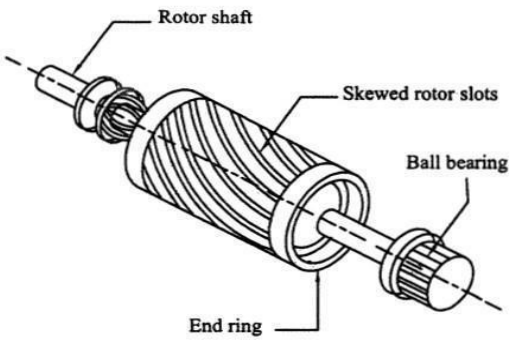
1. The construction is very simple.2. It is the rotating part of the machine.

3. It is cylindrical in shape with slots on its outer surface.

4. The rotor conductors are heavy bars of copper or aluminum.

5. All the ends of the bars are short circuited by means offend rings on both sides.

6. The slots are slightly angled to prevent hum noise and locking of stator and rotor.



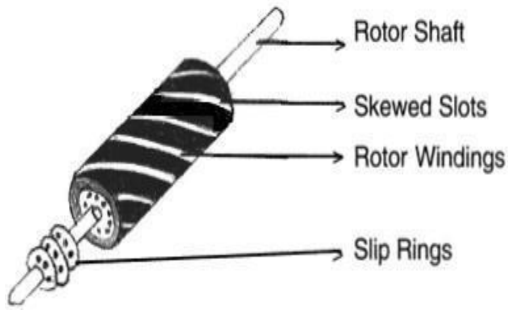
Rotor
Squirel cage rotor

Slip ring or wound rotor:

1. The rotor is wound for the same numbers of poles as that of the stator.

2. The rotor is made up of silicon steel laminations.

3. The open ends of the rotor windings are brought out and they are connected to three slip rings.



4. The three slip rings are mounted on the shaft.
5. The slip rings are insulated from each other.
6. The slip rings are made of phosphor bronze.

Principle of Operation:

1. A three phase supply is given to the stator winding.
2. A rotating magnetic field is produced in the stator which rotates in synchronous speed.
3. Synchronous speed depends upon supply frequency and number of poles.
4. In rotor short circuited copper bars are provided.
5. The rotating magnetic field cuts the short circuited copper conductors, thereby inducing an emf in the rotor conductors.
6. Hence a magnetic field is setup in the rotor.
7. Due to the interaction between the stator and rotor magnetic flux, the rotor rotates.
8. The direction of rotation of rotor is same as that of rotating magnetic field but with the speed lesser than the synchronous speed.

Control of A.C Motor:

1. The speed control of A.C motor is more complex than the D.C motors.

2. The speed of the A.C motor is determined by the frequency of supply.

N= 120 F/P Where, N = speed in rpm.

P = no. of poles.

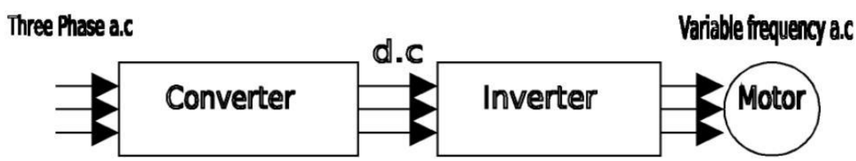
3. Therefore the control of A.C motor is based on the variable frequency supply.

4. The change in the frequency can be achieved by two methods.

A. using a converter and an inverter.

B. using cyclo converter.

Using a converter and an inverter:



1. The three phase **A.C** is rectified to **D.C** by a converter.
2. Then it is inverted back to **A.C.** again but at a frequency that can be selected.

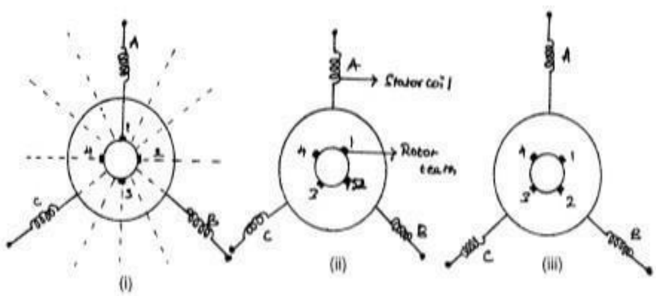
Cyclo converter:

1. It is used to operate slow speed motors.
2. This converts **A.C** at one frequency directly to **A.C** at another frequency without the intermediate D.C conversion.

STEPPER MOTORS:

1. It is a device that produces rotation through equal angle called steps for each digital input.
2. for example :-Suppose say one phase input produces 6O of rotation, then60 phase of input produces 360° of rotation.

Construction and working principle:



1. Stepper motor is a special type synchronous motor.
2. It converts electrical pulses applied to it into discrete rotor movements called steps.
3. **A** 30° per step motor will require 12 pulses to move through one revolution.
4. From diagram, A, B and C are the three stator coils placed at 120° apart around the circumference of the stator.
5. A four pole rotor made of soft iron is placed in between stator coils so as to rotate.
6. When coil A is excited, the rotor teeth 1 & 3 are aligned along 'A' axis as shown in figure (i).
7. When excitation of coil A is removed and if coil B is excited, the rotor teeth 2 is attracted by coil B and thus rotor teeth2 and 4 are aligned 'B' axis as shown in figure (ii).

8. Now when the coil C is excited after removing the excitation of coil B, the rotor teeth 3 gets aligned along 'C' axis as shown in figure (iii).
9. Hence a clockwise motion of the motor is produced when pulses are given in the order of A, B, c, A, B, C.... etc.
10. For each pulse, the rotor moves 30° per step.
11. If no coil is excited, then the rotor stands at any position.
12. When pulses are given for the coils in the order A, C, B, A, C, B.... etc., the rotor rotates in anticlockwise direction.

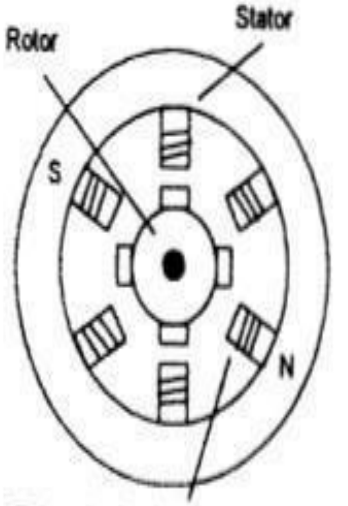
Application:

1. Used in X - Y plotters.
2. Used in machine tools.
3. Used in robots.
4. Used in computer peripherals like floppy disc drives line printers etc.
5. Used in watches.

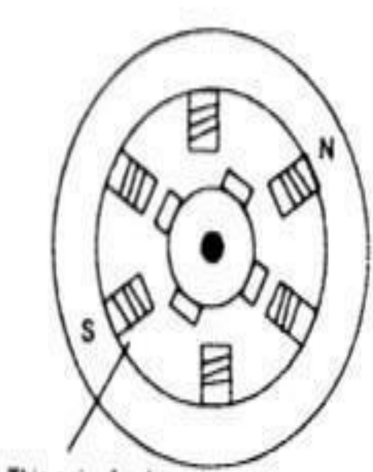
Types of stepper motor:

1. Variable reluctance of stepper motor.

The rotor is made of soft steel and is cylindrical in the four poles. The rotor will rotate until rotor and stator poles line up. This is termed as position of minimum reluctance. This form of stepper gives step Angle of 7.5^0(or) 15^0

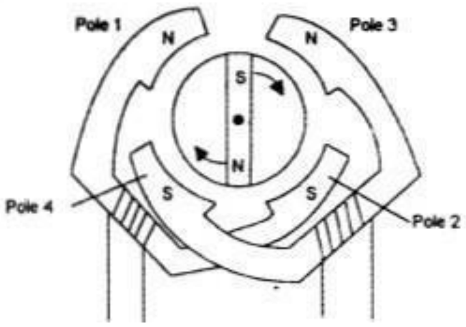


This pair of poles energised by current being switched to them and rotor rotates to position shown below



This pair of poles energised by current being switched to them to give next step

2. Permanent magnet stepper motor:



1. The rotor is a permanent magnet.
2. The motor has a stator with four poles.
3. Each pole is wound with a field winding.
4. The coils in position pair of poles are connected in series.
5. When the current is supplied to the stator windings, the rotor which is a permanent magnet will move to line up with the stator poles.
6. From the figure shown, the rotor will move to the 45^0osition.
7. When the polarity is reversed for the current supply to stator coil, thus the rotor will move on the reversed side to45^0positions.
8. Thus by switching through the coils the rotor rotates in 45^0teps

Unit 3

MICROPROCESSORS IN MECHATRONICS

Microprocessor is defined as a silicon chip embedded with a Central Processing Unit or CPU. It is also referred to as a computer's logic chip, micro chip, and processor.

Advantages of Microprocessors is that these are general purpose electronic processing devices which can be programmed to execute a number of tasks. These are used in personal computers as well as a number of other embedded products.

There are no disadvantages as such but when compared to fixed logic devices or certain ASICs (application specific intergrated circuits), there is a need to program Microprocessors and write software/firmware when used in embedded applications.

Function

The function of a Microprocessor is to conduct arithmetic and logic operations.

Speed

One advantage of a Microprocessor is its speed, which is measured in hertz. For instance, a Microprocessor with 3 gigahertz, shortly GHz, is capable of performing 3 billion tasks per second.

Data Movement

Another advantage of a Microprocessor is that it can quickly move data between the various memory locations.

Complex Mathematics

Microprocessors are used to perform complicated mathematical operations, like operating on the floating point numbers.

Disadvantages

Some of the disadvantages with the Microprocessor are that it might get over-heated, and the limitation it imposes on the size of data.

APPLICATIONS OF MICROPROCESSORS

Microprocessors are a mass storage device. They are the advanced form of computers. They arealso called as microcomputers. The impact of microprocessor in different lures of fields is significant. The availability of low cost, low power and small weight, computing capability makes it useful in different applications. Now a days, a microprocessor based systems are used in instructions, automatic testing product, speed control of motors, traffic light control , light control of furnaces etc. Some of the important areas are mentioned below:

Instrumentation:

It is very useful in the field of instrumentation. Frequency counters, function generators, frequency synthesizers, spectrum analyses and many other instruments are available, when microprocessors are used as controller. It is also used in medical instrumentation.

Control:

Microprocessor based controllers are available in home appliances, such as microwave oven, washing machine etc., microprocessors are being used in controlling various parameters like speed, pressure, temperature etc. These are used with the help of suitable transduction.

Communication:

Microprocessors are being used in a wide range of communication equipments. In telephone industry, these are used in digital telephone sets. Telephone exchanges and modem etc. The use of microprocessor in television, satellite communication have made teleconferencing possible. Railway reservation and air reservation system also uses this technology. LAN and WAN for communication of vertical information through computer network.

Office Automation and Publication:

Microprocessor based micro computer with software packages has changed the office environment. Microprocessors based systems are being used for word processing, spread sheet operations, storage etc. The microprocessor has revolutionize the publication technology.

Consumer:

The use of microprocessor in toys, entertainment equipment and home applications is making them more entertaining and full of features. The use of microprocessors is more widespread and popular.Now the Microprocessors are used in :

1. Calculators
2. Accounting system
3. Games machine
4. Complex Industrial Controllers
5. Traffic light Control
6. Data acquisition systems
7. Multi user, multi-function environments
8. Military applications
9. Communication systems

Evolution of Microprocessor:

Microprocessors were categorized into five generations: first, second, third, fourth, and fifth generations. Their characteristics are described below:

First-generation

The microprocessors that were introduced in 1971 to 1972 were referred to as the first generation systems. First-generation microprocessors processed their instructions serially—they fetched the instruction, decoded it, then executed it. When an instruction was completed, the microprocessor updated the instruction pointer and fetched the next instruction, performing this sequential drill for each instruction in turn.

Second generation

By the late 1970s, enough transistors were available on the IC to usher in the second generation of microprocessor sophistication: 16-bit arithmetic and pipelined instruction processing. Motorola's MC68000 microprocessor, introduced in 1979, is an example. Another example is Intel's 8080. This generation is defined by overlapped fetch, decode, and execute steps (Computer 1996). As the first instruction is processed in the execution unit, the second instruction is decoded and the third instruction is fetched.

The distinction between the first and second generation devices was primarily the use of newer semiconductor technology to fabricate the chips. This new technology resulted in a five-fold increase in instruction, execution, speed, and higher chip densities.

Third generation

The third generation, introduced in 1978, was represented by Intel's 8086 and the Zilog Z8000, which were 16-bit processors with minicomputer-like performance. The third generation came about as IC transistor counts approached 250,000.

Motorola's MC68020, for example, incorporated an on-chip cache for the first time and the depth of the pipeline increased to five or more stages. This generation of microprocessors was different from the previous ones in that all major workstation manufacturers began developing their own RISC-based microprocessor architectures (Computer, 1996).

Fourth generation

As the workstation companies converted from commercial microprocessors to in-house designs, microprocessors entered their fourth generation with designs surpassing a million transistors. Leading-edge microprocessors such as Intel's 80960CA and Motorola's 88100 could issue and retire more than one instruction per clock cycle.

Fifth generation

Microprocessors in their fifth generation, employed decoupled super scalar processing, and their design soon surpassed 10 million transistors. In this generation, PCs are a low-margin, high-volume-business dominated by a single microprocessor.

Classification of Microprocessor:

The microprocessor is identified with the word size of data. For E.g. The ALU can perform a 4- bit data operation at a time these microprocessor is called as 4-bit microprocessor.

4-Bit Processors

INTEL 404 4040

8-Bit Processors

8008 8080 8085 MOTOROLA 6800 (M6800)

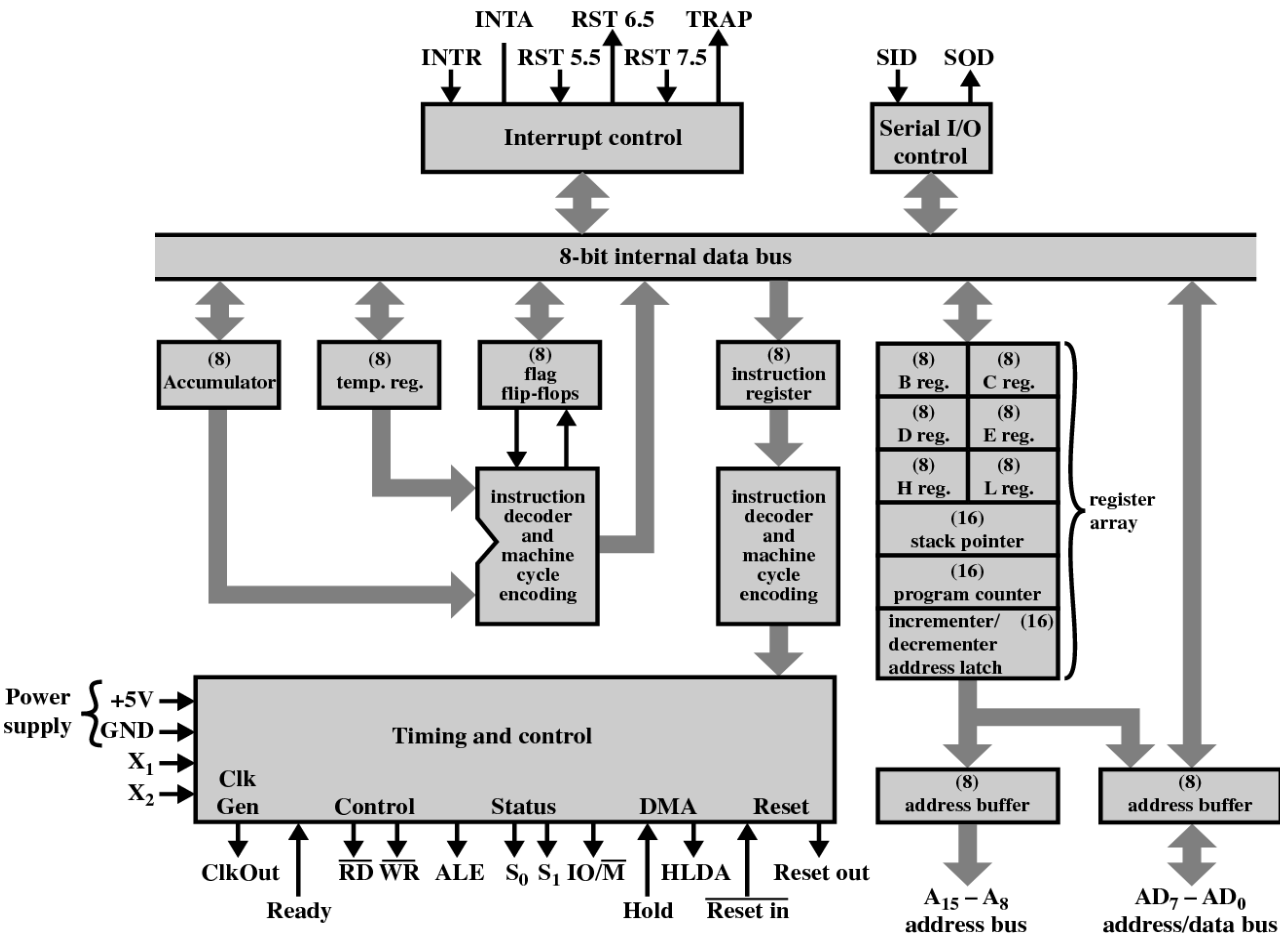
16-Bit Processors

8086 8088 Zilog Z800 80186 80286

32-Bit Processors

Intel 80386 80387 80486 PENTIUM PENTIUM PRO

ARCHITECHTURE OF 8085



This is the functional block diagram of the 8085 Microprocessor.

Acumulator

It is a 8-bit register which is used to perform airthmetical and logical operation. It stores the output of any operation. It also works as registers for i/o accesses.

Temporary Register

It is a 8-bit register which is used to hold the data on which the acumulator is computing operation. It is also called as operand register because it provides operands to ALU.

Registers

These are general purposes registers. Microprocessor consists 6 general purpose registers of 8-bit each named as B,C,D,E,H and L. Generally theses registers are not used for storing the data permanently. It carries the 8-bits data. These are used only during the execution of the instructions. These registers can also be used to carry the 16 bits data by making the pair of 2 registers. The valid register pairs available are BC,DE HL. We can not use other pairs except BC,DEand HL. These registers are programmed by user.

ALU

ALU performs the airthmetic operations and logical operation.

Flag Registers

It consists of 5 flip flop which changes its status according to the result stored in an accumulator. It is also known as status registers. It is connected to the ALU.

There are five flip-flops in the flag register are as follows:

1. Sign(S)
2. zero(z)
3. Auxiliary carry(AC)
4. Parity(P)
5. Carry(C)

The bit position of the flip flop in flag register is:

D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**
S	Z		AC		P		CY

All of the three flip flop set and reset according to the stored result in the accumulator.

1.Sign-

If D7 of the result is 1 then sign flag is set otherwise reset. As we know that a number on the D7 always desides the sign of the number. if D7 is 1: the number is negative. if D7 is 0: the number is positive.

2.Zeros(Z)-

If the result stored in an accumulator is zero then this flip flop is set otherwise it is reset.

3.Auxiliary carry(AC)-

If any carry goes from D3 to D4 in the output then it is set otherwise it is reset.

4.Parity(P)-

If the no of 1's is even in the output stored in the accumulator then it is set otherwise it is reset for the odd.

5.Carry(C)-

If the result stored in an accumulator generates a carry in its final output then it is set otherwise it is reset.

Instruction registers(IR)

It is a 8-bit register. When an instruction is fetched from memory then it is stored in this register.

Instruction Decoder

Instruction decoder identifies the instructions. It takes the informations from instruction register and decodes the instruction to be performed.

Program Counter

It is a 16 bit register used as memory pointer. It stores the memory address of the next instruction to be executed. So we can say that this register is used to sequencing the program. Generally the memory have 16 bit addresses so that it has 16 bit memory. The program counter is set to 0000H.

Stack Pointer

It is also a 16 bit register used as memory pointer. It points to the memory location called stack. Generally stack is a reserved portion of memory where information can be stores or taken back together.

Timing and Control Unit

It provides timing and control signal to the microprocessor to perform the various operation.It has three control signal. It controls all external and internal circuits. It operates with reference to clock signal.It synchronizes all the data transfers.

There are three control signal:

1. ALE-Airthmetic Latch Enable, It provides control signal to synchronize the components of microprocessor.
2. RD- This is active low used for reading operation.
3. WR-This is active low used for writing operation.

There are three status signal used in microprocessor S0, S1 and IO/M. It changes its status according the provided input to these pins.

Serial Input Output Control-

There are two pins in this unit. This unit is used for serial data communication.

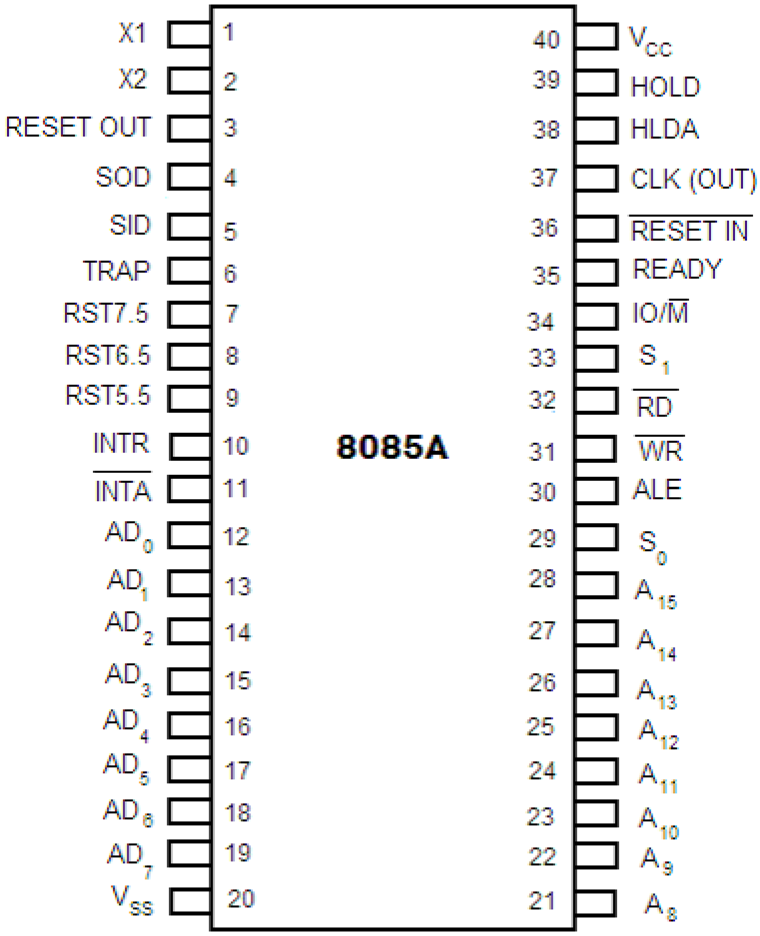
Interrupt Unit

There are 6 interrupt pins in this unit. Generally an external hardware is connected to these pins. These pins provide interrupt signal sent by external hardware to microprocessor and microprocessor sends acknowledgement for receiving the interrupt signal. Generally INTA is used for acknowledgement.

Register Section

Many registers has been used in microprocessor. PIPO shift register It consists of PIPO(Parallel Input Parallel Output) register.

PIN DIAGRAM AND PIN DESCRIPTION OF 8085



8085a 40 pin IC, The signals from the pins can be grouped as follows

1. Power supply and clock signals
2. Address bus
3. Data bus
4. Control and status signals
5. Interrupts and externally initiated signals
6. Serial I/O ports

1. **Power supply and Clock frequency signals:**

Vcc:
+ 5 volt power supply

Vss:
Ground

X1, X2 :
Crystal or R/C network or LC network connections to set the frequency of internal clock generator. The frequency is internally divided by two. Since the basic operating timing frequency is 3 MHz, a 6 MHz crystal is connected externally. CLK (output)-Clock Output is used as the system clock for peripheral and devices interfaced with the microprocessor.

2. Address Bus:

A8 - A15:
(output; 3-state) It carries the most significant 8 bits of the memory address or the 8 bits of the I/O address;

3. Data bus:

AD0 - AD7 (input/output; 3-state)
These multiplexed set of lines used to carry the lower order 8 bit address as well as data bus.
During the opcode fetch operation, in the first clock cycle, the lines deliver the lower order address A0 - A7.
In the subsequent IO / memory, read / write clock cycle the lines are used as data bus.
The CPU may read or write out data through these lines.

4. Control and Status signals:

ALE (output) - Address Latch Enable.
It is an output signal used to give information of AD0-AD7 contents.
It is a positive going pulse generated when a new operation is started by uP.
When pulse goes high it indicates that AD0-AD7 are address.
When it is low it indicates that the contents are data.

RD (output 3-state, active low) - Read memory or IO device.
This indicates that the selected memory location or I/O device is to be read and that the data bus is ready for accepting data from the memory or I/O device

WR (output 3-state, active low) - Write memory or IO device.

This indicates that the data on the data bus is to be written into the selected memory location or I/O device.

IO/M (output) - Select memory or an IO device.

This status signal indicates that the read / write operation relates to whether the memory or I/O device.

It goes high to indicate an I/O operation.

It goes low for memory operations.

5. Status Signals:

S1:

S2:

It is used to know the type of current operation of the microprocessor.

IO/M	S1	S0	OPERATION
0	1	1	Opcode fetch
0	1	0	Memory read
0	0	1	Memory write
1	1	0	I/O read
1	0	1	I/O write
1	1	0	Interrupt acknowledge
Z	0	1	Halt
Z	x	x	Hold
Z	x	x	Reset

6. Interrupts and Externally initiated operations:

They are the signals initiated by an external device to request the microprocessor to do a particular task or work.

There are five hardware interrupts called,

1.TRAP

2.RST 7.5

3.RST 6.5

4.RST 5.5

5.INTA

On receipt of an interrupt, the microprocessor acknowledges the interrupt by the active low INTA (Interrupt Acknowledge) signal.

Reset In (input, active low)

This signal is used to reset the microprocessor.

The program counter inside the microprocessor is set to zero.

The buses are tri-stated.

Reset Out (Output)

It indicates CPU is being reset.
Used to reset all the connected devices when the microprocessor is reset.

7. Direct Memory Access (DMA): Tri state devices:

When 2 or more devices are connected to a common bus, to prevent the devices from interfering with each other, the tristate gates are used to disconnect all devices except the one that is communicating at a given instant.

The CPU controls the data transfer operation between memory and I/O device. Direct Memory Access operation is used for large volume data transfer between memory and an I/O device directly.

The CPU is disabled by tri-stating its buses and the transfer is effected directly by external control circuits.

HOLD signal is generated by the DMA controller circuit. On receipt of this signal, the microprocessor acknowledges the request by sending out **HLDA** signal and leaves out the control of the buses. After the HLDA signal the DMA controller starts the direct transfer of data.

READY (input)

Memory and I/O devices will have slower response compared to microprocessors.
Before completing the present job such a slow peripheral may not be able to handle further data or control signal from CPU.
The processor sets the READY signal after completing the present job to access the data.
The microprocessor enters into WAIT state while the READY pin is disabled.

8. Single Bit Serial I/O ports:

SID (input) - Serial input data line
SOD (output) - Serial output data line
These signals are used for serial communication.

ADDRESSING MODES IN 8085

1. Immediate Addressing Mode
2. Register Addressing Mode
3. Direct Addressing Mode
4. Indirect Addressing Mode
5. Implied/implicit Addressing Mode

Immediate Addressing Mode:

An immediate is transferred directly to the register.
Eg: -

MVI A, 30H (30H is copied into the register A)

MVI B,40H(40H is copied into the register B).

Register Addressing Mode
Data is copied from one register to another register.
Eg: -

MOV B, A (the content of A is copied into the register B)
MOV A, C (the content of C is copied into the register A).

Direct Addressing Mode
Data is directly copied from the given address to the register.
Eg: -

LDA 3000H (The content at the location 3000H is copied to the register A).

Indirect Addressing Mode
The data is transferred from the address pointed by the data in a register to other register.
Eg: -

MOV A, M (data is transferred from the memory location pointed by the regiser to the accumulator).

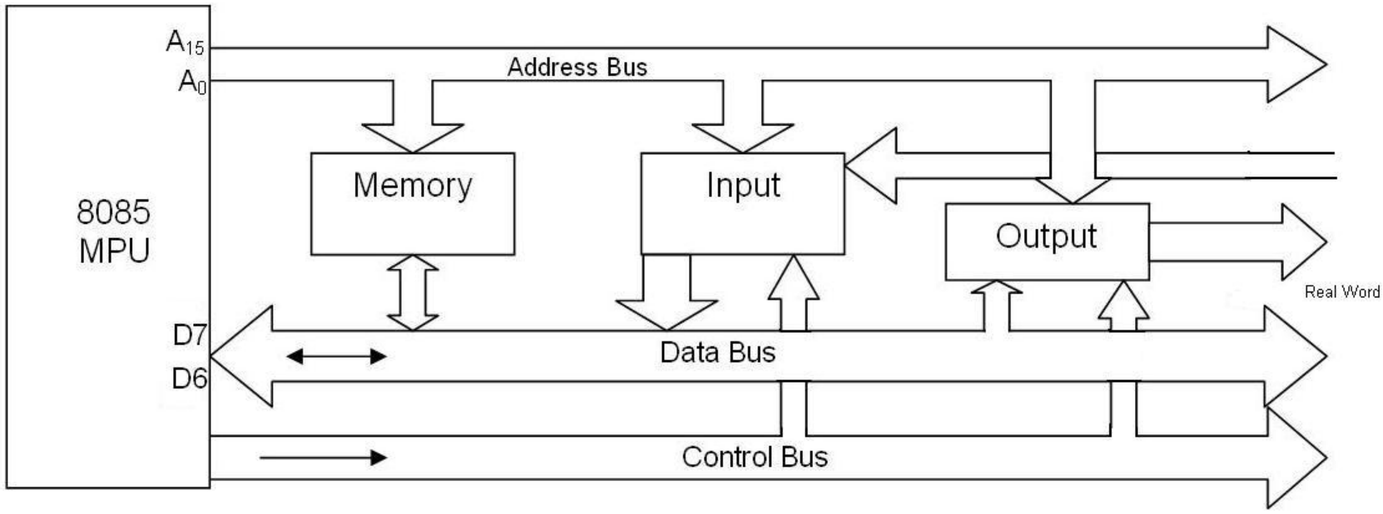
Implied Addressing Mode
This mode doesn't require any operand. The data is specified by opcode itself.
Eg: -

RAL
CMP

BUS STRUCTURE IN 8085

There are three buses in Microprocessor:

1. Address Bus
2. Data Bus
3. Control Bus



Address Bus

Genearlly, Microprocessor has 16 bit address bus. The bus over which the CPU sends out the address of the memory location is known as Address bus. The address bus carries the address of memory location to be written or to be read from.

The address bus is unidirectional. It means bits flowing occurs only in one direction, only from microprocessor to peripheral devices. We can find that how much memory location it can using the formula 2^N. where N is the number of bits used for address lines.

Data Bus

8085 Microprocessor has 8 bit data bus. So it can be used to carry the 8 bit data starting from 00000000H(00H) to 11111111H(FFH). Here 'H' tells the Hexadecimal Number. It is bidirectional. These lines are used for data flowing in both direction means data can be transferred or can be received through these lines. The data bus also connects the I/O ports and CPU. The largest number that can appear on the data bus is 11111111.

It has 8 parallel lines of data bus. So it can access upto 2^8 = 256 data bus lines.

Control Bus

The control bus is used for sending control signals to the memory and I/O devices. The CPU sends control signal on the control bus to enable the outputs of addressed memory devices or I/O port devices.

Some of the control bus signals are as follows:

1. Memory read
2. Memory write

3. I/O read
4. I/O write

Programmable logic controllers

Control loop basics

A familiar example of a control loop is the action taken when adjusting hot and cold faucet valves to maintain the faucet water at the desired temperature. This typically involves the mixing of two process streams, the hot and cold water. The person touches the water to sense or measure its temperature. Based on this feedback they perform a control action to adjust the hot and cold water valves until the process temperature stabilizes at the desired value.

Sensing water temperature is analogous to taking a measurement of the process value or process variable (PV). The desired temperature is called the setpoint (SP). The input to the process (the water valve position) is called the manipulated variable (MV). The difference between the temperature measurement and the setpoint is the error (e) and quantifies whether the water is too hot or too cold and by how much.

After measuring the temperature (PV), and then calculating the error, the controller decides when to change the tap position (MV) and by how much. When the controller first turns the valve on, it may turn the hot valve only slightly if warm water is desired, or it may open the valve all the way if very hot water is desired. This is an example of a simple proportional control. In the event that hot water does not arrive quickly, the controller may try to speed-up the process by opening up the hot water valve more-and-more as time goes by. This is an example of an integral control.

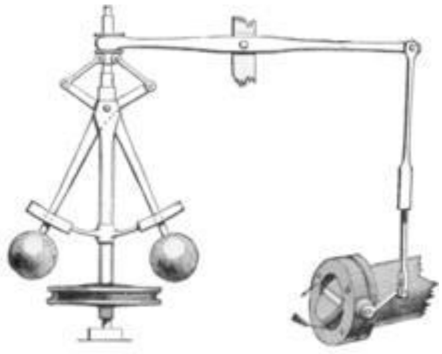
Making a change that is too large when the error is small is equivalent to a high gain controller and will lead to overshoot. If the controller were to repeatedly make changes that were too large and repeatedly overshoot the target, the output would oscillate around the setpoint in either a constant, growing, or decaying sinusoid. If the oscillations increase with time then the system is unstable, whereas if they decrease the system is stable. If the oscillations remain at a constant magnitude the system is marginally stable.

In the interest of achieving a gradual convergence at the desired temperature (SP), the controller may wish to damp the anticipated future oscillations. So in order to compensate for this effect, the controller may elect to temper their adjustments. This can be thought of as a derivative control method.

If a controller starts from a stable state at zero error (PV = SP), then further changes by the controller will be in response to changes in other measured or unmeasured inputs to the process that impact on the process, and hence on the PV. Variables that impact on the process other than the MV are known as disturbances. Generally controllers are used to reject disturbances and/or implement setpoint changes. Changes in feedwater temperature constitute a disturbance to the faucet temperature control process.

In theory, a controller can be used to control any process which has a measurable output (PV), a known ideal value for that output (SP) and an input to the process (MV) that will affect the relevant PV. Controllers are used in industry to regulate temperature, pressure, flow rate, chemical composition, speed and practically every other variable for which a measurement exists.

Proportional control



The fly-ball governor is a classic example of proportional control.

A proportional control system is a type of linear feedback control system. Two classic mechanical examples are the toilet bowl float proportioning valve and the fly-ball governor.

The proportional control system is more complex than an on-off control system like a bi-metallic domestic thermostat, but simpler than a proportional-integral-derivative (PID) control system used in something like an automobile cruise control. On-off control will work where the overall system has a relatively long response time, but will result in instability if the system being controlled has a rapid response time. Proportional control overcomes this by modulating the output to the controlling device, such as a continuously variable valve.

An analogy to on-off control is driving a car by applying either full power or no power and varying the duty cycle, to control speed. The power would be on until the target speed is reached, and then the power would be removed, so the car reduces speed. When the speed falls below the target, with a certain hysteresis, full power would again be applied. It can be seen that this looks like pulse-width modulation, but would obviously result in poor control and large variations in speed. The more powerful the engine, the greater the instability; the heavier the car, the greater the stability. Stability may be expressed as correlating to the power-to-weight ratio of the vehicle.

Proportional control is how most drivers control the speed of a car. If the car is at target speed and the speed increases slightly, the power is reduced slightly, or in proportion to the error (the actual versus target speed), so that the car reduces speed gradually and reaches the target point with very little, if any, "overshoot", so the result is much smoother control than on-off control.

Further refinements like PID control would help compensate for additional variables like hills, where the amount of power needed for a given speed change would vary, which would be accounted for by the integral function of the PID control.

Proportional Control Theory

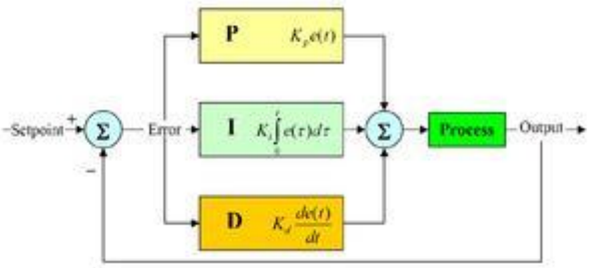
In the proportional control algorithm, the controller output is proportional to the error signal, which is the difference between the set point and the process variable. In other words, the output of a proportional controller is the multiplication product of the error signal and the proportional gain.

This can be mathematically expressed as

where

- P_{out}: Output of the proportional controller
- K_p: Proportional gain
- $e(t)$: Instantaneous process error at time t. $e(t) = SP - PV$
- SP: Set point
- PV: Process variable

PID controller



A proportional–integral–derivative controller (PID controller) is a generic control loop feedback mechanism (controller) widely used in industrial control systems – a PID is the most commonly used feedback controller. A PID controller calculates an "error" value as the difference between a measured process variable and a desired setpoint. The controller attempts to minimize the error by adjusting the process control inputs.

The PID controller calculation (algorithm) involves three separate parameters, and is accordingly sometimes called three-term control: the proportional, the integral and derivative values, denoted *P*, *I,* and *D.* Heuristically, these values can be interpreted in terms of time: *P* depends on the *present* error, *I* on the accumulation of *past* errors, and *D* is a prediction of *future* errors, based on current rate of change.[1] The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve or the power supply of a heating element.

In the absence of knowledge of the underlying process, a PID controller is the best controller.[2] By tuning the three constants in the PID controller algorithm, the controller can provide control action designed for specific process requirements. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the setpoint and the degree of system oscillation. Note that the use of the PID algorithm for control does not guarantee optimal control of the system or system stability.

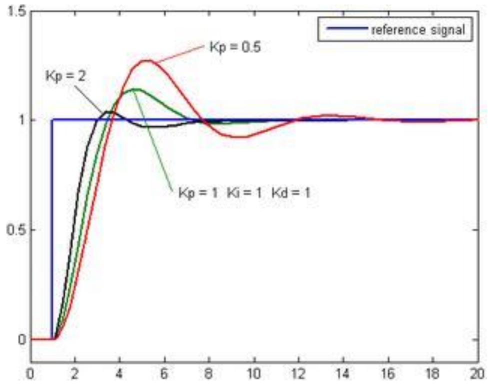
Some applications may require using only one or two modes to provide the appropriate system control. This is achieved by setting the gain of undesired control outputs to zero. A PID controller will be called a PI, PD, P or I controller in the absence of the respective control actions. PI controllers are fairly common, since derivative action is sensitive to measurement noise, whereas the absence of an integral value may prevent the system from reaching its target value due to the control action.

PID controller theory

The PID control scheme is named after its three correcting terms, whose sum constitutes the manipulated variable (MV). Hence:

$$\mathrm{MV(t)} = P_{\mathrm{out}} + I_{\mathrm{out}} + D_{\mathrm{out}}$$

Where P_{out}, I_{out}, and D_{out} are the contributions to the output from the PID controller from each of the three terms, as defined below.



The proportional term (sometimes called *gain*) makes a change to the output that is proportional to the current error value. The proportional response can be adjusted by multiplying the error by a constant K_p, called the proportional gain.

The proportional term is given by:

$$P_{\mathrm{out}} = K_p\, e(t)$$

where

P_{out}: Proportional term of output
K_p: Proportional gain, a tuning parameter
SP: Setpoint, the desired value
PV: Process value (or process variable), the measured value
e: Error = $SP - PV$
t: Time or instantaneous time (the present)

A high proportional gain results in a large change in the output for a given change in the error. If the proportional gain is too high, the system can become unstable (see the section on loop tuning). In contrast, a small gain results in a small output response to a large input error, and a less responsive (or sensitive) controller. If the proportional gain is too low, the control action may be too small when responding to system disturbances.

Droop

A pure proportional controller will not always settle at its target value, but may retain a steady-state error. Specifically, the process gain - drift in the absence of control, such as cooling of a furnace towards room temperature, biases a pure proportional controller. If the process gain is down, as in cooling, then the bias will be *below* the set point, hence the term "droop".

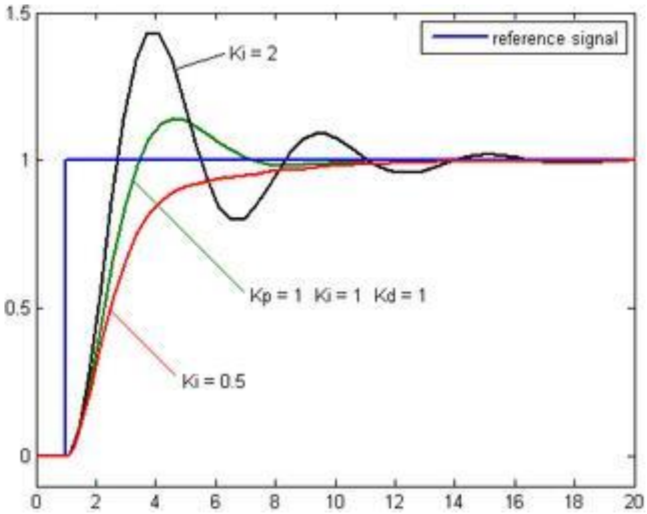
Droop is proportional to process gain and inversely proportional to proportional gain. Specifically the steady-state error is given by:

$e = G / K_p$

Droop is an inherent defect of purely proportional control. Droop may be mitigated by adding a compensating *bias* term (setting the setpoint above the true desired value), or corrected by adding an integration term (in a PI or PID controller), which effectively computes a bias adaptively.

Despite droop, both tuning theory and industrial practice indicate that it is the proportional term that should contribute the bulk of the output change.

Integral term



The contribution from the integral term (sometimes called *reset*) is proportional to both the magnitude of the error and the duration of the error. Summing the instantaneous error over time (integrating the error) gives the accumulated offset that should have been corrected previously. The accumulated error is then multiplied by the integral gain and added to the controller output. The magnitude of the contribution of the integral term to the overall control action is determined by the integral gain, K_i.

The integral term is given by:

$$I_{\text{out}} = K_i \int_0^t e(\tau)\, d\tau$$

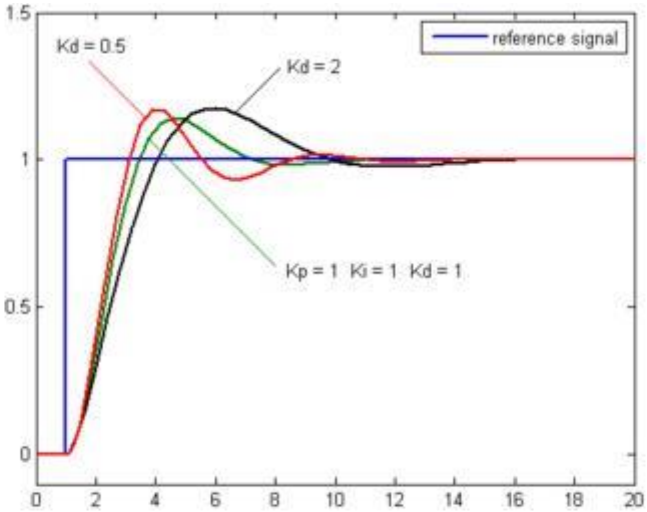
where

I_{out}: Integral term of output
K_i: Integral gain, a tuning parameter
SP: Setpoint, the desired value
PV: Process value (or process variable), the measured value

e: Error = $SP - PV$
t: Time or instantaneous time (the present)
τ: a dummy integration variable

The integral term (when added to the proportional term) accelerates the movement of the process towards setpoint and eliminates the residual steady-state error that occurs with a proportional only controller. However, since the integral term is responding to accumulated errors from the past, it can cause the present value to overshoot the setpoint value (cross over the setpoint and then create a deviation in the other direction). For further notes regarding integral gain tuning and controller stability, see the section on loop tuning.

Derivative term



The rate of change of the process error is calculated by determining the slope of the error over time (i.e., its first derivative with respect to time) and multiplying this rate of change by the derivative gain K_d. The magnitude of the contribution of the derivative term (sometimes called *rate*) to the overall control action is termed the derivative gain, K_d.

The derivative term is given by:

$$D_{\text{out}} = K_d \frac{d}{dt} e(t)$$

where

D_{out}: Derivative term of output
K_d: Derivative gain, a tuning parameter
SP: Setpoint, the desired value
PV: Process value (or process variable), the measured value
e: Error = $SP - PV$
t: Time or instantaneous time (the present)

The derivative term slows the rate of change of the controller output and this effect is most noticeable close to the controller setpoint. Hence, derivative control is used to reduce the magnitude of the overshoot produced by the integral component and improve the combined controller-process stability. However, differentiation of a signal amplifies noise and thus this term in the controller is highly sensitive to noise in the error term, and can cause a process to become unstable if the noise and the derivative gain are sufficiently large. Hence an approximation to a differentiator with a limited bandwidth is more commonly used. Such a circuit is known as a Phase-Lead compensator.

Summary

The proportional, integral, and derivative terms are summed to calculate the output of the PID controller. Defining $u(t)$ as the controller output, the final form of the PID algorithm is:

$$\mathrm{u(t)} = \mathrm{MV(t)} = K_p e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{d}{dt} e(t)$$

where the tuning parameters are:

Proportional gain, K_p

Larger values typically mean faster response since the larger the error, the larger the proportional term compensation. An excessively large proportional gain will lead to process instability and oscillation.

Integral gain, K_i

Larger values imply steady state errors are eliminated more quickly. The trade-off is larger overshoot: any negative error integrated during transient response must be integrated away by positive error before reaching steady state.

Derivative gain, K_d

Larger values decrease overshoot, but slow down transient response and may lead to instability due to signal noise amplification in the differentiation of the error.

Motion control

Motion control is a sub-field of automation, in which the position and/or velocity of machines are controlled using some type of device such as a hydraulic pump, linear actuator, or an electric motor, generally a servo. Motion control is an important part of robotics and CNC machine tools, however it is more complex than in the use of specialized machines, where the kinematics are usually simpler. The latter is often called General Motion Control (GMC). Motion control is widely used in the packaging, printing, textile, semiconductor production, and assembly industries.

The basic architecture of a motion control system contains:

- A motion controller to generate set points (the desired output or motion profile) and close a position and/or velocity feedback loop.
- A drive or amplifier to transform the control signal from the motion controller

into a higher power electrical current or voltage that is presented to the actuator. Newer "intelligent" drives can close the position and velocity loops internally, resulting in much more accurate control.

- An actuator such as a hydraulic pump, air cylinder, linear actuator, or electric motor for output motion.
- One or more feedback sensors such as optical encoders, resolvers or Hall effect devices to return the position and/or velocity of the actuator to the motion controller in order to close the position and/or velocity control loops.
- Mechanical components to transform the motion of the actuator into the desired motion, including: gears, shafting, ball screw, belts, linkages, and linear and rotational bearings.

PROGRAMMABLE LOGIC CONTROLLER

A programmable Logic Controller (PLC) is defined as a digital electronic device that uses a programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting and arithmetic in order to control machines and processes.

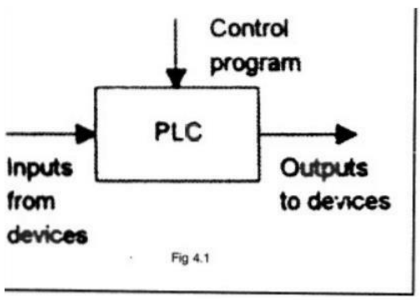


Fig 4.1

Features of PLC as a Controller:

PLC's are rugged and designed to withstand vibrations, temperature, humidity and noise. The interfacing for inputs and output is inside the controller. PLC's are easily programmable and have an easily understandable programming language. Programming is primarily concerned with logic and Switching operations.

BASIC STRUCTURE

The fig. shows the basic internal structure of a PLC. It consists essentially of a central processing unit (CPU), memory and input/output (I/0) circuitry. The CPU controls and processes all the operations within the PLC. It is supplied with a clock of frequency typically between 1 and 8 MHz. This frequency determines the operating speed of the PLC and provides the timing and synchronization for all elements in the system. A bus system carries information and data to and from the CPU, memory and input/output units. There are several memory elements: a system ROM to give permanent storage for the operating system and fixed data; RAM for the user's program, and temporary buffer storage for I/0 channels. The programs in RAM can be changed by the user. However, to prevent the loss of these programs during power failure, a battery is likely to be used in the PLC to hold the RAM contents for a period

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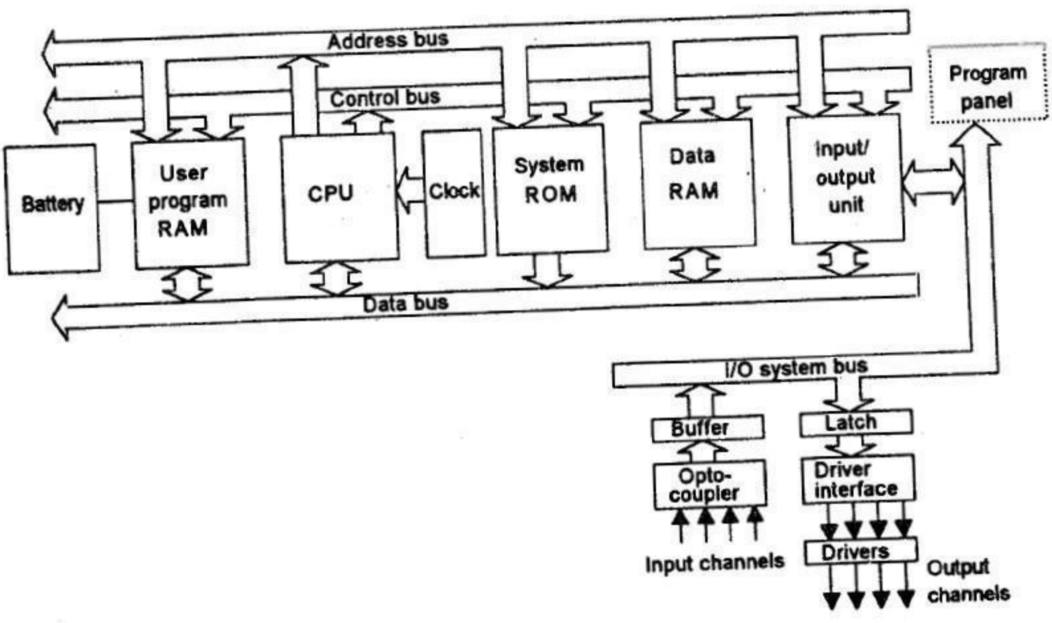
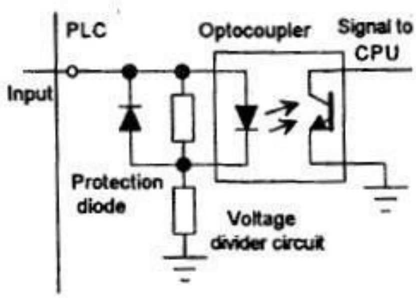


After a program has been developed in RAM, it may be loaded into an EPROM memory chip and so made permanent. The I/0 unit provides the interface between the system and the outside world. Programs are entered into the system through input devices like key pad or sometimes through Personal Computer (PC) which is loaded with an appropriate software package. The I/0 channels have signal conditioning and isolation units, so that sensors and actuators can be generally directly connected to them without the need for any other circuitry. The figure shows the basic form of an input channel. Common input voltages are 5V and 24VCommon output voltages are 24V and 240V.



There are three types of output

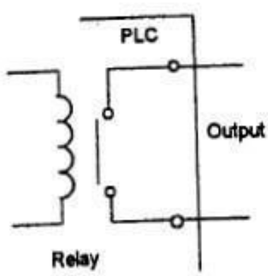
1) Relay type.

2) Transistor type.

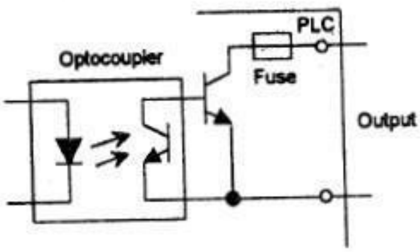
3) Triac type

1) Relay Type

With relay type, the signal from the **PLC** output is used to operate a relay and so is able to switch currents of the order of few amperes in an external circuit. The relay isolates the **PLC** from the external circuit and can be used for both d.c and a.c switching Relays are relatively slow to operate.



2) Transistor type



The transistor type of output (fig) uses a transistor to switch current through the external circuit. This provides a faster switching action. Opto isolators are used with transistor switches to provide isolation between the external circuit and the **PLC.** The transistor output is only for D.C. switching.

3) Triac type:

Triac outputs can be used to control external loads which are connected to the a.c. power supply. Opto isolators are again used to provide isolation.

INPUT / OUTPUT PROCESSING

The programming commonly used with PLC is ladder programming. This involves each program task being specified as through a rung of a ladder. This each rung could be specify that the state of switches A&B.The inputs, be examined and if A&B are both closed then a solenoid, the output is energized. The sequence followed by a PLC when carrying out a program can be as follows

1. Scan the inputs associated with one rung of the ladder program.

2. Solve the logic operation involving those inputs.

3. Set/reset the output for that rung.

4. Move on the next rung and repeat the operations 1, 2, 3.

Thus a PLC is continuously running through its program and updating it as a result of input signal. Each such loop is termed as cycle. This continues until the program is competed.

There are two methods that can be used for I/0 processing:

1. Continuous updating

In this method, the **CPU** scans input channels as they occurring the program instructions. Each input is examined individually and its effect on the program determined. there involves a time delay, typically about 3 ms, when each input is scanned in order to ensure that only valid input signals are read by the microprocessor.

This delay enable **CPU** to avoid counting an input signal twice, A number of inputs may have to be scanned, each with a 3 ms delay, before the program has the instruction for a logic operation to be executed and an output to occur. The outputs are latched so that they retain their status until the next update. The 3 ms built-in delay for each input is, for ensuring the signals read by the **CPU** is the valid one. or more frequently, if there is contact bounce at a switch.

2. Mass I/0 Copying

In the above method, with 3 ms delay on each input, the time taken to examine several hundred I/0 points can become comparatively long. To allow a more rapid execution of a program, a specific area of RAM is used as a buffer store between the control logic and I/0 units. Each I/0 have and address in this memory. At the start of each program is executed the stored input data is read, as required, from RAM and

the logic operations carried out. The resulting output signals are stored in the reserved I/0 section RAM. At the end of each program cycle, all the outputs are transferred from RAM to the output channels. The outputs are latched so that they retain their status until the next update.

PROGRAMMING

Ladder diagram

PLC's are programmed using ladder diagram techniques. A special standard schematic representation of the physical components arrangement (hardware) and its way of connections made between them is called as ladder diagram. These are line diagram the represent both the system hardware and the process controller.

A ladder diagram consists of two vertical lines called power power rails are connected along with I/O devices and other components as horizontal lines between the two vertical lines known as rungs.

Rules followed in ladder diagram

1. The vertical lines of the diagram represent the power rails, and the horizontal lines representing the rungs.

2. Each rung on the ladder defines one operation in the control process.

3. A ladder diagram must read from left to right and from top to bottom. when the scanning of first rung is completed then the second rung starts from left to right.

4. Each rung must start with an input and must end with an output.

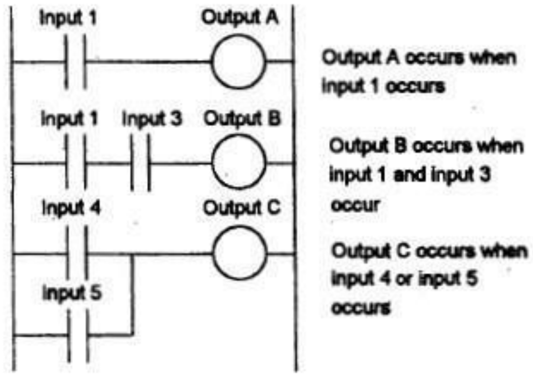
5. Each rung must have more than one input but only one output.

6. The input must always located at the rung left and the output at the right end of the rung.

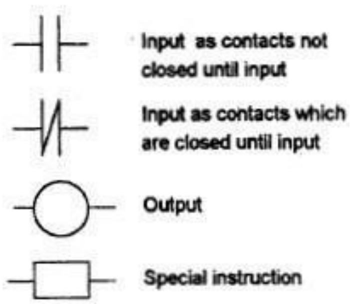
7. Electrical devices are shown in their normal condition.

Ladder diagram can be entering from a monitor screen by using mouse. When entered, they translated by the PLC into machine language for microprocessor to understand it. The nature of input determines whether the output is to be energized or not.

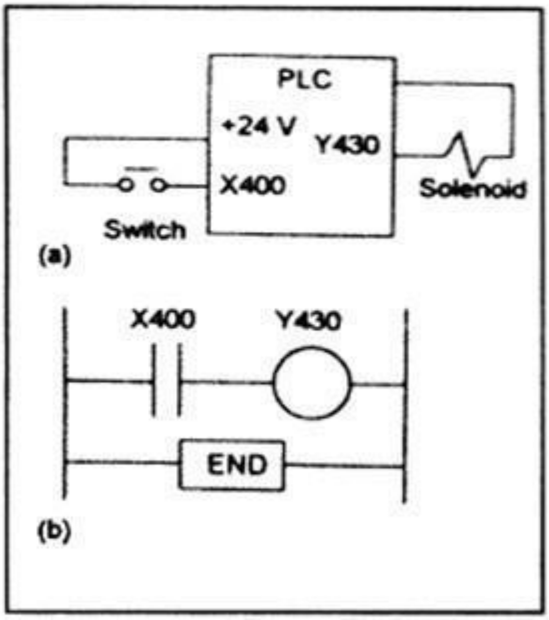
The Ladder programming is one of the basic forms of programming commonly used with PLC's. In this type of programming, each program task being specified as though a rung of ladder. Circuits are connected between these two vertical lines as horizontal lines, i.e. the rungs of the ladder. Fig. shows the basic symbols that are used in the ladder diagram.



Ladder Symbols



Precede outputs and depending on, the different **PLC** manufacturer, different notations are used. For example, the Mitsubishi F series of PLC's precedes inputs elements by an X and output elements by a Y and uses the following numbers: Numbering schemes are followed for inputs and outputs and depending on, the different PLC manufacturer, different notations are used. For example, the Mitsubishi F series of PLC's precedes inputs elements by an X and output elements by a Y and uses the following numbers:



Inputs X300 - 307,310 - 313 X600 - 607,610 - 61 3

(24 possible inputs)

Outputs Y330-337

Y 430 - 437

(1 6 possible outputs)

To illustrate the drawing of a ladder diagram, consider a situation where the output from the PLC is to energies a solenoid when a normally open start switch connected to the input is activated by being closed (Fig. (a)). the program required is shown in

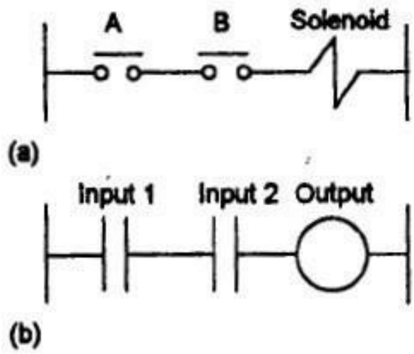
Starting with the input, we have the normally open symbol 11. This might have an input addressX400. The line terminates with the output, the solenoid, with the symbol

0. This might have the output address Y430. To indicate the end of the program the end rung is marked. When the switch is closed the solenoid is activated. This might, for example, be a solenoid valve which opens to allow water to enter a vessel.

LOGIC FUNCTIONS

Logic functions may be obtained through various combinations of switches. Also it is explained how one can write ladder program using such combinations.

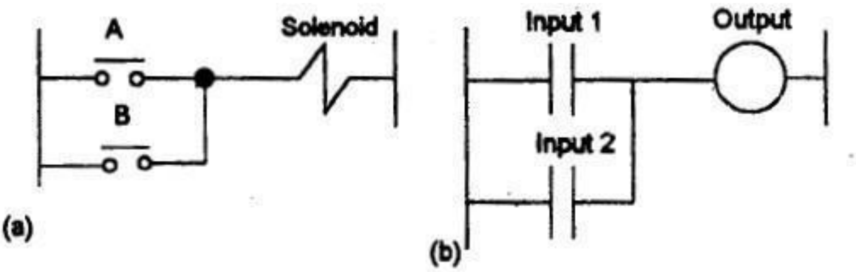
1. And function



Only when both the switches are closed simultaneously, the lamp will be lit, otherwise it is put off. Thus, this situation corresponds to an **AND** logic function. The ladder diagram representing the **AND** function is shown in Fig.(b). The switches A and B are represented as input 1 and input 2 and lamp is represented as an output.

2. OR function

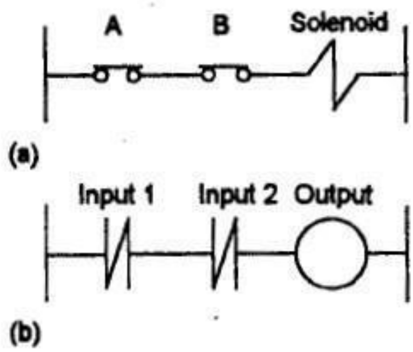
Consider a situation shown in Fig.



If either one of the switch A or B is closed, then the lamp will be lit. If both switches are opened simultaneously, then lamp will be put off. This situation Corresponds to an OR system. The ladder diagram representing the OR function is shown in fig.(b) The switches A and B are represented as output.

3. **Nor function**

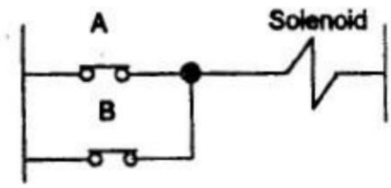
Consider a situation show in Fig. (a)



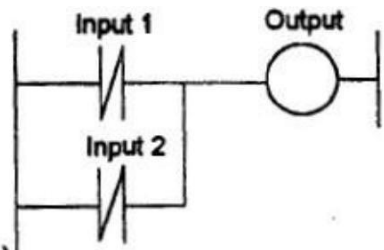
When neither A nor B have an input (i.e., neither switch A nor switch B is opened) the lamp will be lit. When there is input to A or B (i.e., if switch A or B is opened) the lamp will be put off. This situation corresponds to a NOR system. The ladder diagram representing NOR function is shown in Fig. (b) Switch A and B are represented as input 1 and input 2; and lamp is represented as output. In this case the switches A and B are normally closed. When input occurs, the corresponding switch is opened. There will be output if neither of the input occurs. There will not be output if any of the input occurs.

4. NAND Function

Consider a situation show in Fig. (a)



(a)

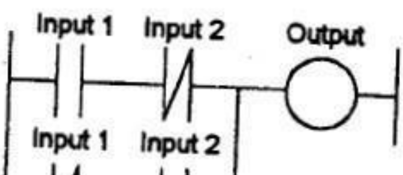


(b)

The lamp will not be lit, when both A and B have input simultaneously (i.e., when both are opened simultaneously the lamp will be lit if both inputs did not occur simultaneously (i.e., when both are not opened simultaneously). The ladder diagram is shown in Fig. (b)

5. EXCLUSIVE-OR (XOR) function

Consider a situation shown in Fig. (a) In this system, there will be output (i.e., the lamp will be lit) if any one of the input occurs. There will not be output if both inputs occur or if both do not occur. The ladder diagram is shown in Fig (b) Note that, it is represented, each input by two sets of contacts, one normally open and one normally closed.



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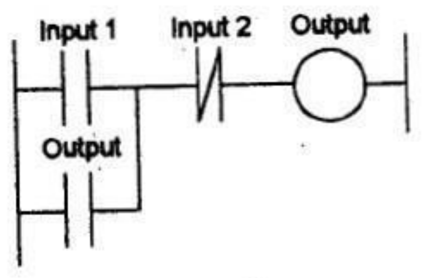
LATCHING

There are often situation where it is necessary to hold a coil energized, even when the input which energized it ceases. The term latch circuit is used for the circuit used to carry out such and operation. It is a self-maintaining circuit in that, after being energized, it maintains that state until another input is received. It remembers its last state.



UNIT – V

DESIGN OF MECHATRONICS SYSTEMS

Introduction

Design through mechatronics approach requires the integration of a wide range of material and information to provide more flexible and of high performance products including wide range of features.

The mechatronic approach to engineering design thus involves an integration of the electronics and computing technologies with the mechanical system through out the design process. This mechatronic approach may be used to provide enhanced performance products and other outputs to customer. Stages in designing Mechatronic Systems

The design of mechatronic systems can be divided into a number of stages.

1. The Need:

The design process starts with the need of a customer. By adequate market research and knowledge, the potential needs of a customer can be clearly identified. In come cases, company may create a market need but failures are more in this area. Hence, market research technology is necessary.

2. Analysis of the Problem:

This is the first stage and also the critical stage in the design process. After knowing the customer need, analysis should be done to know the true nature of the problem. Shady, to define a problem accurately, analysis should be done carefully otherwise. The design leads to waste of time and may not fulfill the need.

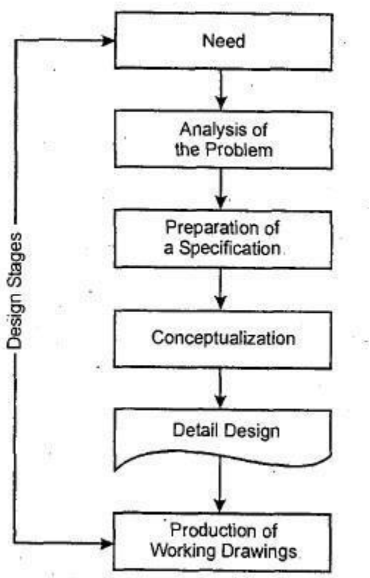
3. Preparation of a Specification:

The second stage of the mechatronic process involves in the preparation of a specification. The specification must be given to understand everyone the requirements and functions to be met. The specification might have the statements about mass dimensions, types, accuracy, input/output requirements, interfaces, power requirements, operating environment, relevant standards and codes of practice, space requirements and constrain payload, velocities and speed of motion, accelerations, resolution, control functions, life etc.

4. Conceptualization:

In this stage, possible solutions should be generated for each of the functions required. Such as shape, size, material cost etc.,., It should be possible to think of at

least six solution for realizing each function. For obtaining a solution, similar problems that are solved linearly days are compared or newly generated techniques may be used.



5. Optimization:

This stage involves in a selection of a best solution for the problem. Optimization is defined as a technique in which a best solution is selected among a group of solutions to solve a problem. The various possible solutions are evaluated and the most suitable solution is selected.

6. Detail Design:

. Once optimizing a solution is completed, the detail design of that solution is developed. This may require a production of prototype etc., Mechanical layout is to be made whether physically all components can be accommodated. Also whether components are accessible for replacement/ maintenance is to be checked.

7. Production of working Drawings:

manufacturing tolerances for each component.

Difference between Traditional and Mechatronics Approach

S.No	Traditional Approach	Mechatronics Approach
1.	Bulky system	Compact
2.	It is a complex process involving interactions between many skills and disciplines.	It is the basic of integration of various emerging technology with mechanical engineering.
3.	The control is accomplished by manually.	A microprocessor is used a controller by programming it.
4.	Complex mechanisms	Simplified mechanism may transferred to the software through programs.
5.	Non-adjustable movement cycles	Programmed movements.
6.	Constant speed drives	Variable speed drives
7.	Mechanical Synchronization	Electronic Synchronization
8.	Rigid heavy structures	Lighter Structures.
9.	Accuracy determined by tolerance of mechanism	Accuracy achieved by feedback
10.	Flexibility is less	Flexibility is more.
11.	Less accurate	More accurate.
12.	It consists of more components and moving parts.	It involves less components and moving parts
13.	Less cost	High cost.

POSSIBLE DESIGN SOLUTIONS

One can design or generate more than one possible solution for every problem which are faced during designing a product or system. The possible design solutions for some systems are given below.

1. Timed Switch

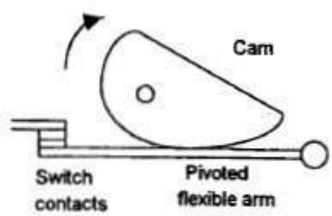
Time switch is a device like cam that is used to switch ON a motor (or) some actuator for some period of time.

Possible Solution

a) Mechanical Solution

Timed switch uses a mechanical cam for this purpose. The rotating member (cam) of a system is rotating at a constant rate.

Consider a requirement for a device which is used to switch on a motor for some prescribed time. For this problem, a traditional mechanical system consists of a rotating cam and pivoted flexible arm as shown in Figure. The cam is rotated at a constant rate and the pivoted flexible arm which acts as a cam follower is used to actuate a switch. The amount of time for which the switch is closed depends on the shape of the cam and speed of the revolution of cam. Some of the possible solution for this problem using a mechatronics approach is explained below.

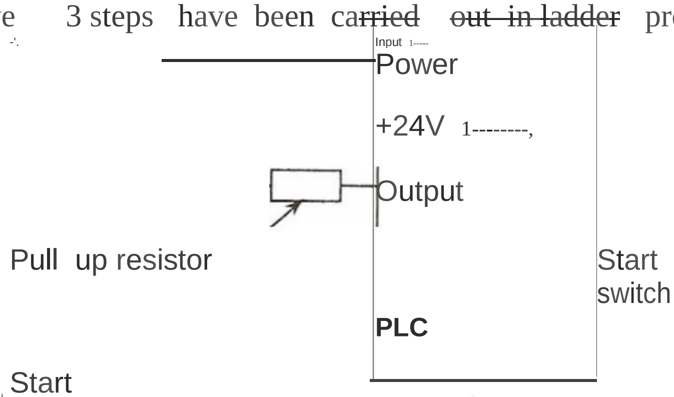


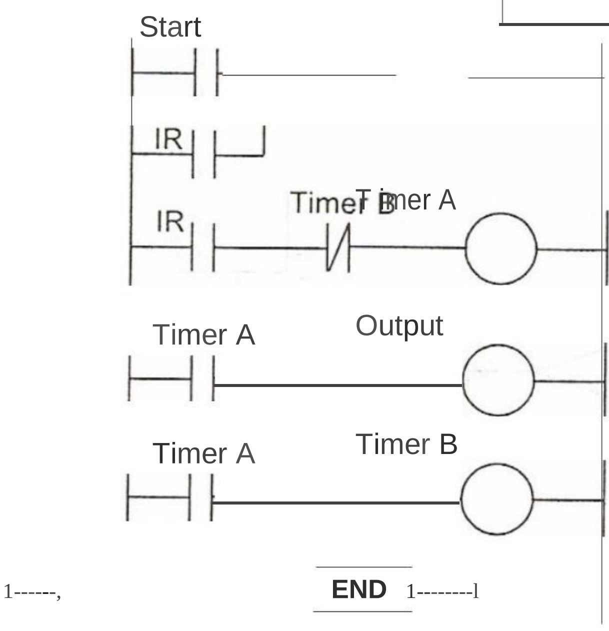
Possible solution1:

The above problem can be solved by PLC arrangement as shown Figure The ladder program is also shown in this Figure. To start the timer the following requirements should be satisfied.

- Start the pulse applied.
- Check the timer whether it is ON or OFF condition.
- The timer should be in OFF condition before triggering.

The above 3 steps have been carried out in ladder program.





Apply the start pulse which energies the IR

Switch on timer A by IR. Set the timer for which the timer is in ON

Get the output from timer A

Timer B started when timer A switched ON and determines the time at which output switched OFF

The duration of the timer A and timer B can be varied by using a microprocessor with a memory chip and input/output interfaces. The memory chip can be activated by an assembly .angnage program. The program is written in such a manner that the timer is turned ON by a

start pulse, after a particular duration (i.e., delay time) the timer is turned OFF.

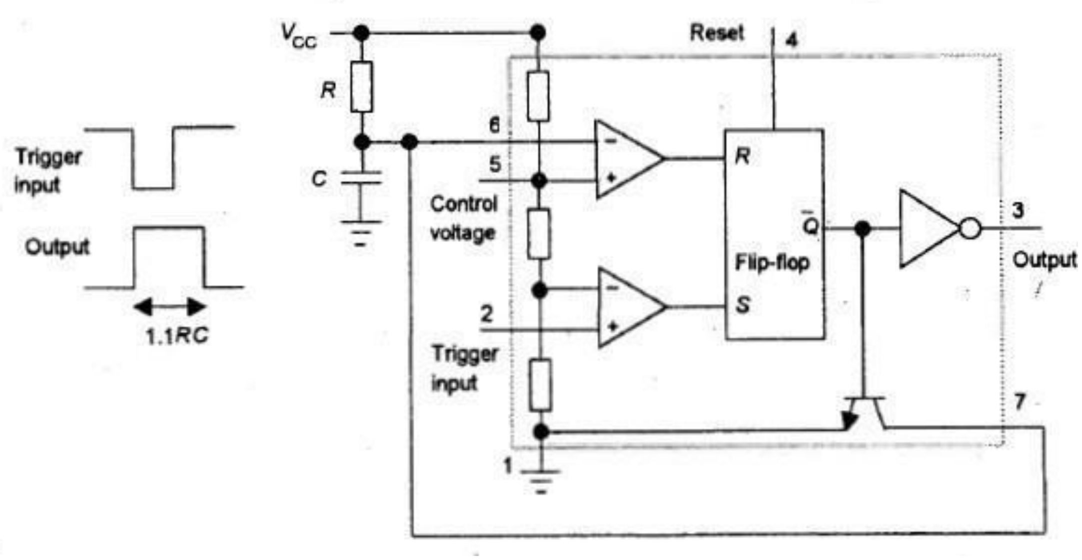
Solution through 555 Timer IC Module

This system uses microprocessor with a 555 Timer IC module. The external resistors and capacitors are used to set the timing intervals in 555 timer.

When the circuit is triggered with input, the output is tuned ON and the time duration of ON output being 1.1 RC where R is the resistance in ohms and C is the capacitance in farads.

Most probably, the values of R and C are very large R varies from IKR to IMR and correspondingly C varies from 0.1 µF to 10µF. When electrolytic capacitors are used. The accuracy is maintained within this limit of R and C values otherwise leakage capacitance becomes a problem.

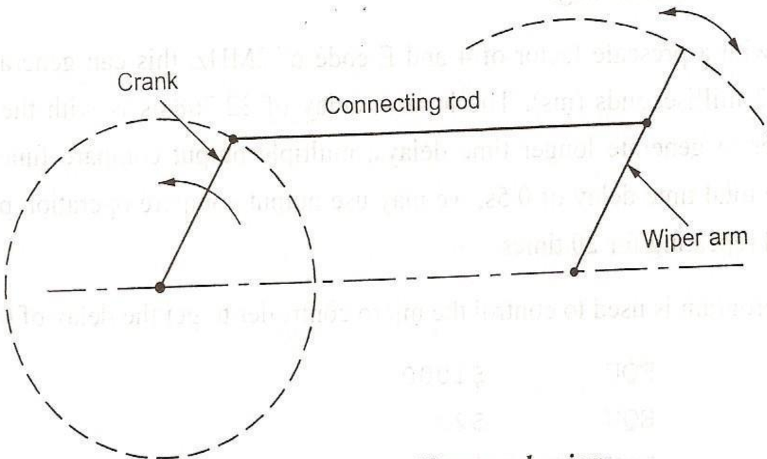
Thus the circuit shown is suited where time delay is less than 10s. If more time delay is required about from 16ms to days, 555 timer is replaced with ZN 1034E timer.



Wind Screen -Wiper Motion

Wind screen Wiper is a device which is used to clear the front glass of the vehicles, during rainy season. It consists of an arm which oscillates back and forth in an arc like a wind screen wiper.

Windscreen wiper motion



Wiper mechanism

A windscreen wiper is a device which is used to clear the front glass of cars, buses, trains etc., during rainy days. It will oscillate an arm back and forth in an arc like a windscreen wiper. A traditional mechanical solution for this problem is shown in Figure It uses a principle of four-bar mechanisms. It consists of a crank which rotates about its center and a connecting rod. The end of the connecting rod is connected to the crank and the other one with a wiper arm. The rotation of the crank causes the connecting rod to impart an oscillatory motion to the wiper arm.

An alternative mechatronics approach for this problem is to use a stepper motor. For operating a stepper motor a microprocessor with a PIA, or a micro controller can be used. Figure shows a circuit for interfacing a stepper motor with a micro controller or PIA.

The input to the stepper motor is required to cause it to rotate a number of steps in one direction and reversing the same number of steps in the other direction while the data is reversed.

b) Mechatronic approach

The mechatronics approach uses a stepper motor with microprocessor for controlling it. The input to the stepper is required to cause it to rotate a number of steps in one direction and then reverse to rotate the same number of steps in other direction.

In the figure, isolating diodes are used to prevent the current flew into the micro controller from interfacing circuits. Transistors are used as a switch for controlling the stepper motor. Data in the data bus causes the transistors to turn OFF/ON according to the data conditions 0 or 1 respectively.

To start and rotate the motor, the coils of the stepper motor are to be energized in a proper sequence. Stepper motor can be operated in two configurations.

1. Full step Configuration.
2. Half step Configuration.

1. Full Step Configuration

If the stepper motor is to be rotated in full step configuration then the outputs are tabulated as shown. To rotate the motor in a forward direction, the output sequence is A, 9, 5, 6 and then back to A. To rotate the motor in a reverse direction, the output sequences 6, 5, 9, A and then back to 6.

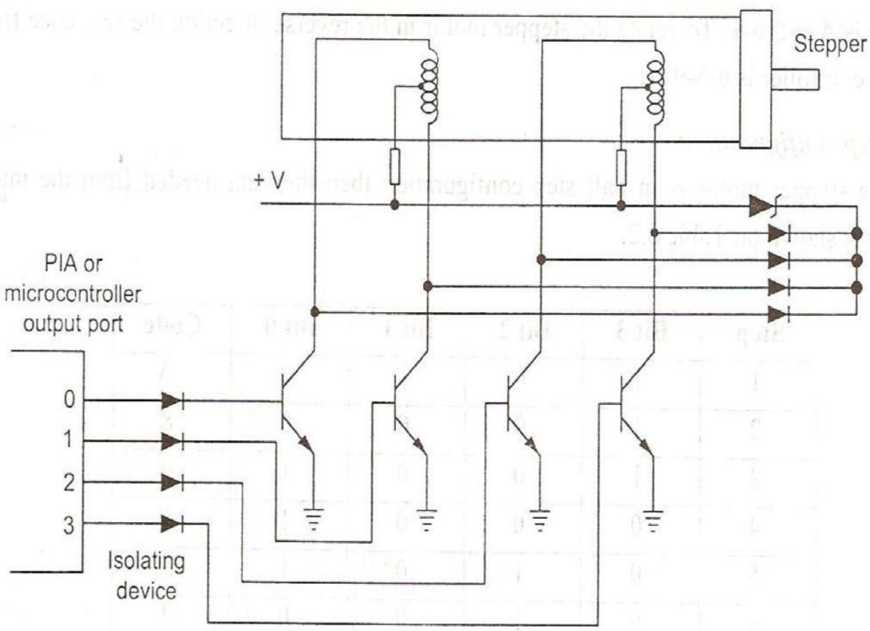
Table

Step	Bit 3	Bit 2	Bit 1	Bit 0	Code
1	1	0	1	0	A
2	1	0	0	1	9
3	0	1	0	1	5
4	0	1	1	0	6
1	1	0	1	0	1

2. Half Step Configuration

If the motor is to be rotated in 'half-step configuration' then the outputs are tabulated as shown. To rotate the motor in a forward direction, the output sequence is A,

8,9,1,5,4,6,2 and then back to A. To rotate the motor in a reverse direction, the output sequences 2,6,4,5, 1, 9, 8 A and then back to 2.



Step	Bit 3	Bit 2	Bit 1	Bit 0	Code
1	1	0	1	0	A
2	1	0	0	0	8
3	1	0	0	1	9
4	0	0	0	1	1
5	0	1	0	1	5
6	0	1	0	0	4
7	0	1	1	0	6
8	0	0	1	0	2
1	1	0	1	0	A

requirement is that when a person stands on a platform the weight is to be indicated with reasonable speed and accuracy independent of where on the platform the person stands.

It consists of two parallel leaf springs which deflects due to the weight of a person standing on the platform. The deflection of the leaf spring can be transformed into movement of a pointer across a scale through the rack and pinion arrangement with a bevel gear. Rack and pinion arrangement transforms the linear motion into circular motion about a horizontal axis which is then transformed into a rotation of a pointer about a vertical axis by means of bevel gear.

Weighing scales

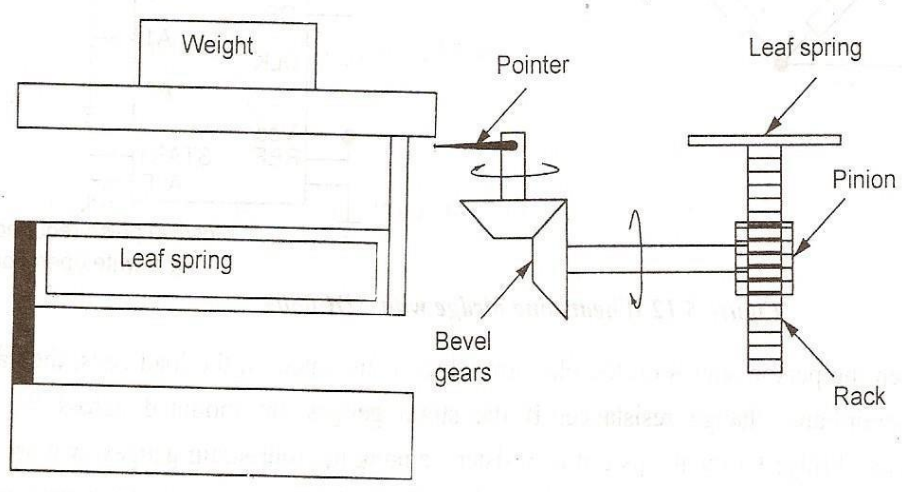
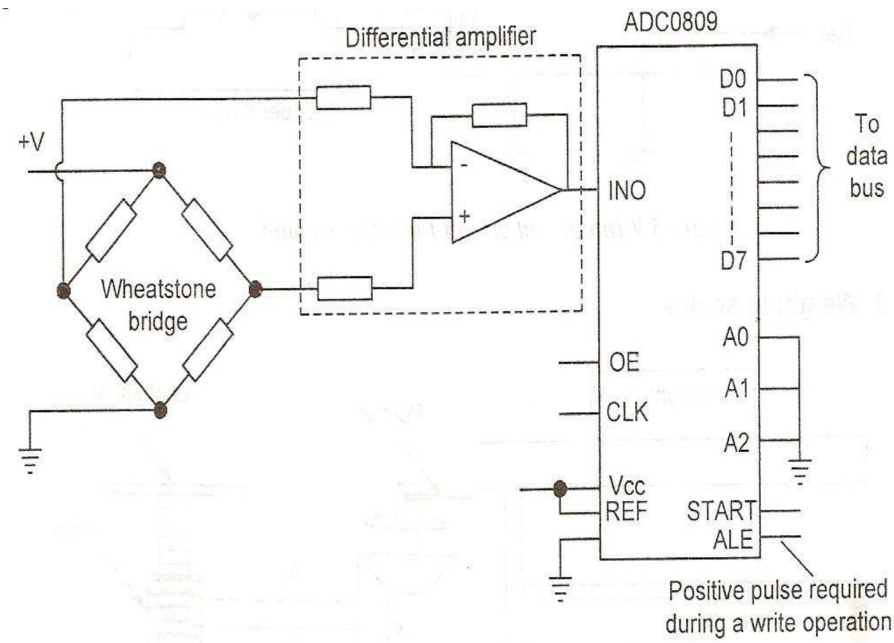


Figure Weighing scale *Figure Weighing scale - Mechanism*

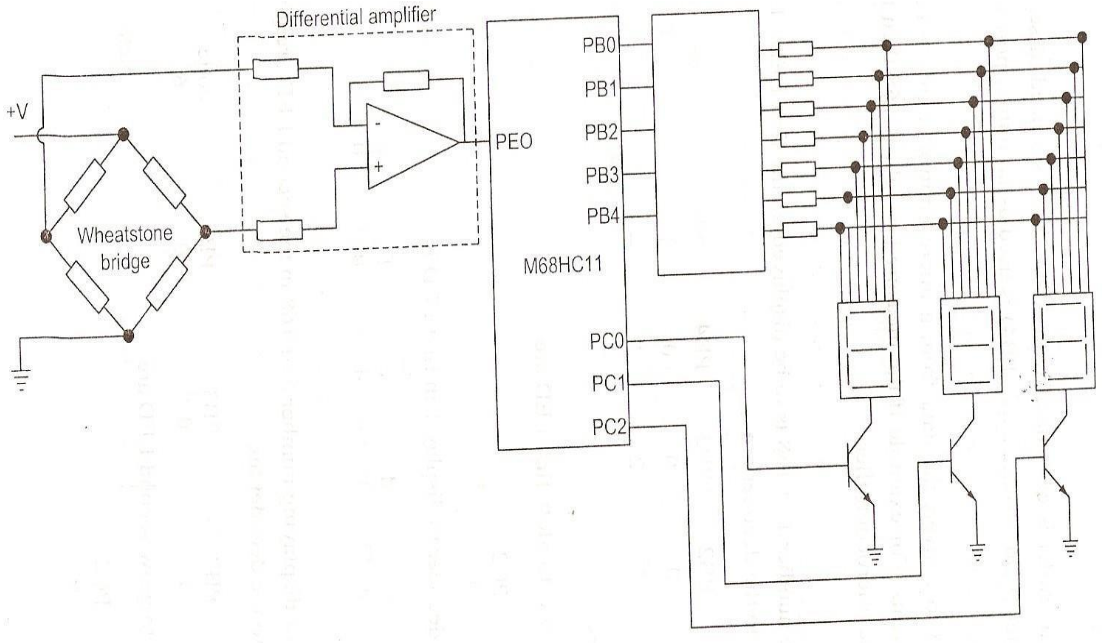
(1) Mechatronic Solution

The mechatronics solution uses a microprocessor for this problem. The platform can be mounted on load ceils employing electrical resistance strain gauges. When the person stands on the platform gauges suffer strain and change resistance. If the gauges are mounted in a four-active arm Wheatstone bridge, then the output is the out-of-balance voltage which is a measure of the weight of the person. This is amplified by a differential operational Amplifier. Among the four resisters, two in tension and two in compression When as load is applied on strain gauges, the resistance of the strain gauges varies and causes imbalance in Wheatstone bridge. This in-turn measured as a voltage across the Wheatstone bridge. The resulting amplified analogue signal is then fed through a latched ADC for inputting to the microprocessor.



b) Microcontroller Solution

If a microcontroller is used then memory is preset within the single microprocessor chip. ADC is used to provide the inputs for microcontroller. When a load is applied, the voltage is produced in the strain gauges. This is amplified by an operational amplifier and then given to the micro controller through ADC interface.



The outputs of the micro controller are passed through ports B and C to a Decoder and hence a LED disp1ay.Decoder is used to convert the data from microcontroller into seven segment data to glow the LED segments. By writing proper program, the data (weight of a person) will be displayed the LED.

Step 1:

Initially the number 1 of 168 is to be displayed on the first LED. For this purpose the input data given to the decoder are

PB0	PB1	PB2	PB3	PB4	code
1	0	0	0	0	1
2^0	2^1	2^2	2^3	2^4	--

Weighting factors.

The data from port C to glow first LED are

PC0	PC1	PC2
1	0	0

The output from decoder to display 1 in first LED is

a	b	c	d	e	f	g
0	0	0	1	1	0	0

Step 2:

Similarly, for displaying number 6 of 168 in the second LED are given as follows:
Input data given to the decoder are

PB0	PB1	PB2	PB3	PB4	code
0	1	1	0	0	6

Data from port C to glow second LED are

PC0	PC1	PC2
0	1	0

Step 3:

For displaying number 8 of 168 in the third LED is given as follows.

Input data given to decoder are

PB0	PB1	PB2	PB3	PB4	code
0	0	0	1	0	8

Data from port C to glow second LED are

PC0	PC1	PC2
0	0	1

The output from decoder to display 1 in first LED is

a	b	c	d	e	f	g
1	1	1	1	1	1	1

CASE STUDIES OF MECHATRONICS SYSTEMS Now-a-days in many industries. Some of the example outlines are given below.

1. Pick and Place robot

Figure shows the basic form of a pick and place robot unit. The robot has three axes and about these three axes only motion occurs. The following movements are required for this robot.

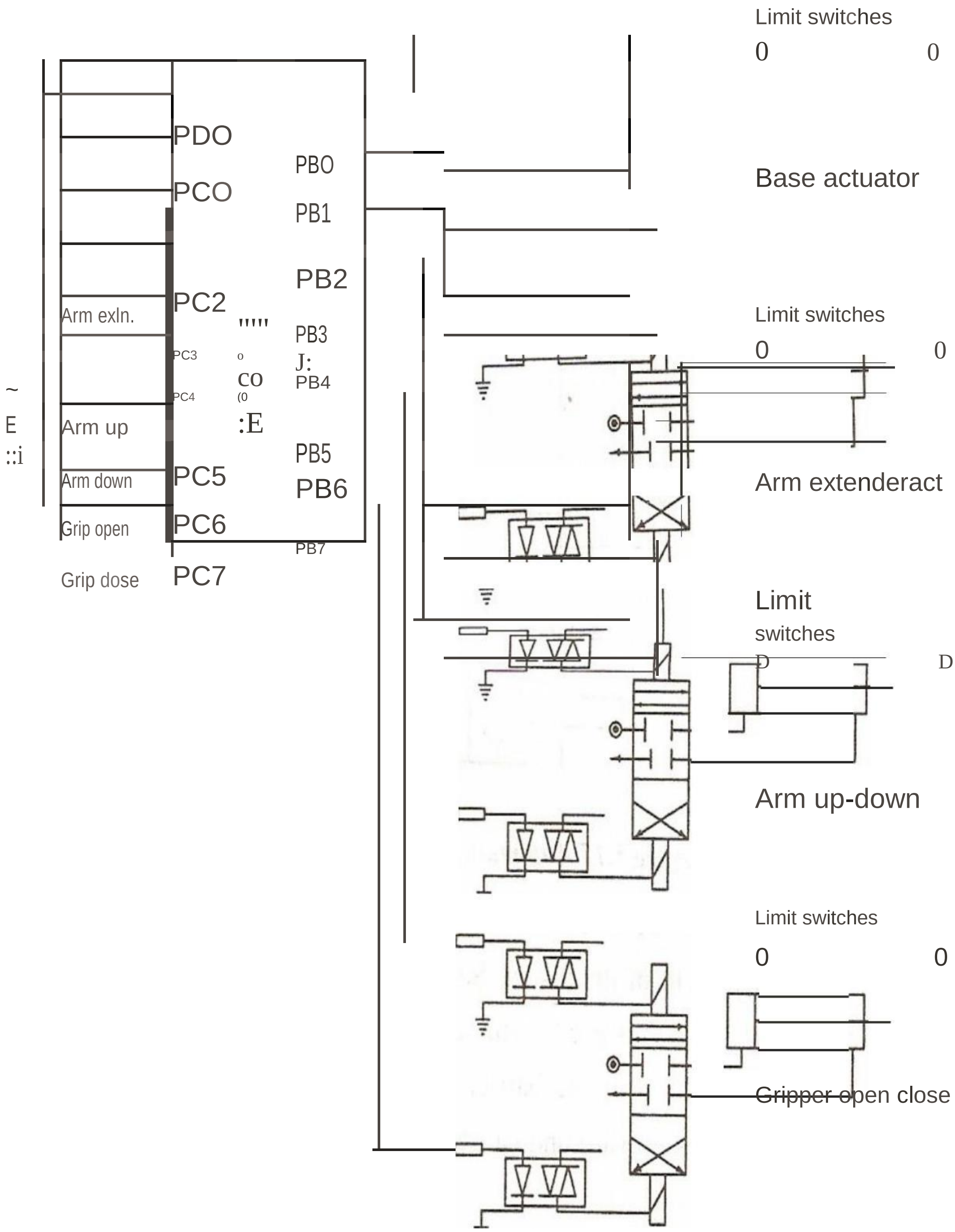
1. Clockwise and Anti-clockwise rotation of the robot unit on its base
2. Horizontal linear movement of the arm to extend or contraction
3. Up and down movement of the arm and
4. Open or close movement of the gripper

The above movements are accomplished by the use of pneumatic cylinders operated by solenoid controlled values with limit switches. The limit switches are used to indicate when a motion is completed. Thus, a clockwise rotation of the robot unit can be obtained from a piston and cylinder arrangement during its extension and that of counter clockwise during its retraction, Likewise, the upward and downward movement of the arm can be obtained from a piston and cylinder arrangement during the extension and retraction of a piston respectively.

Similarly, the gripper can be opened or closed by the piston in a linear cylinder during its extension is shown in figure. Another figure shows the micro controller used to control the solenoid values and hence the movements of the robot unit.

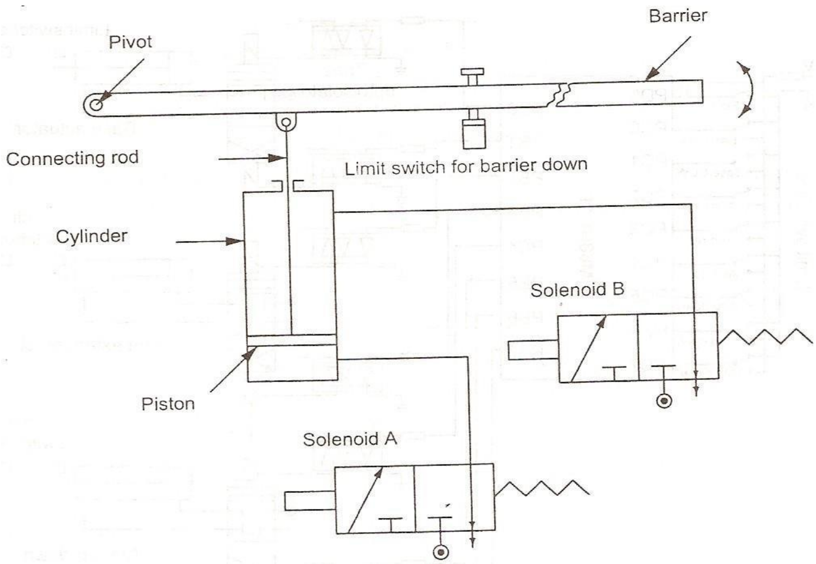
The type of microcontroller used in M68C11. A software program is used to control the robot. Eight c port lines PC_0, - PC_7, are used to sense the position of eight separate limit switches used for eight different robotic movements. Also one line from port D is used to start or stop the robot operation. The switch in its one position will provide +5V (a logic high signal), to the corresponding port lines and the switch in its position will provide 0V (a logic low signal), to the port lines. So the two positions of a switch will provide either a logic high or logic low to the corresponding PC_0, - PC_7, and PD_0, lines.

Eight part B lines (PB_0,-PB_7,) are used to control eight different movements. These are Base CW, Base CEW, Arm extends, Arm retract, Arm up, Arm down Gripper close and Gripper open of the robot. PB_0, is connected to the Triac opto isolator
Through resistor.



2. Automatic Car Park System

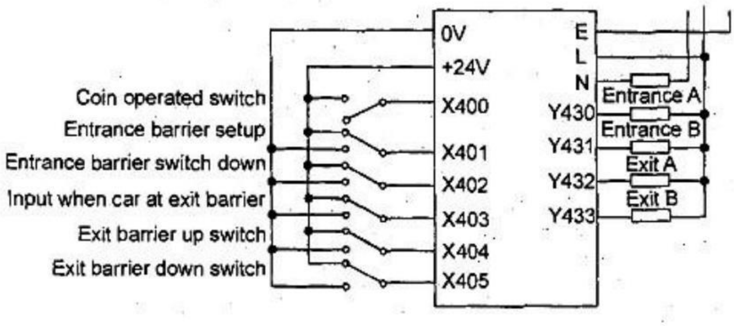
Consider the coin-operated car park system with barriers. The main requirement of the system is that, the in-barrier is to be opened to allow the car inside if correct money (coin) is inserted in the collection box and the out barrier is to be opened to allow the car outside, if the car is detected at the car park side of the barrier. Figure shows the automatic car park barrier along with the mechanism to lift and lower it.



When the current flows through the solenoid A, the piston in the cylinder extends to move upward and causes the barrier to rotate about its pivot and thus the barrier rises to allow the car inside.

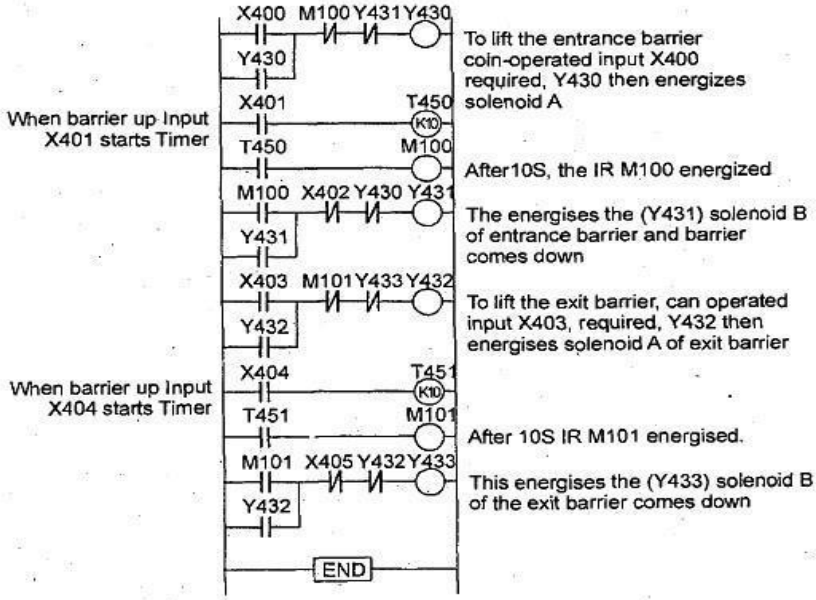
When the current flows through the solenoid A ceases, the spring on the solenoid valve makes the contacts to open and thus makes the valve to its original position. When the current flows through solenoid B, the piston in the cylinder moves downward end causes the barrier to get down. Limit switches are used to detect when the barrier is down and also when fully up.

This control can be controlled by PLC **as** shown in figure.



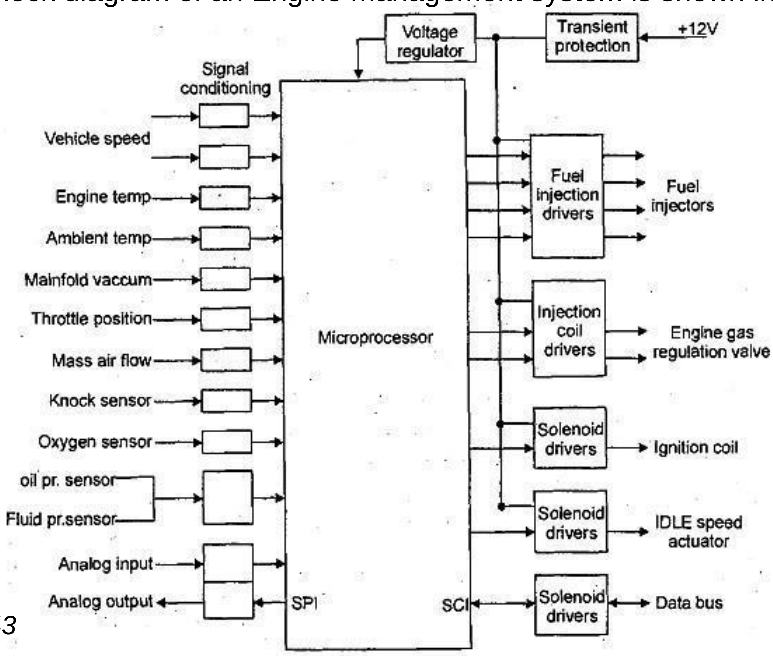
X400	-	coin operated switch at entrance to car park
X401	-	switch activated when entrance barrier is out
X402	-	switch activated when entrance barrier down
X403	-	switch activated when car at exit barrier
X404	-	switch activated when exit barrier is up
X405	-	switch activated when exit barrier is down.
Y430	-	solenoid on valve A for entrance barrier
Y431	-	solenoid on valve B for entrance barrier
Y432	-	solenoid on valve A for exit barrier
Y432	-	solenoid on valve B for exit barrier

Six inputs (X400 to X405) is required for the PLC to sense the six limit switch position namely coin-operated switch, entrance barrier up switch, down switch, car at exit barrier switch, exit barrier up switch, Exit barrier down switch as indicated in the diagram. When ever, a switch is operated, 0V signal is provided to the corresponding inputs and otherwise +24v signal is provided to the inputs. Four outputs (Y430 to Y433) is required to operate the two solenoid valves A and B.



3. ENGINE MANAGEMENT SYSTEM

Engine management system is now-a-days, used in many of the modem cars such as Benz, Mitsubishi and Toyota etc., these cars includes many electronic control systems such as microcontrollers for the control of various engine factors. The Generalized block diagram of an Engine management system is shown in figure below.

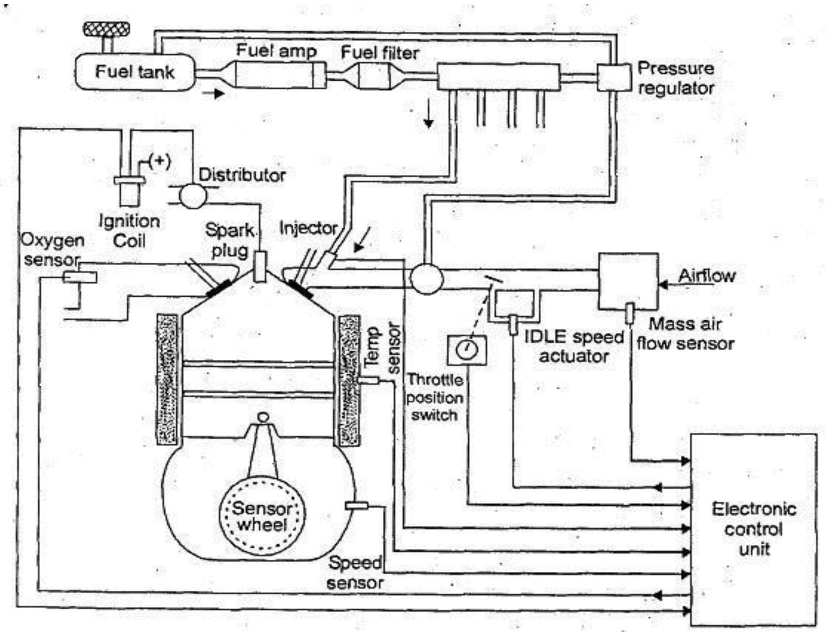


The main objective of the system being to ensure that the engine is operated at its Optimum settings. The engine management system of a car is responsible for managing the ignition and fueling requirements of the engine.

The power and speed of the engine are controlled by varying the ignition timing and the Air-he1 mixture. In modem cars, this is done by microprocessor.

To control the ignition delay, the crank shaft drives a distribution which makes electrical contacts for each spark plug in turn and a timing wheel. This timing wheel generates pulses to indicate the crankshaft position. The microprocessor then adjusts the timing at which high voltage pulses are sent to the distributor so that they occur at right moments of time.

To control the amount of air-he1 mixture entering into a cylinder during the suction stroke, the microprocessor varies the time for which a solenoid is activated to the inlet valve on the basis of inputs received by the engine temperature and the throttle position.



The amount of fuel to be injected into the air stream can be determined on input from a sensor of the mass rate of air, or computed from other measurements. The
microprocessor then gives as output to control of fuel inject valve. The system hence consists of number of sensor for observing vehicle speed, Engine temperature, oil

and fuel pressure, air flow etc., these sensors supplies input signals to the microprocessor after suitable signal conditioning and provides output signals via drivers to actuate corresponding actuators.

Engine Speed Sensors:

The Engine speed sensor is an inductive type sensor used to measure or sense the engine speed. It consists of a coil and c sensor wheel.

When the teeth of the sensor wheel pass through the sensor, the inductance of the coil changes. This change in inductance produces an oscillating voltage.

Engine Temperature Sensor:

The engine temperature sensor is used to sense the temperature of the engine. It is usually a thermistor or a thermocouple. The thermocouple consists of a bimetallic strip or a thermistor whose resistance changes when there is a variation in temperature of the engine.

Hot wire Anemometer:

Hotwire Anemometer is used as a mass airflow rate sensor in which a heated wire gets cooled when air passes across it. The amount of coding depends on the mass flow rate.

Oxygen Sensor:

The oxygen sensor is usually a closed end tube made of zirconium oxide with porous platinum electrodes on the inner and outer surfaces. When the temperature is above 300°C, the sensor becomes permeable to oxygen ions so that melt age will be produced between the electrodes.

The various drivers such as fuel injection drivers, ignition coil driver's solenoid drivers and are used to actuate actuators according to the signal by various sensors.

Analog signals are converted into digital signals by using ADC and are sensed by various sensors which in turn sent to the microcontroller.

The microcontroller compares these input values with the set points stored in its memory and it issues control signals to the corresponding our drivers. The output signals are converted into analogue signal by using ADC.

The transient protection circuit prevents any sudden surge a rise or far in the power supply in the power supply to the micro controller. A +12V voltage regulator is used to supply the dc voltage required for the microcontroller operation.

15BEME 703 – MECHATRONICS SYSTEM
FOE/KAHE

Multiple choice Questions

OPTION-1	OPTION-2	OPTION-3	OPTION-4	ANSWERS
Mechanical systems are assisting for computer systems	Electrical systems are assisting for computer systems	Electronic systems are assisting for mechanical systems	Computer systems are assisting for mechanical systems	Electronic systems are assisting for mechanical systems
Bicycle	Shaping machine	CNC machine	All of the above	CNC machine
Motion producers	Motion controllers	Energy sources	All of the above	Motion producers
Senses system parameters and control it	Collect system parameters and do logic decision making	Senses systems parameters and control the display in output device	Collect system parameters and send to control system	Collect system parameters and send to control system
sensing	actuating	controlling	displaying	controlling
graphical display	) sensor	controller	input device	graphical display
connects the control circuits and I/P device	connects the control circuits and I/P sensors	connects the control circuits and O/P sensors	all of the above	all of the above
sensors	input devices	printer outputs	all of the above	printer outputs
control system	measurement system	actuation	all of the above	measurement system
sensors, controller, actuator	transducer, signal processor, recorder	sensor, signal processor, actuator	transducer, controller, sensor	transducer, signal processor, recorder
one input and one output	more than one input and output	one input and more than one output	none of the above	one input and one output
reference input	modified input	sensors input	none of the above	reference input

open loop systems	closed loop system	semi closed loop system	all of the above	closed loop system
increment the magnitude of the signal voltage	modulates the magnitude of the signal voltage	de-modulates magnitude of the signal voltage	digitizes the signal	increment the magnitude of the signal voltage
input unit	output display unit	control unit	none of the above	output display unit
used to measure gap	used to measure distance	used to measure pressure	none of the above	used to measure gap
distance measurement	small gap measurement	small gap measurement	none of the above	distance measurement
Transducers + signal conditioning units	Transducers - signal conditioning units	Transducers + Amplifiers	Transducers - Amplifiers	Transducers + signal conditioning units
proximity sensor	range sensor	displacement sensor	all of the above	displacement sensor
proximity sensor	range sensor	displacement sensor	all of the above	displacement sensor
type of displacement	time dependence of displacement	magnitude of displacement	all of the above	all of the above
active transducer	passive transducer	ideal transducer	none of the above	passive transducer
differential output	integral output	stepped output	none of the above	differential output
one primary winding and two secondary windings	one primary winding and one secondary windings	one secondary winding and two primary windings	two primary winding and two secondary windings	one primary winding and two secondary windings
serial, in phase	serial opposition phase	parallel in phase	parallel opposition phase	serial opposition phase
more	less	zero	one	more

more	less	zero	one	less
linear measurement	angular measurement	force measurement	stress measurement	angular measurement
not require external excitation	require external excitation	primary transducer	none of the above	require external excitation
require external excitation	not require external excitation	secondary transducer	None of the above	not require external excitation
AC Voltage signal	DC Voltage signal	DC/AC Current signal	All of the above	DC Voltage signal
Energy creation in sensors	Energy Transformation in sensors	Signal Transformation	Signal Conditioning	Energy Transformation in sensors
Light ray	Current	Heat	Vibration	Light ray
Variation in capacitance	Variation in light	Variation in electrical conduction	Variation in Inductance	Variation in electrical conduction
Light ray	Current	Heat	Vibration	Current
Change in current due to light rags	Change in voltage due to light rags	Change in resistance due to light rags	None of the above	Change in resistance due to light rags
Change in electromagnetic induction	Change in mutual inductance	a) and (b)	None of the above	Change in electromagnetic induction
The capacitive between the reference electrode and the sensitive electrode	The capacitive of the air between the object and transducer	The capacitive between the object and the electrode	all of the above	The capacitive between the reference electrode and the sensitive electrode
Change the pressure / fore into light energy	Change the pressure / fore into heat energy	Change the pressure / fore into electric energy	Change the pressure / fore into thermal energy	Change the pressure / fore into electric energy

Eddy current effect	Mutual inductance	Electromagnetic inductance	All of the above	Eddy current effect
Electrical transducer	Optical transducer	Mechanical transducer	Hydraulic transducer	Mechanical transducer
Electrical transducer	Optical transducer	Mechanical transducer	Hydraulic transducer	Electrical transducer
Electrical transducer	Optical transducer	Mechanical transducer	Hydraulic transducer	Mechanical transducer
Linear motion	Linear velocity	Angular motion	All of the above	Angular motion
Light reflection	Light refraction	Light conduction	Light emission	Light emission
Transducer	Sensor	Strain gauge	All of the above	Strain gauge
diaphragm	floating disc	float chamber	needle	diaphragm
0.003mm	0.03 mm	0.3 mm	3.0 mm	0.003mm
amplifier	rectifier	filter	Wheatstone bridge	Wheatstone bridge
Δr/r = g . e	Δr/(r+Δr) = g . e	Δr/r = g +e	Δr/r = g – e	Δr/r = g . e
Diaphragms like Deformable members	Fins	Valves	All of the above	Diaphragms like Deformable members
placing a abstraction in the flow path and measuring it	allowing to flow in a open pipe	allowing to flow in a channel	all of the above	placing a abstraction in the flow path and measuring it
orifice meter	roto meter	pilot tube	all of the above	all of the above
float (or) displacer	bellow (or) capsule	rotometer (or) flow nozzle	none of the above	float (or) displacer
see-beck effect	column’s effect	Raman’s effect	none of the above	see-beck effect
positive temperature coefficient principle	negative temperature coefficient principle	zero temperature coefficient principle	none of the above	positive temperature coefficient principle
positive temperature coefficient	negative temperature coefficient	zero temperature coefficient principle	none of the above	negative temperature coefficient

principle	principle			principle
electrically conductive fluids	electrically non-conductive fluids	magnetically conductive fluids	magnetically non conductive fluids	magnetically non conductive fluids
linear type instrument	non- linear type instrument	temperature measuring instrument	pressure measuring instrument	non- linear type instrument
cold junction compensation is required	EMF Vs Temp curve is not linear	very small output	all the above	cold junction compensation is required
to respond to the external signal and to cause motion	to control the system	both (a) and (b)	none of the above	to respond to the external signal and to cause motion
pneumatic system is used	Hydraulic system is used	Electrical system is used	All of the above	Hydraulic system is used
pneumatic system is used	Hydraulic system is used	Electrical system is used	All of the above	pneumatic system is used
pneumatic system is used	Hydraulic system is used	Electrical system is used	All of the above	Electrical system is used
spring tension	compressed fluid	flow control valve	All of the above	spring tension
excellent control and minimum maintenance	economical	can be used for high power	all of the above	excellent control and minimum maintenance
to control the output force of the cylinder	to control the speed of the cylinder	both (a) and (b	None of the above	to control the output force of the cylinder
direction control valve	flow control valve	pressure control valve	all of the above	direction control valve
Greater flexibility	Eliminate shocks	Cutting tool protection	all of the above	Greater flexibility
to actuate two cylinders in a sequence	to actuate single cylinder in forward and	both(a)and (b)	none of the above	to actuate two cylinders in a sequence

	reverse direction			
by mechanical energy	by hydraulic energy	by electrical energy	by pneumatic energy	by electrical energy
positive discharge pumps	non positive discharge pumps	centrifugal pumps	all of the above	positive discharge pumps
converting mechanical energy into hydraulic energy	converting hydraulic energy into mechanical energy	converting pressure energy into kinetic energy	all of the above	converting mechanical energy into hydraulic energy
have 3 ports and 2 stages	have 3 stages and 2 ports	have 5 ports and 2 stages	have 2 stages and 5 ports	have 3 ports and 2 stages
hydraulic energy into rotational motion	mechanical energy into hydraulic energy	linear motion to rotary motion	none of the above	hydraulic energy into rotational motion
Uni-directional flow	Bi directional flow	Both (a) and (b)	None of the above	Uni-directional flow
1,1 and 2 respectively	1,2 and 1 respectively	2, 1 and 1 respectively	None of the above	1,1 and 2 respectively
air	oil	hydraulic fluid	none of the above	hydraulic fluid
good torque	good speed	good control ability	none of the above	good control ability
discrete angular motions	discrete linear motions	continues angular motion	continues linear motion	discrete angular motions
speed reduction	torque reduction	speed increase	torque increase	speed reduction
finite position	control position	infinite position	flow position	infinite position
simple ON/ OFF switch	water tap	electric light dimmer	machine switch	water tap
finite position	control position	infinite position	flow position	finite position
no of ports	no of ways	position	direction	position
3	4	6	2	4

Poppet valve	Check valve	Spool valve	Rotary valve	Poppet valve
no of brushes	no of gears	no of cylinders	none of the above	no of cylinders
forward flow position	neutral position	reverse flow position	closed position	neutral position
rotary valve	servo valves	spool valves	poppet valves	servo valves
Intrinsically safe	Inherently torque limited by the available supply pressure	Robust against mechanical shock or jamming	All the above	All the above
2000 to 10000μr/min	500 to 2000μr/min	1000 to 1500μr/min	None of the above	2000 to 10000μr/min
intrinsically not safe	Inherently torque is not limited by the available supply pressure	Require exhaust silencer	None of the above	Require exhaust silencer
reversible	irreversibl	all of the above	none of the above	reversible
variable inductance and variable reluctance stepper motor	variable reluctance and permanent magnet stepper motor	permanent magnet stepper motor and variable capacitance	permanent magnet stepper motor alone	variable reluctance and permanent magnet stepper motor
high speed	high efficiency	high torque and power with low weight and bulk	all the above	high torque and power with low weight and bulk
continues controlled rotation	discrete controlled rotation	periodic controlled rotation	none of the above	discrete controlled rotation
hybrid	variable reluctance	permanent magnet	all the above	permanent magnet
variable inductance and variable	variable reluctance and permanent	permanent magnet stepper motor and	permanent magnet stepper motor alone	variable reluctance and permanent

reluctance stepper motor	magnet stepper motor	variable capacitance		magnet stepper motor
Slip	Drag	Slack	None of the above	Slip
Spur gear	Bevel gear	Worm gear	All the above	Bevel gear
ball bearing	Roller bearing	Slider contact bearing	all of the above	Slider contact bearing
Positive drive	Non positive drive	Reverse drive	None of the above	Non positive drive
circular	Rectangula	Square	Trapezoidal	Trapezoidal
Positive drives	Non positive drives	Reversing drives	None of the above	Positive drives
180mm	360mm	90mm	45mm	90mm
Cotters	Bolt and Nuts	Keys	None of the above	Keys
(T_1-T_2) v	(T_1+T_2) v	(T_1-T_2)/w	(T_1+T_2)/ w	(T_1-T_2) v
$T_1/T_2= e^{\theta}$	$T_1/T_2= e^{\cos\theta}$	$T_1/T_2= e^{\mu\theta}$	$T_1/T_2= e^{\sin\theta}$	$T_1/T_2= e^{\mu\theta}$
journal bearing	pivot bearing	collar bearing	roller bearing	journal bearing
journal bearing	pivot bearing	ball and roller bearings	collar bearing	ball and roller bearings
DC series motor	DC compound motor	DC shunt motor	Permanent magnet DC motor	DC shunt motor
stepper motor	servo motor	Induction motor	synchronous motor	stepper motor
solenoid	diode	thyristor	transistor	solenoid
diode	tyristors	transistors	all of the above	all of the above
D C series Motor	D C shunt Motor	D C compound wound motor	D C permanent magnet motor	D C permanent magnet motor
D C series Motor	D C shunt Motor	D C compound wound motor	D C permanent magnet motor	D C series Motor
pump	compressor	pressure regulator	valve	compressor

bevel gear	helical gear	spur gear	rack and pinion	rack and pinion
90 watts	50 watts	2800 watts	1400 watts	1400 watts
understand how the systems behave	to analyze their working	to estimate their performance	all of the above	All of the above
building blocks of the system	softwares	physical components	all of the above	building blocks of the system
mechanical and electrical systems	electrical and thermal systems	thermal and mechanical system	all of the above	all of the above
Springs	Dashpots	Masses	All of the above	all of the above
linearity	stiffness	flexibility	all of the above	stiffness
the forces opposing motion	linearity	flexibility	none of the above	the forces opposing motion
momentum	Inertia	opposing force	all of the above	Inertia
translational system	rotational system	mechanical system	all of the above	rotational system
electrical system	hydraulic system	pneumatic system	mechanical system	mechanical system
$\frac{1}{2}.I.\omega^2$	$\frac{1}{2}.I^2.\omega$	$2\omega^2.I$	$2I^2\omega$	$\frac{1}{2}.I.\omega^2$
resistor	inductors	capacitors	all of the above	all of the above
current	thermal conductivity	electrical change	none of the above	current
electrical change	rate of change of current	resistance	none of the above	resistance
current	resistance	electrical charge	none of the above	electrical charge
hydraulic resistance	hydraulic inertance	hydraulic capacitance	none of the above	hydraulic resistance
hydraulic resistance	hydraulic inertance	hydraulic capacitance	none of the above	hydraulic inertance
hydraulic resistance	hydraulic iterance	hydraulic capacitance	none of the above	hydraulic capacitance

thermal resistance, thermal capacitance	thermal conductivity and thermal resistance	thermal capacitance and thermal conductivity]	all of the above	thermal resistance, thermal capacitance
steady state error	proportion error	derivative error	none of the above	steady state error
proportional mode	derivative mode	integral mode	on-off mode	on-off mode
Slow process	Fast process	Continuous process	None of the above	Slow process
the size of the controller o/p is proportional to the size of error	the size of the controller o/p is equal to the size of error	the size of the controller o/p is more than the size of the error	none of the above	the size of the controller o/p is proportional to the size of error
Shaft with lead screw	Gear trains	Electrical motor	Piston cylinder	Shaft with lead screw
Shaft with lead screw	Gear trains	Electrical motor	Piston cylinder	Electrical motor
Shaft with lead screw	Gear trains	Electrical motor	Piston cylinder	Piston cylinder
Shaft with lead screw	Gear trains	Electrical motor	Piston cylinder	Gear trains
analog	digital	both (a) and (b)	none of the above	digital
analog	digital	both (a) and (b)	none of the above	digital
sampling, comparing, calculating and sending o/p	comparing, sampling, calculating and sending o/p	calculating, sampling, comparing and sending o/p	none of the above	sampling, comparing, calculating and sending o/p
control action can be changed easily	no alteration in hardware	no extra wiring is required	all of the above	all of the above
easily programmable	rugged structure	both (a) and (b)	none of the above	none of the above
less	more	zero	none of the	zero

			above	
continuous	discrete	not continuous	none of the above	not continuous
$P=C.v^2$	$P= v\ C^2$	$P=C/\ v^2$	$P=v^2/C$	$P=C.v^2$
$E = 1/2mv^2$	$E = 2mv^2$	$E = 2vm^2$	$E = 1/2vm^2$	$E = 1/2mv^2$
$E =2\theta.k^2$	$E =1/2\ k^{2\cdot}\theta$	$E = 1/2\ k\cdot\theta^2$	$E = 2.k.\theta^2$	$E = 1/2\ k\cdot\theta^2$
directly proportional to moment of inertia	directly proportional to square of angular velocity	both (a) and (b)	none of the above	directly proportional to square of angular velocity
hydraulic – mechanical system	electro-mechanical system	thermo-mechanical system	none of the above	electro-mechanical system
proportional to the size of the error signal	proportional to the rate of change of the error signal	both (a) and (b)	none of the above	proportional to the rate of change of the error signal
proportional to the size of the error	proportional to the rate of change of the error	both (a) and (b)	none of the above	proportional to the size of the error
ohm's law	Pascal's law	Kirchhoff's law	faradays law	Kirchhoff's law
first order differential equation	second order differential equation	third order differential equation	none of the above	first order differential equation
first order differential equation	second order differential equation	third order differential equation	none of the above	second order differential equation
resistance to flow due to values	resistance to flow due change in pipe diameter	resistance to flow due bends, currents etc	all of the above	all of the above
potential energy stored in the liquid	kinetic energy of liquid	pressure energy of liquid	all of the above	potential energy stored in the liquid

spring	dashpot	gear train	all of the above	spring
spring	dashpot	mass	none of the above	dashpot
spring	dashpot	mass	none of the above	spring
spring	dashpot	mass	none of the above	mass
$q = t_2\text{-}t_1 / R$	$q = t_2 \times t_1 / R$	$q = R / t_2\text{-}t_1$	$q = R / t_2 \times t_1$	$q = t_2\text{-}t_1 / R$
$q_1\text{-}q_2 = C . (d_T/d_t)$	$q_1\text{-}q_2 = C / (d_T/d_t)$	$q_1+q_2 = C . (d_T/d_t)$	$q_1+q_2 = C / (d_T/d_t)$	$q_1\text{-}q_2 = C . (d_T/d_t)$
first order differential equation	second order differential equation	straight line equation	none of the above	first order differential equation
no change in control o/p	max change in control o/p	minimum change in controller o/p	none of the above	no change in control o/p
$P = k_p / e_p + p_o$	$P = (k_p + e_p) . p_o$	$P = (k_p \times e_p) + p_o$	$P = k_p + (e_p \times p_o)$	$P = (k_p \times e_p) + p_o$
on-off	integra	proportional	all of the above	proportional
on-off	integral	proportional	all of the above	proportional
on-off	integral	proportional	derivative	proportional
In industrial process where to handle fast load charges	In industrial process where large dead time equal	In industrial process where slow load changes	None of the above	In industrial process where to handle fast load charges
no offset error	reduces oscillations	both (a) and (b)	none of the above	both
PID control	PLC	Adaptive control	All of the above	Adaptive control
Programmable logic controller	Programmable logistic controller	Programmable logic gates controller	none of the above	Programmable logic controller
television	microcontroller	microprocessor	computer	computer
1	2	3	4	4
electronic	electrical	Digital electronic	none of the	Digital electronic

			above	
1968	1967	1969	1966	1968
datas	controls	above all	none of the above	datas
1	2	3	4	2
rungs	timer	relay	lader diagrams	lader diagrams
power rails	rungs	above all	none of the above	power rails
2	3	4	5	5
self tuning	self maintaining	above all	none of the above	self maintaining
2	3	4	5	4
Delay ON timer	Delay OFF timer	555 Timer	cascade timer	cascade timer
timer	counter	above all	none of the above	timer
relay	auxilary relay	Mnemonics	above all	auxilary relay
relay	marker	Mnemonics	above all	marker
relay	timer	Mnemonics	above all	relay
single input	multiple input	above all	none of the above	multiple input
counter	timer	above all	none of the above	counter
1	2	3	4	2
microcontroller	microprocessor	computer	PLC	PLC
registers	shift registers	bit registers	above all	shift registers
1	2	3	4	3
1	2	3	4	4
compare	move	above all	none of the above	move
compare	move	above all	none of the above	compare
add	subtract	add and subtract	none of the	add and subtract

			above	
cost	material	above all	none of the above	cost
input	output	power suply	above all	above all
memory	cost	size	above all	above all
5	6	7	8	7
need	design	analysing problem	preparation	need
cam	Plc	Relay	timer	cam
cam	switch contact	cam follower	PLC timer system	PLC timer system
Delay ON timer	Delay OFF timer	555 Timer	cascade timer	555 Timer
1	2	3	4	3
stepper motor	DC motor	AC motor	Ordinary motor	stepper motor
body temperature	Eye power	weight	height	weight
body temperature machine	Eye power machine	weighing machine	all of the above	weighing machine
cam	PLC timer system	Leaf spring	all of the above	Leaf spring
linear	circular	rotational	all of the above	linear
LCD	LED	None of these	Above two	LED
1	2	3	4	3
Solenoid valve	DCV	Diaphragm valve	all of the above	Solenoid valve
Solenoid valve	cam	Diaphragm valve	all of the above	Solenoid valve
1	2	3	4	2
in barries	out barries	both barrier	all of the above	in barries
in barries	out barries	both barrier	all of the above	out barries
lift	lower	lift and lower	pivoting	lift and lower

1	2	3	4	2
cam	switch contact	diaphragm blades	PLC timer system	diaphragm blades
inductive sensor	proximity	LVDT	all of the above	inductive sensor
inductive sensor	proximity	LVDT	thermister	thermister
parallel of black and white bars	series of black and white bars	parallel and series	none of the above	series of black and white bars
UPC	EAN	EPN	ESN	UPC
UPC	EAN	EPN	ESN	EAN
Positive drive	Non positive drive	Reverse drive	None of the above	Non positive drive
circular	Rectangula	Square	Trapezoidal	Trapezoidal
Positive drives	Non positive drives	Reversing drives	None of the above	Positive drives
180mm	360mm	90mm	45mm	90mm
Cotters	Bolt and Nuts	Keys	None of the above	Keys
$(T_1-T_2)\ v$	$(T_1+T_2)\ v$	$(T_1-T_2)/w$	$(T_1+T_2)/\ w$	$(T_1-T_2)\ v$
$T_1/T_2= e^{\theta}$	$T_1/T_2= e^{\cos\theta}$	$T_1/T_2= e^{\mu\theta}$	$T_1/T_2= e^{\sin\theta}$	$T_1/T_2= e^{\mu\theta}$
journal bearing	pivot bearing	collar bearing	roller bearing	journal bearing
linearity	stiffness	flexibility	all of the above	stiffness
spring	dashpot	mass	none of the above	mass
counter	timer	above all	none of the above	counter
1	2	3	4	2
microcontroller	microprocessor	computer	PLC	PLC
registers	shift registers	bit registers	above all	shift registers