UNIT I
INTRODUCTION

1. Introduction to Mechatronics Systems

Mechatronics is one of the new and existing fields on the engineering landscape, combining parts of traditional engineering fields and requiring a broader approach to the design of systems that we can formally call as mechatronics systems.

1.1 Definitions

"Mechatronics may be defined as a multi-disciplinary field of study that implies the synergistic integration of electronic engineering, electrical engineering, control engineering and computer technology with mechanical engineering for the design, manufacture, analyze and maintenance of a wide range of engineering products and processes".

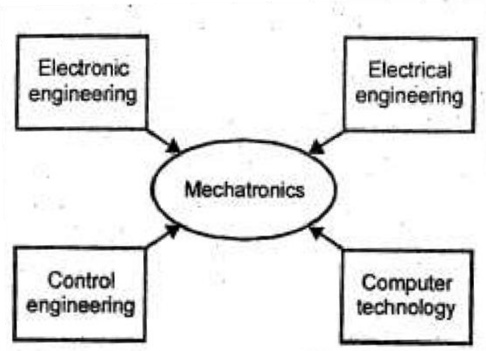


Figure 1.1: Mechatronics System

"The integration across the traditional boundaries of mechanical engineering, electrical engineering, electronics and control engineering has to occur at the earliest stages of the design process if cheaper, more reliable, more flexible systems are to be developed.

Mechatronic System

1.3.1System

A system may be defined as a black box which has an input and an output. System is concerned only with the relationship between the input and output and not on the process going on inside the box.

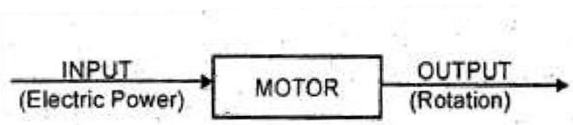


Figure 1.2: System

Measurement Systems

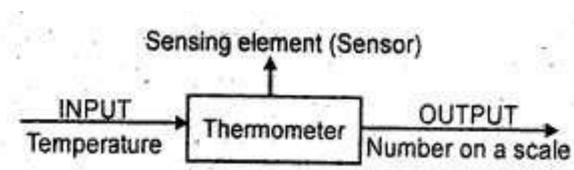


Figure 1.3: Temperature Measurement System

Elements of Measurement Systems

Measurement system consists of the following three elements.
a) Sensor b) Signal Conditioner c) Display System.

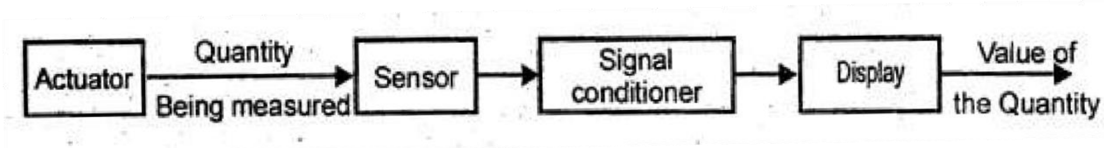


Figure 1.4: Elements of Measurement System

a) Sensor

A sensor consists of transducer whose function is to convert the one form of energy into electrical form of energy. A sensor is a sensing element of measurement system that converts the input quantity being measured into an output signal which is related to the Quantity.

Temperature Sensor - Thermocouple
Input - Temperature
Output - E.M.F (Electrical Parameter).

b) Signal Conditioner

A signal conditioner receives signal from the sensor and manipulates it into a suitable condition for display. The signal conditioner performs filtering, amplification or other signal conditioning on the sensor output.

Temperature measurement - Single Conditioner function (Amplifier)
Input - Small E.M.F value (From sensor)
Output - Big E.M.F Value (Amplified).

c) Display System

A display system displays the data (output) from the signal conditioner by analog or digital. A digital system is a temporary store such as recorder.

Display - L.E.D (or) Number on scale by pointer movement
Input - Conditioned Signal (from signal conditioner)
Output - Value of the quantity (Temperature)

Temperature Measurement System

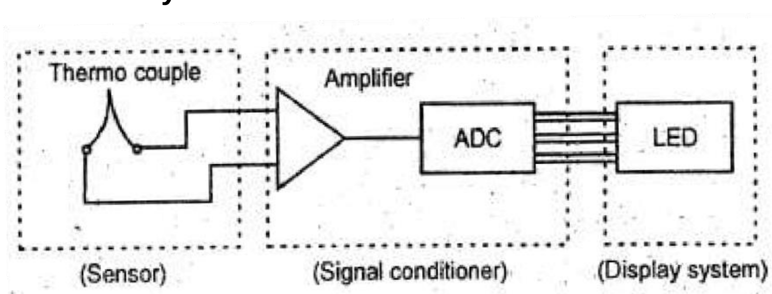


Figure.1. 5: Temperature Measurement System

Control System

A control system may be defined as a black box which is used to control its output in some particular value (Preset Value).

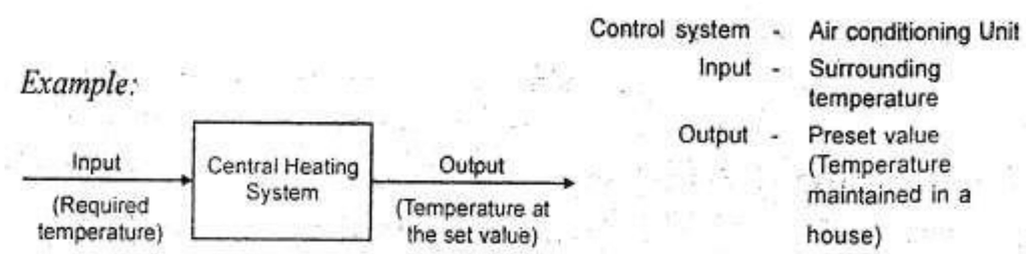


Figure 1.6: Control System

Open-loop and Closed-loop Control SystemOpen loop Control System

If there is no feedback device to compare the actual value with the desired one, then the system is known as open loop control system.

This system has no control over its input (based on output) as there is no feedback signal.

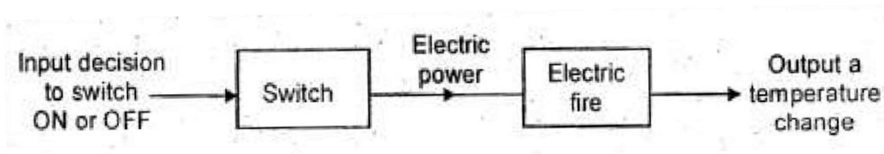


Figure 1.7: Open loop Control System

Consider an electric fire which has to be switched ON or OFF by either a 1 KW or 2K W heating element which is to be selected according to the conditions.

Generally, if a person wants to heat the room, he/she chooses and switches the 1 KW heating elements.

The room will get heated up and reaches a desired value. If the window or door is opened, the heat losses to the surrounding; so there is no way to adjust or compensate this heat.

Closed loop Control System

If there is a feedback device to compare and correct the actual value with the desired one, then it is known as closed loop control system.

This system has an effect over its input (based on output) as there is a feedback signal.

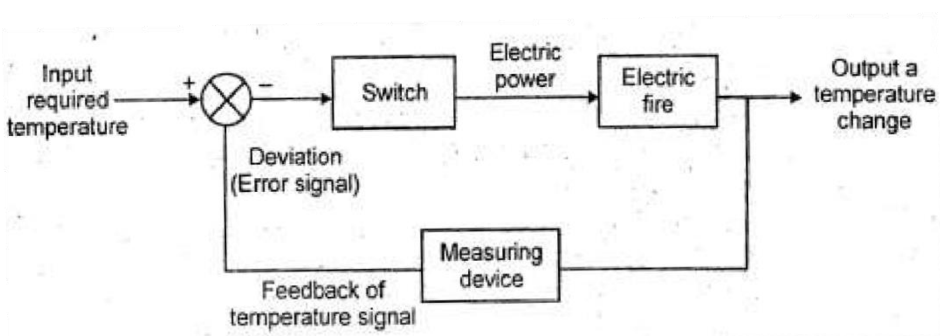


Figure 1.8 Closed loop Control System

Closed loop Control System

The same heating system can be made as a closed loop control system by incorporating a feedback device and a comparison element.

In this system, a person switches on either 1 KW or 2KW element according to the difference between the actual temperature and the required temperature to maintain the room at constant temperature.

The comparison element is of course a person made here.

Elements of a Closed loop Control System

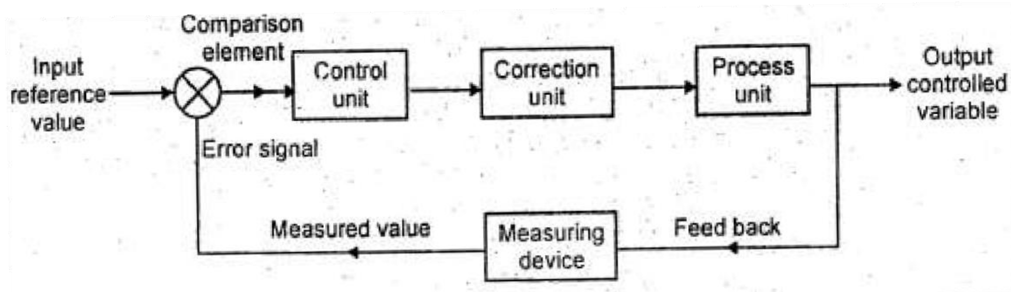


Figure 1.9 shows the basic elements of a closed loop control system.

The elements of closed loop control system are

1. Comparison Element
2. Control Element
3. Correction Element
4. Process Element
5. Measurement Element

1. Comparison Element

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

Error Signal = Reference value - measured value

Normally, feedback input signal is marked as negative and the reference signal or positive so that the sum gives the difference between the signals.

Feedback loop is joined with comparison element.

There are two types of feedback.

Negative feed back

Positive feed back

The feedback is said to be negative one, if the feedback signal subtracts from the input value due to negative error signal produced.

The feedback is said to be positive one, if the feedback signal adds to the input value due to positive error signal produced.

2. Control Element

This element decides the corrective action to be taken when an error signal is received by it. A signal is to operate switch ON/OFF or valve open / close.

3. Correction Element

Correction element is an actuator that produces a change in a process to correct or change the controller condition.

It also provides the power to carry out the control action; hence it is known as actuator.

4. Process Element

An element that controls the process is known as process element. Example: Room temperature of a house is being controlled.

5. Measurement Element

The measurement element produces a signal related to the variable condition of the process that is being controlled. Thermocouple gives EMF related to temperature.

a) System of Controlling Room Temperature

Controlled Variable	Room temperature
Reference Variable	Required Room temperature (Preset value)
Comparison element	Person compares the measured value with required value
Error signal	Difference between the measured and required temperatures.
Control	Unit Person
Correction Unit	The switch on the fire
Process	Heating by the fire
Measuring device	Thermometer.

b) Automatic Speed Control of Rotating Shaft

Potentiometer	To set the reference value (Voltage to be supplied to differential amplifier)
Differential Amplifier	To compare amplify the difference between the reference and feedback values
Tachogenerator	To measure the speed of the rotating shaft and is connected to the rotating shaft by means of a pair of level gears.

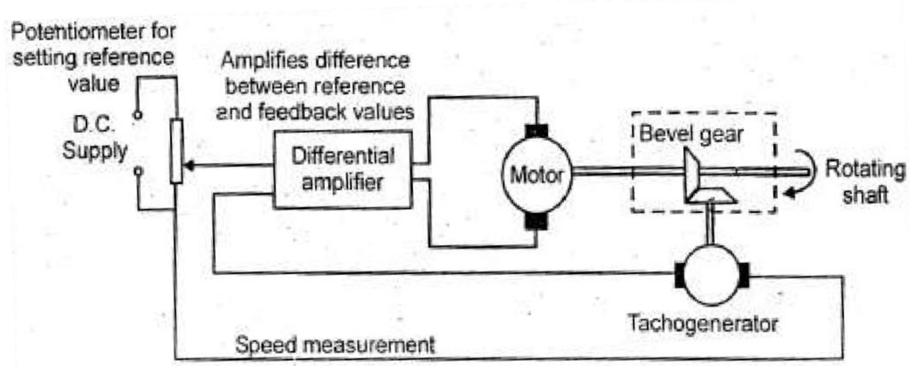
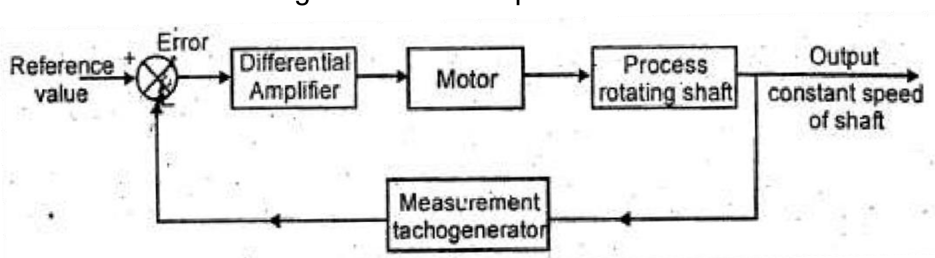


Figure 1.9: Shaft Speed Control



The speed is measured by tachogenerator and the signal from which is fed back to the differential amplifier.

The amplified error signal is then fed to a motor which in turn adjusts the speed of a rotating shaft.

Sequential Controllers

Sequential controllers are control systems that are used to control the process that are strictly ordered in a time or event driven sequence.

Consider a domestic washing machine as an example. A number of operations have to be carried out in the correct sequence.

This operating sequence is called a program the sequence of instructions in each programs and built into the controller used.

The system that used to be used for the washing machine controller was a mechanical system which involved a set of cam-operated switches the mechanical switches.

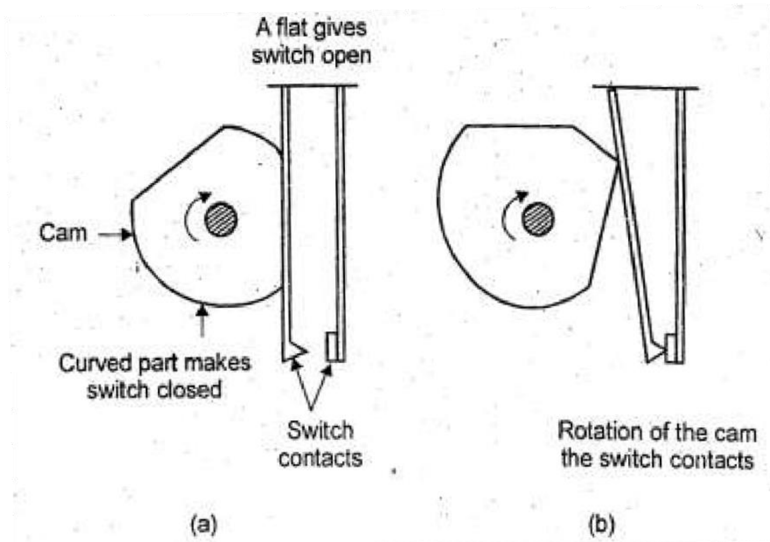


Figure 1.10: CAM Operation Switch Sequence of Operations

The sequence of operations of a washing machine consists of following Cycles.

a) Pre-wash cycle b) Main wash cycle
c) Rinse cycle d) Spinning cycle

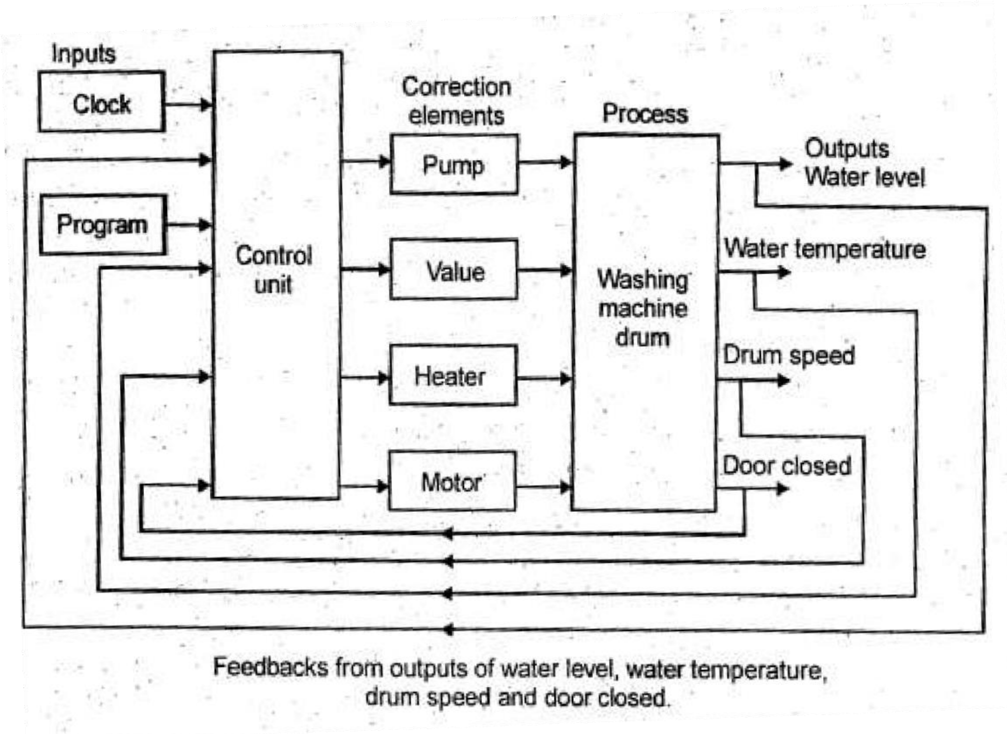


Figure 1.11: Washing Machine System

a. Working of Cam Operated Switch

When the machine is switched on, a small electric motor rotates its shaft slowly, giving on amount of rotation proportional to time.

Its rotation turns the controller cams so that each in turn operates electrical switches and so switches on the circuit in the correct sequence.

The contour of a cam determines the time at which it operates a switch.

Thus the contours of the cams are the means by which the program is specified and stored in the machine.

b. Programming of a Washing 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.

c. Pre-wash Cycle

Pre-wash cycle may involve the following sequence of operations.

- Opening of valve to fill the drum when a current is supplied
- Microprocessor is used to operate the switch for opening closing the valve.
- Closing of valve after receiving the signal from a sensor when the required level of water is filled in the washing drum.
- Stopping the flow of water after the current is switched off by the microprocessor.
- Switch on the motor to rotate the drum for stipulated time.
- Initiates the operation of pump to empty the water from the drum.
- Pre-wash cycle involves washing the clothes in the drum by cold water.

d. Main Wash Cycle

Main wash cycle involves washing the clothes in the drum by hot water

- Cold water is supplied after the Pre-wash cycle is completed.
- Current is supplied in large amount to switch on the heater for heating the cold water.
- Temperature sensor switches off the current after the water is heated to required temperature.
- Microprocessor or cam switches ON the motor to rotate the drum.
- Microprocessor or cam switches on the current to a discharge pump to empty the drum.

e. Rinse Cycle

Rinse cycle involves washing out the clothes with cold water a number of times

- Opening of valve to allow cold water into the drum when the microprocessor are given signals to supply current after the main wash cycle is completed.
- Switches off the supply current by the signals from microprocessor
- Operation of motor to rotate the drum
- Operation of pump to empty the drum and respect this sequence a number of times.

f. Spinning Cycle

Spinning cycle involves removing of water from the clothes

- Switching on the drum motor when the or a cam switches the supply current to rotate it at a higher speed than a rinsing cycle.

1.8 Microprocessor Based Controllers

Microprocessors are now rapidly replacing the mechanical systems; controllers due to their advantage of become feasible to greater variety of programs.

For simple system, microprocessor with all memory integrated on one chip is used.

For complex system, Microprocessor with programmable logic controller is used.

Programmable Logic Controller (PLC) is a microprocessor based controller which uses programmable memory to store instructions to implement functions such as logic, sequence, timing counting and arithmetic to control events and can be readily reprogrammed for different tasks.

Microprocessor based systems have been introduced in many places.

Automatic camera
Engine management
Copying machine

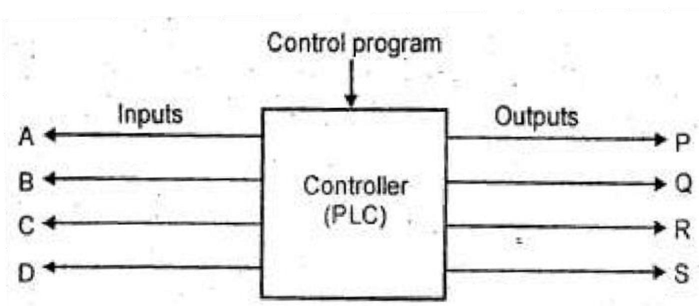


Figure 1.12: Programmable Logic Controller

1.7.1 Application example of Microprocessor control

When the switch is operated to activate the system and the camera pointed at the object being photographed.

The microprocessor takes input from the range sensor and gives an output to the lens position drive to achieve focusing.

The lens position is feedback to the microprocessor so that the feedback signal can be used. to modify the lens position according to the inputs from the range sensor.

The light sensor gives an input to the microprocessor and sends an output to determine whether the photographer has selected the shutter controlled rather than aperture controlled mode, the time for which the shutter will be opened.

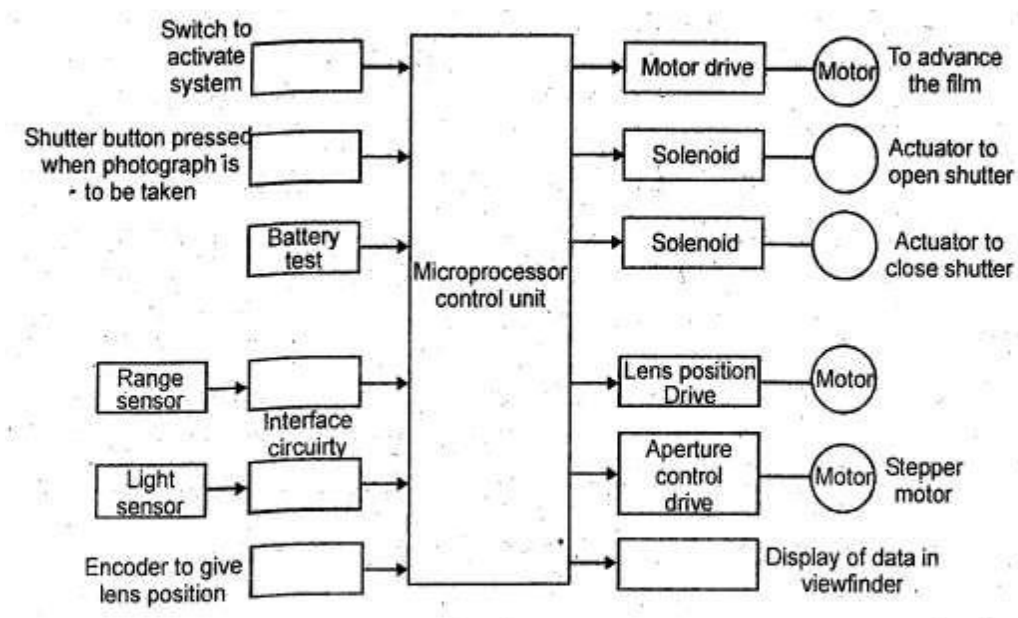


Figure 1.13: Automatic Camera

Sensors and Transducers

Sensor is used for an element which produces a signal relating to the quantity being measured.

Transducers are defined as the active element of a sensor that converts one form of energy into another.

Definition of Transducer

The term transducer is used in place of sensor. It is defined as element that when subjected to some physical changes experience a related change. Thus sensors· are transducers.

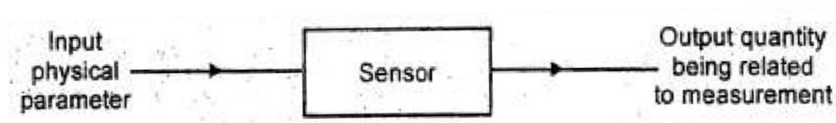


Figure 1.14: Sensor

Transducer

Transducer may be defined as an active element of a sensor in a measurement system that converts one form of energy into another form.

Usually, transducer converts non electrical Quantity into electrical Quantity.

Transducer works on the principle of transduction. Transduction is a process of converting the energy from one form into another.

Classification of Sensor /Transducer

Sensors are classified in the following ways.

a) According to the power supply
 1) Active type 2) Passive type

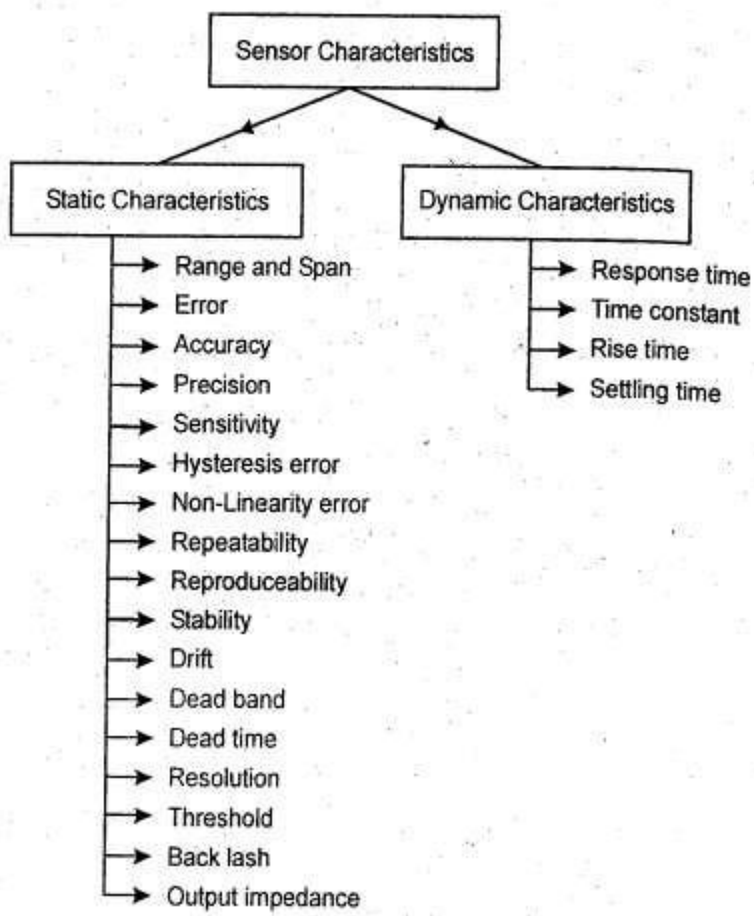
b) According to the mode of operation
 1) Null type 2) Deflection type

c) According to the signal characteristics (or) output
 1) Analog 2) Coded type 3) Digital type 4) Frequency type

d) According to the measurement (or) Function
 1) Displacement 2) Velocity 3) Acceleration 4) Dimensional
 5) Mass 6) Force 7) Proximity 8) Pressure
 9) Fluid Flow 10) Liquid level 11) Temperature

e) According to the performance characteristics
 1) Accuracy 2) Repeatability 3) Linearity 4) Sensitivity 5) Range

Sensor Characteristics



a) Static Characteristics

The static characteristics are the values given after the steady state condition has reached.

These are the values given when the transducer has settled down after receiving some input.

1. Range and Span

The region between the limits within which an input can vary is called the range of a sensor. The algebraic difference between the maximum and minimum limits of an input value is known as span of a sensor.

For example, the temperature, Range = 10°C to 80°C and Span = 80-10 = 70°C

2. Error

The algebraic difference between the measured value and the true value of a quantity being measured is known as Error.

For example, if a measurement system indicates a . temperature as 30°C when the actual (true) value being 25°C then the error is +5°C.

If the actual temperature being 35°C then the error is -5°C. Error may be negative or positive Quantity.

:. Error = Measured value - True value

3. Accuracy

Accuracy is the octant to which the measureed value might be wrong. Accuracy may be defined as the degree of closeness to the true value of the quantity being measured.

For example, a temperature measuring instrument might be specified as having an accuracy of ±2°C.

4. Precision

Precision is the degree of repeatability. Precision refers to the degree of closeness of agreement within which a group of measurements are repeatedly made under the prescribed conditions.

5. Sensitivity

Sensitivity is the relationship indicating how much output change when the input changes.

It may also be defined as the ratio of change in output signal to the charge in input signal. It is also called as scale factor.

6. Hysteresis Error

When input increases, output also increases and a calibration curve can be drawn.

If the input is decreased from maximum value and output does not follow the same curve, then there will be a residual output when input is zero.

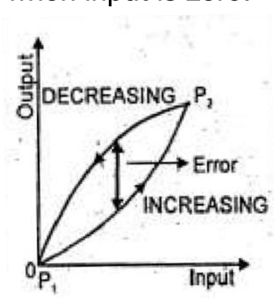


Figure 1.15 Hysteresis Error.

7. Non-linearity Error

The maximum deviation of the output curve from the best-fit straight line curve during a calibration cycle is known as non-linearity error.

There are three methods to find the numerical value of the non-linearity error.

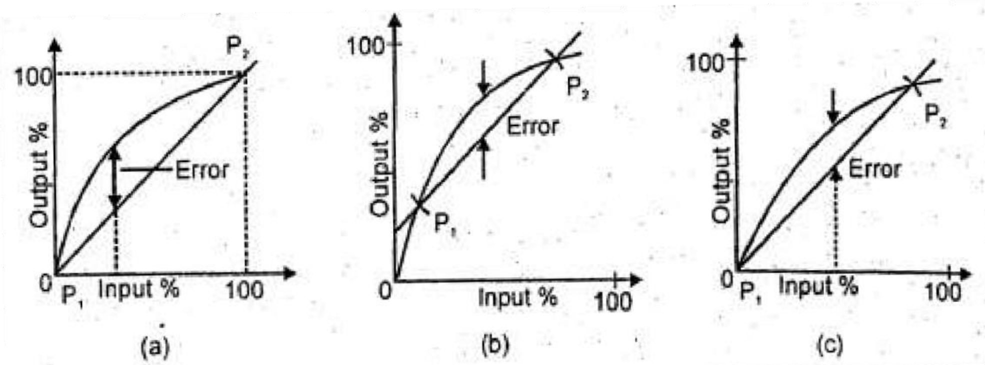


Figure 1.16: Non-linearity Error

Repeatability may be defined as the ability of a sensor to give the same output for repeated applications of the same input value under same environment conditions.

$$\text{Repeatability} = \left(\frac{\text{Max.} - \text{Min. values given}}{\text{full range}}\right) \times 100$$

9. Reproducibility

Reproducibility may be defined as the ability of a sensor to reproduce the same output for repeated applications of the same input value under different environment conditions.

10. Stability

The stability of a sensor refers to its ability to give the same output when used to measure a constant input over a period of time.

11. Drift

The term drift is an undesirable change or gradual departure in output over a period of time that is unrelated to change in input, operating conditions or load.

The drift may be expressed as a percentage of the full range output. Zero drift is used when there is a change in output at zero input.

12. Dead Band

Dead band or Dead zone or Dead space is the largest range of input values for which there is no output. It is caused by factors such as friction, backlash and hysteresis within the system.

13. Dead Time

Dead time is the time required by a transducer to begin to respond to a change in input value.

14. Resolution

Resolution or Discrimination is the smallest change in the input value that is required to cause an appreciable change in the output.

15. Threshold

Threshold is the minimum value of the input required to cause the pointer to move from zero position.

16. Backlash

Backlash may be defined as the maximum distance or angle through which any part of a mechanical system can be moved without causing any motion of next part of the system.

The degree of backlash may well vary with loading system.

17. Output Impedance

Output impedance of a measuring system is defined as its equivalent impedance as seen by the load.

A measuring system should have low output impedance to avoid loading effect.

A real voltage source can be modeled as an ideal voltage source in series with a resistance called the output impedance.

b) Dynamic Characteristics

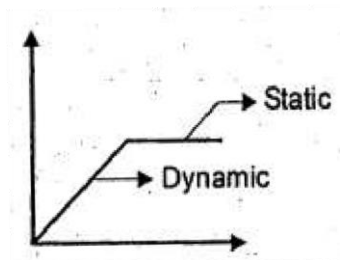


Figure 1.16: Dynamic Characteristics

1. Response Time

The time taken by a system to produce an output after a constant input, a step input, is applied to it is known as response time.

2. Time Constant

The time constant is the measure of the inertia of the sensor,and sohow fast it will react to changes in its input. The bigger the time constant, the slower will be its reaction to a varying input signal. This is 63.2% of response time.

3. Rise Time

Rise time is the time required for the output to rise from 10% to 95% of the steady state value.

4. Settling Time

Settling time is the time required for the output to settle down within some percentage normally 3% ofthe steady state value. .

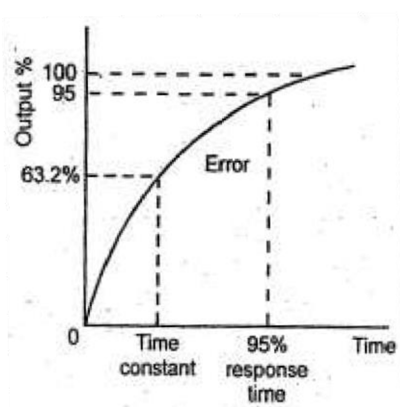


Figure 1.17: Sensor Dynamic Characteristics Curve

Sensors for Displacement, Position and Proximity Sensors
Displacement Sensors

Displacement sensors are concerned with the measurement of the amount by which some object has been moved. The displacement is frequently measured in relation with some other measurement and hence displacement sensors are fundamental components of any measurement system.

Position Sensors

Position sensors are concerned with the determination of the position of the object. With reference to some reference point. Displacement and position sensors can be grouped into Contact Sensor and Non-contact sensors. .

In contact sensors, the object to be measured comes into mechanical contact with the sensor. In Non-contact Sensor, there is no physical contact between the measured object and the sensor.

Proximity Sensors

Proximity sensors are a form of position sensors which are used to determine when object has moved to within some particular critical distance of the sensor.

Magnetic, electrical capacitance, inductance and eddy current methods are particularly suited to design a proximity sensor. They are on-off devices.

Selection of Displacement, Position or Proximity Sensors

- Size of the displacement (mm)
- Displacement type (Linear Of Angular)
- Resolution required
- Accuracy Required
- Material of the object
- Cost

Potentiometer

Potentiometers are mainly used to measure displacement pressure, position. A displacement or position transducer that uses the variable resistance transduction principle can be manufactured with a rotary or linear potentiometer.

Principle

Linear or Rotary potentiometer is a variable resistance displacement transducer which uses the variable resistance transduction principle in which the displacement or rotation is converted into a potential difference due to the movement of sliding contact over a resistive element.

Construction and Working

It consist a resistor, which has three terminals. Two end terminals and one middle terminal (Wiper). The middle terminal is movable. The two end terminals are connected to the external input voltage signal, and the middle terminal along with the one end terminal is taken as output.

The wiper slides over a resistive element to convert the-displacement into a potential difference.

Rotary Potentiometer

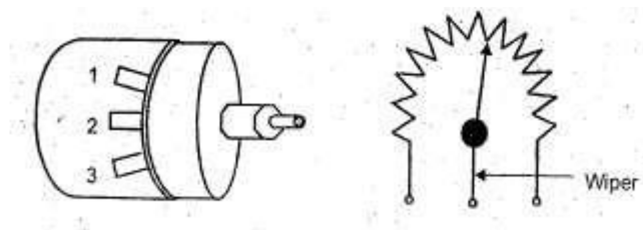


Figure1.18: Rotary Potentiometer

In the rotary potentiometer, the slider moves in a circular path along a resistance element, the rotational information is converted into information in the form of a potential difference. The output of the rotary transducer is proportional to the angular movement.

The resistor element is a circular wire-wound track which may be single turn or helical turn.

Characteristics:

Resistance element	=	Precision Drawn wire with a diameter of about 25 to 50 microns, and wound over a cylindrical or a flat mandrel of ceramic, glass, or Anodized aluminum.
	=	For high resolution, wire is made by using ceramic (cennet) or conductive plastic film due to low noise levels.
Wipers (Sliders)	=	Tempered phosphor bronze, beryllium copper or other precious alloys.
Wire Material	=	Strong, ductile and protected from surface corrosion by enameling or oxidation. Materials are alloys of copper nickel, Nickel-chromium, and silver palladium.
Resistance Range	=	20nΩ to 200K Ω and for plastic 500 Ω to 80K Ω
Non-linearity Error	=	0.1%to 1 % and for plastic 0.05%

The circuit when connected to a load.

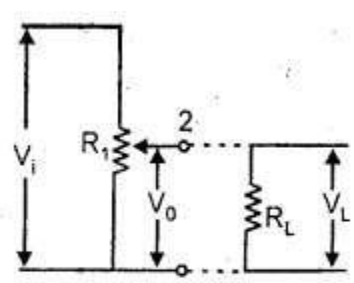


Figure 1.19 CIRCUIT

Then this may be converted into a simple potential divider circuit as follows

Advantages

- Less expensive
- Different sizes and shapes of potentiometers in different ranges are easily available
- High output
- A.C Excitation
- Rugged Construction
- Less sensitive towards vibration and temperature

- High electrical efficiency
- Operation is simple

Disadvantages

- Slow Dynamic Response
- Low Resolution
- Early wear of the wiper is possible
- Noisy output under high speed operation or high vibrating conditions
- Noise becomes too high when the slide velocity exceeds 3 m/sec

Strain Gauge

Principle

Strain gauges are passive type resistance sensor whose electrical resistance change when it is stretched or compressed (mechanically strained) under the application of force.

The electrical resistance is changed due to the change in length (increases) and cross sectional area (decreases) of the strain gauge.

This change in resistance is then usually converted into voltage by connecting one, two or four similar gauges as arms of a Wheatstone bridge (known as Strain Gauge Bridge) and applying excitation to the bridge.

The bridge output voltage is then a measure of strain, sensed by each strain gauge.

Strain gauges are generally two types. They are

1) Unbonded type
2) Bonded type

UnBonded Type Strain Gauges

In unbonded type, fine wire filaments (resistance wires) are stretched around rigid and electrically insulated pins on two frames.

One frame is fixed and the other is movable. The frames are held close with a spring loaded mechanism.

Due to the relative motion between two frames, the resistance wires are strained.

This strain is then can be detected through measurement of the change in electrical resistance since they are not cemented with the surfaces, they can be detached and reused.

This type of strain gauge is not suitable for displacement measurement because of its massive structure.

Bonded Type Strain Gauges

Bonded type strain gauges consists of resistance elements arranged in the form of a grid of fine wire, which is cemented to a thin paper sheet or very thin Bakelite sheet, and covered with a protective sheet of paper or thin Bakelite.

The paper sheet is then bonded to the surface to be strained. The gauges have a bonding material which acts an adhesive material during bonding process of a surface with e gauge element.

Under the application of force, the surface to which the strain gauge is bonded gets disturbed and strained.

So, the member elongates and its cross-sectional area reduces which makes the strain gauge also to get strain.

Due to this, the electrical resistance also changes from which the strain is measured.

Equation

Gauge factor is also known as strain sensitivity factor.

$$\boxed{\frac{\Delta R}{R} = G\varepsilon}$$

where,

ΔR = Change in Resistance, Ω

R = Resistance, Ω

G = Gauge factor (No Unit)

ε = Strain (No Unit)

$G = 1 + 2\mu$

μ = Possion's ratio

Classification of Bonded Type Strain Gauges

Based on the resistive materials used, or base or baking material and the gauge configurations, the bonded type strain gauges are classified as

1) Fine Wire Gauges
2) Metal Foil Gauges
3) Semiconductor Filaments Type

Wire Type Gauges

Very fine wires of about 3 microns to 25 microns are arranged in the fonn of grid shape consisting of a series of parallel long loops onto the mechanical part on which is to be strained.

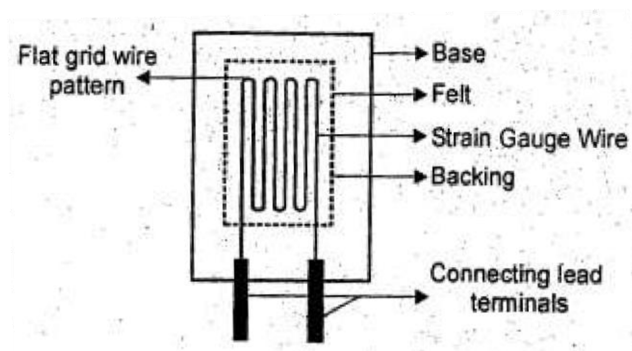


Figure 1.20: Wire type gauge

This is done by first cementing the grid to a thin paper sheet or to a very thin Bakelite sheet and Covered with a protective covering of paper, felt or thin Bakelite to provide mechanical and environmental protection to the gauge and leads wire attachment.

Metal foil Gauges

Metal foil strain gauge consists of a thin foil of metal, usually constantain, deposited as a grid pattern onto a plastic backing material, usually polyimide. The foil pattern is terminated at both ends with large metallic pads that allows lead wires to be easily attached with solder. The entire gauge is usually very small of about 5-15 mm long. For measurement, the strained surface (or) component is adhesively directly bonded to the gauge usually by epoxy

The backing makes the foil gauge easy to handle and provides a good bonding surface that also electrically insulates the metal foil from the component.

Semiconductor Filament Type

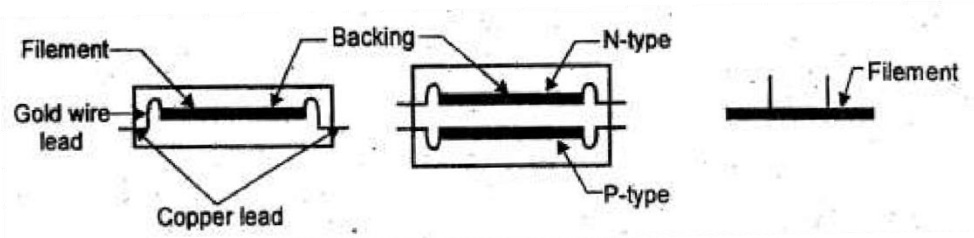


Figure 1.21: Semiconductor Filament Type

These gauges are produced in wafers from silicon or germanium crystals in which, amount of special impurities such as boron have been added to import certain desirable characteristics.

This process is called doping and the crystals are known as doped crystals. This Semiconductor filament mounted on a epoxy resin backing with copper on nickel leads.

Strain-Gauged Element

The strain gauge as a displacement sensor is only when it is attached to flexible elements in the form of cantilevers, rings or V-shapes.

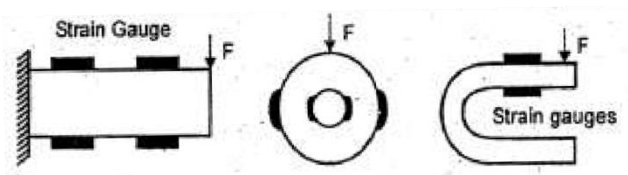


Figure 1.22: Strain Gauge elements

When the flexible element is bent or deformed as a result of forces being applied by a contact point being displaced.

Then the electrical resistance strain gauges mounted on the element is strained and so gives a resistance change which can be monitored.

Capacitive Sensors

Capacitive sensors are used for measuring, displacement, thickness, velocity, Liquid, level, flow, force, acceleration, pressure, audio signal/Relative humidity, strain etc.,

Principle

Capacitive sensors are passive type capacitive sensors in which equal and opposite charges are generated on the plates due to voltage applied across the plates which are separated by a dielectric material (insulator).

The mechanical displacement is generally measured in terms of change in capacitance due to change in area or change in dielectric or change in distance of separation.

The capacitance 'C' of a parallel plate capacitor is given by

$$C = \frac{\varepsilon_r \varepsilon_0 A}{d}$$

where ε_r = Permittivity of the dielectric between the plates [= 1 for air]

ε_0 = Permittivity of free space [= 8.854×10^{-12} F/m for air]

A = Area of overlap between two plates in m^2

d = Distance between two plates in m.

Capacitive Sensor as a Displacement Sensor

Capacitive Sensor is used for measuring displacement in three ways.

- By changing the Distance between two plates.
- By varying the Area of overlap
- By varying the dielectric.

a) By Changing the distance between two plates

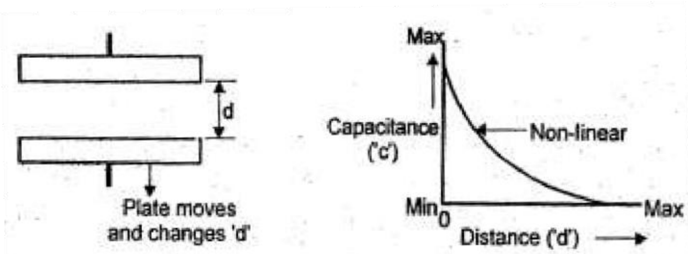


Figure 1.21: By Changing the distance between two plates

In this method, the displacement is measured due to the change in capacitance.

When the bottom plate is fixed, and the top plate is moved due to the displacement which is to be measured in terms of capacitances. C is given by

$$C = \frac{\varepsilon_r \varepsilon_0 A}{d}$$

The change in capacitance is inversely proportional to the plate separation. If the separation'd' is increased by a displacement 'x' then

$$C - \Delta c = \frac{\varepsilon_r \varepsilon_0 A}{d+x}$$

$$\frac{\Delta c}{c} = \frac{+d}{d+x} - 1 = \frac{d-d-x}{d+x} = \frac{-x}{d+x}$$

$$\frac{\Delta c}{c} = \frac{-(x/d)}{1+(x/d)}$$

Hence, there is a non-linear relationship between the capacitance change and distance (x). So, it is suitable for only small measurements where the output is approximately linear.

b) By varying the area of overlap

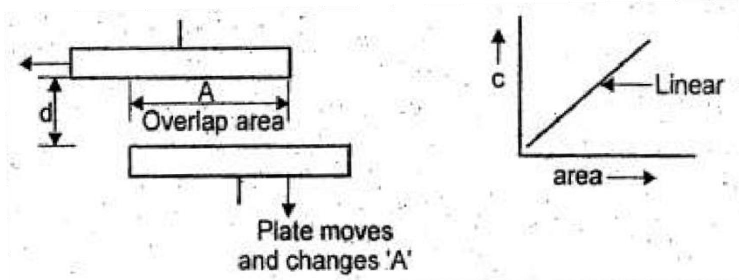


Figure1.22: By varying the area overlap

In this method, the displacement causes the area of overlap to vary.

Here, the Capacitance is directly proportional to the area of the plates and varies linearly with changes in the displacement between the plates.

This type of transducers is used to measure relatively large displacements.

c) By varying the Dielectric Constant

The change in capacitance can be measured due to change in dielectric constant as a result of displacement.

When the dielectric material is moved due to the displacement, the material causes the dielectric constant to vary in the region where the two electrodes are separated that results in a charge in capacitance.

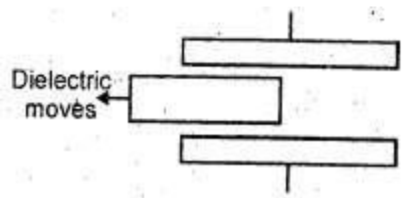


Figure 1.23: By varying the Dielectric Constant

d) Push pull Sensor

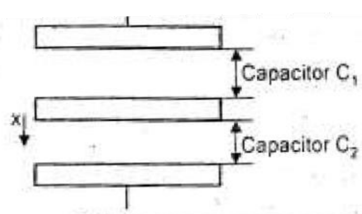
This Push pull displacement sensor is used to overcome the non-linearity errors.

This sensor consists of three plates with the upper pair forming one capacitor and the lower pair forming another capacitor.

The displacement moves central plate between the two other plates. I

f the central plate moves downwards, the plate separation of the upper capacitor increases and the separation of the lower one decreases.

$$\therefore C_1 = \frac{\varepsilon_0 \varepsilon_r A}{d + x} \quad \text{and} \quad C_2 = \frac{\varepsilon_0 \varepsilon_r A}{d - x}$$



Linear Variable Differential Transformer

Linear variable Differential Transformer (LVDT) is mainly used to measure displacement, position, force, acceleration, vibration, Liquid level etc.,

Principle

Linear variable Differential Transformer is variable inductances Transducers which are based on a change in the magnetic characteristics of an electric circuit in response to a measurement and such as displacement, velocity, acceleration etc.,

Inductance transducers measure the displacement by using the principle of change in mutual Inductance of a coil at varying core positions.

Mutual Inductance refers to the setup of an EMF in a coil or circuit element due to the change in the varying flux field in neighboring coil a circuit element.

LVDT Translates linear displacement into electrical signals.

Construction and Working

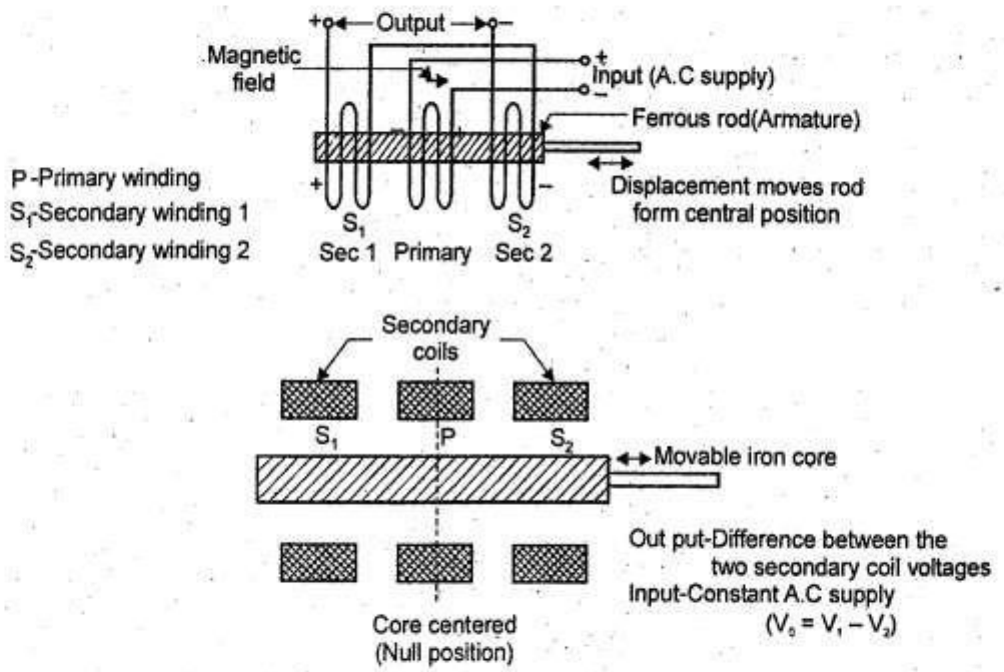


Figure 1.24: Linear Variable Differential Transformer (LVDT)

A LVDT consists of three symmetrically spaced coils or windings which are arranged concentrically and next to each other.

The central coil is the primary coil and the other two are identical secondary coils which are connected in series in such a way that their-outputs oppose each other.

These three coils are along an insulated tube and an ferrite magnetic core is moved through the central tube as a result of the displacement being monitored.

The LVDT must be excited by an AC signal to induce an AC response in the secondary.

The core position can be determined by measuring the secondary response.

When an AC current is supplied as an input to the primary winding, the magnetic flux generated by this coil is disturbed by the armature so that alternating EMFs are induced in the secondary

The net output from the coil is the difference between the two EMFs as they are connected such that their outputs oppose each other.

The core position determines the amount of voltage induced in the secondary coils. Let the voltages induced in secondary coil and secondary coil 2 as V_I and V_2 respectively and E is the output voltage induced.

a) Central-Output Position

When the core is in central position, the amount of magnetic material, in each of the secondary coils are same. Thus the EMFs induced in each coil are the same but EMF induced opposes each other.

Thus the net output is zero. This position is known as Electrical zero position or balance point or Null position (EZP).

b) Variable-Output Position

A variation in the core position from its null position produces an unbalance in the reactance of secondary windings to the primary windings.

There is a greater amount of magnetic material in one coil than the other. Thus, the EMFs is greater in the secondary winding towards which the core is displaced increases.

A simultaneous decrease induced EMF result from the other secondary coil. Thus, there is a net output from the two coils.

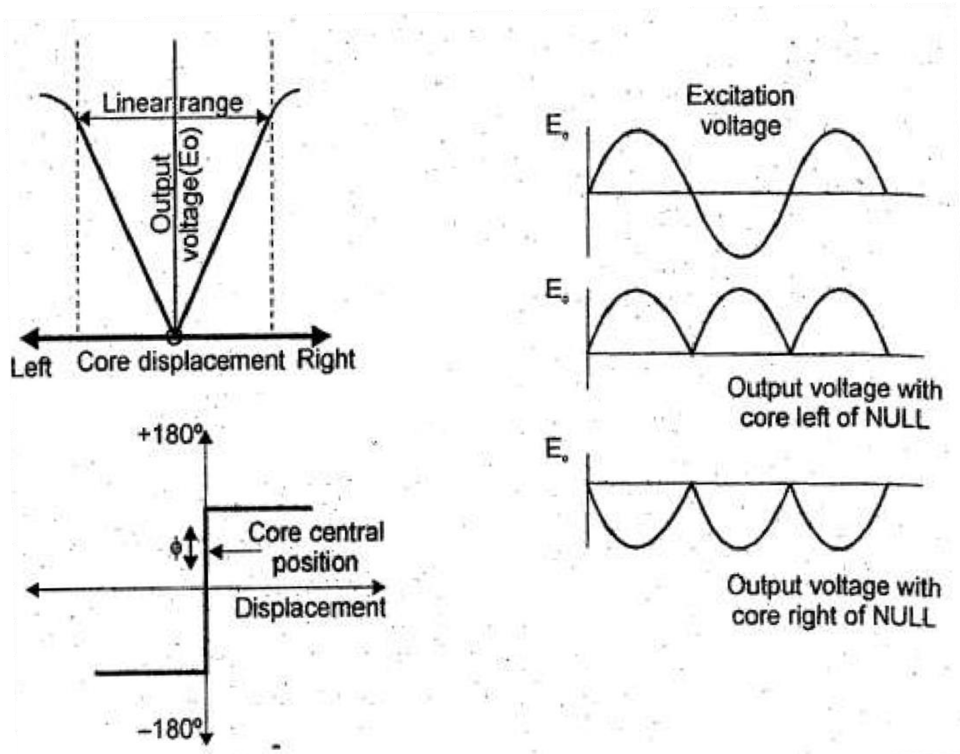


Figure 1.25: Various core Positions

Advantages of LVDT

- Operating ranges from about ±2 rom to ±400 mm with non-linearity errors of about±0.25% (High degree of linearity).
- Highly accurate and good stability
- Infinite Resolution up to 0.0 I % of full range and high output
- High Sensitivity and low cross sensitivity
- They can usually tolerate a high degree of shock and vibration without any adverse effects.
- They are simple, light in weight, and easy to align and maintain.
- They are low hysteresis, rugged and durable construction.

• Negligible operative force and no wear of moving parts.
• High range frictional and electrical isolation
• Less power Consumption
• LVDT can be used for measuring short displacements.

Disadvantages

• LVDT must be excited only by AC. voltage
• They are disturbed by external magnetic fields
• They are less sensitive when used for dynamic measurements.
• They are not well suited for frequencies greater than 1/10 of the excitation frequency.
• Mass of the core introducer some amount of mechanical loading error.
• Temperature affects the performance of the transducer.

Applications of LVDT

• LVDT is widely used as primary Transducers for monitoring displacements.
•LVDT is used as secondary Transducers for measuring force, weight, pressure, acceleration etc.,
•They are mostly found in automotive industry, servo control systems, process control, automation, electronic industry, and research laboratories etc.,
• Measurement of the precision gap between weld torch and work surface in welding applications.
• Measurement of the thickness of metal plates during the process of manufacturing in rolling mills.
• Detection of surface irregularity in engineering parts (finished).
• Measurement of liquid level
• Precision detection of specimen size

Rotary Variable Differential Transformer (RVDT)

A rotary variable differential Transformer (RVDT) operates on the same principle as the LVDT. The magnetic material used for making the core is a cardioids-shaped piece.

The rotation of core causes to pass it into one secondary coil more than the other. The result is the displacement measurement.

RVDT are used to measure rotation of an angular shaft. The range of operation is ±40° with a linearity error of about ±0.5% of the range.

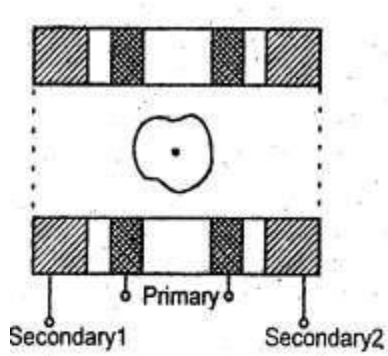


Figure 1.26: Rotary Variable Differential Transformer (RVDT)

Eddy Current Proximity Sensors

Proximity simply tells the control system whether a moving part is at a certain place. Proximity sensors come under the non-contact type sensors.

In other words, a proximity sensor consists of an element that changes either it state or an analog signal when it is close to, but not actually touching, an object.

These eddy current proximity sensors are used to detect the presence (or) Absence of non-magnetic but conductive materials.

Principle

When a coil is supplied with an alternating current, an alternating magnetic field is produced which induces an EMF in it.

If there is a metal object in close proximity to this alternating magnetic field, on EMF is induced in it.

This EMF causes localized current to flow. The localized currents are called eddy currents.

Eddy currents can be induced in any conductor but are most noticeable in solid conductors.

Construction and Working

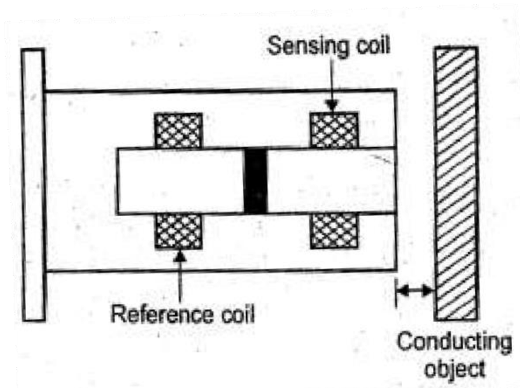


Figure 1.27: Eddy Current Proximity Sensors

The eddy current sensor has two identical coils. One coil is used as a reference coil and the other as a sensing coil to sense the magnetic current in the conductive object.

When there is a metal object in close proximity to this alternating magnetic field, an EMF is induced in it which causes the eddy currents to flow.

The eddy current themselves produces a magnetic field that opposes that of the sensing coil.

This distorts the magnetic field responsible for their production, resulting in a reduction of flux.

When the plate is nearer to the coil, the eddy currents and the change in magnetic impedance are both trigger and so the amplitude of the alternating current.

In the absence of an target object, the output impedance is zero.

At some preset level, the change can be used to trigger a switch. Using sensitive eddy current transducers, it is easy to detect differential motions of 0.00 1 mm.

Advantages

- Inexpensive
- Small in size
- High reliability
- High Sensitivity to small displacements

• Effectiveness while operating at elevated temperatures.

Inductive Proximity Sensors

It consists of a coil wound round a core. When there is a metal object in close proximity to this coil end, the inductance changes.

A resonance circuit may be connected to this coil for monitoring the effect of this inductance charge.

At some preset level, this change can be used to trigger a switch. It can only be used for the detection of metal objects and its best suitability is for ferrous metals.

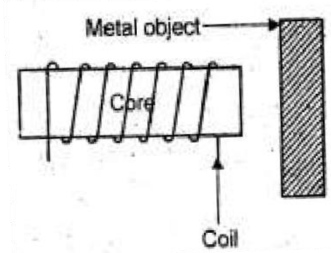


Figure 1.27: Inductive Proximity Sensor

Pneumatic Proximity Sensors

Pneumatic Sensors are used in the measurement of displacement (or) proximity of an object in the form of air pressure.

Principle

Pneumatic proximity, sensors uses compressed air as a medium for the transmission of signal and power.

These types of sensors are non-electrical in nature and are widely used in industrial instrumentation for measurement and gauging application

Construction and Working,

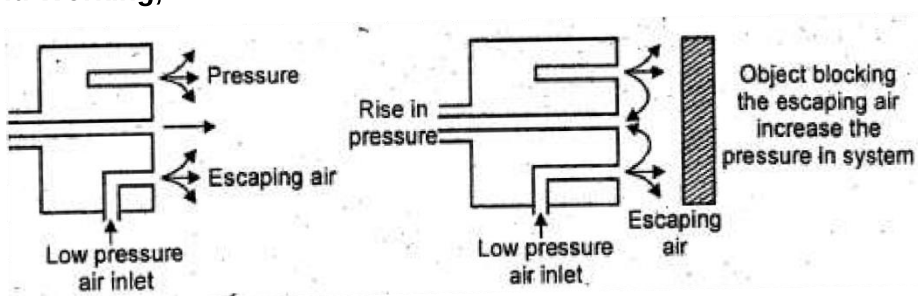


Figure 1.28: Pneumatic Proximity Sensors

Air from the compressor relatively at low pressure is allowed to escape from the sensor through a port located at the front side.

When there is on absence of object, the air escapes freely to the atmosphere and sense the pressure decreases at the nearby sensor output port.

When there is an object, the escaping air is blocked and return back to the system. So the air cannot escapes freely to the atmosphere and hence the pressure increases at the, nearby Sensor output port.

Thus the object presence or absence decides the output pressure of the air from the sensors.

Such sensors are used for the measurement of displacements of fractions of millimeters in ranges which typically are about 3 to 12 mm.

Proximity Switches

There are a number of forms of switch which can activate or deactivate on presence or absence of an object in order to give a proximity sensor with on output which is either on or off.

These are considered to be very importance sensing elements, mainly used in robotics. NC machines, material handling systems, assembly lines etc., in order to sense the end points, arrival of the object, presence of work piece and end of task etc., respectively.

These proximity switches are categorized into

a. Micro Switch b. Reed Switch
c. Photo Sensitive Switch d. Mechanical Switch

a. Micro Switch

This is one of form of limit switch operated by using levers, Rollers and cams. A micro switch is a small electrical switch which requires physical contact and a small operating force to close the contacts.

For Instance, In material handling systems, to find the presence of an object. On a belt conveyor, the spring sets depressed due to the weight of the object;

This depressed spring position is due to depression on belt. Due to this action, the contact switch was closed.

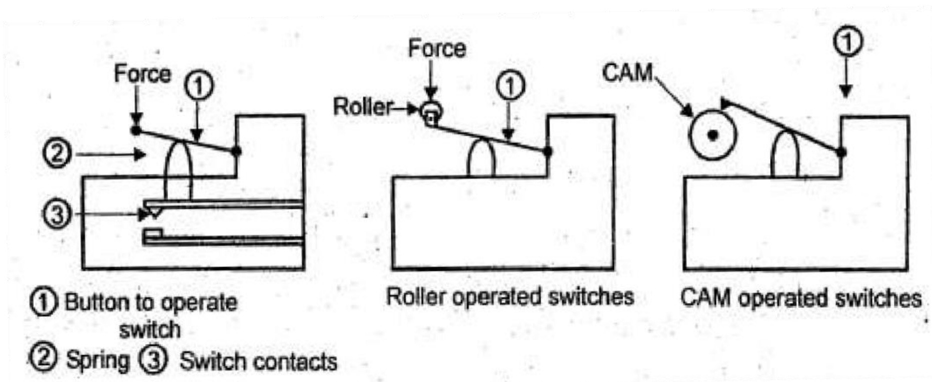


Figure 1.29: Actuating Mechanisms of Switching

This soft touch type's switch does not take much power to close them. This sensor can be used to reverse the direction of the drive motor or other vehicle when it suddenly strikes an obstacle. For example, a lever can increase the sensitivity of a micro switch.

Push buttons can also be used as sensors. It is important to choose a switch that can be easily closed by the mechanisms available.

Micro switch can be used as impact detector, position sensors, displacement sensors, and Acceleration / deceleration sensor.

b. Reed Switch

A reed switch is a non-contact proximity switch that consists of two magnetic switch contacts enclosed in a glass tube fined with an inert gas.

When the magnet is moved close to the switch, the magnetic contacts are attracted to each other and close the switch contacts. It normally uses single pole single throw (SPST) switch.

Reed switches are very sensitive but can't handle large currents. Typical currents are in the range of 50 to 500 mA. Since they can switch a circuit very quickly, they can be used in high speed applications, sensing the rotation of a shaft or any mobile post of a mechanism.

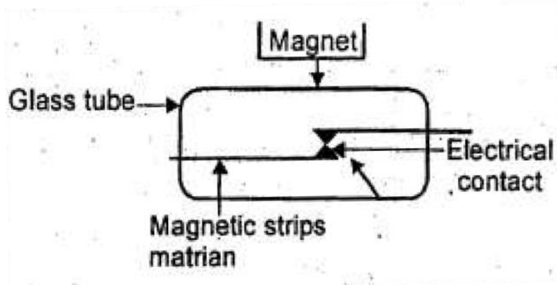


Figure 1.30: Reed switch

Reed switch is used as sensors as position sensors, Inclination sensors, Speed or (RPM) sensors, Limit switches, Reed relay, Proximity Sensors.

c. Photo Sensitive Devices

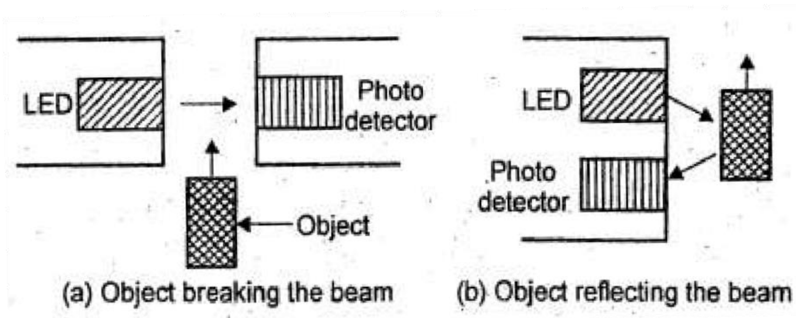


Figure 1.31: Photo Sensitive Devices

Photo sensitive devices are used to detect the presence or, absence of an opaque object. Photo detector receives a beam of light produced by the LED.

When an opaque object is passed, the beam gets broken. In another case, the infrared radiation (beam) falling on the object is reflected to the photo detector and the object is thus detected.

d. Mechanical Switches

Mechanical switches consists of one or more pairs of contacts which can be mechanically closed or opened to make or break electrical circuits and 0 and 1 signals are generated.

All switches are used to open or close within circuits. Switches are normal characterized by the number of poles and throws.

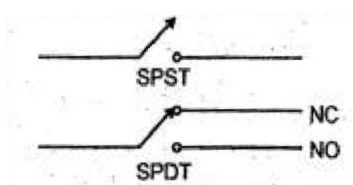


Figure 1.32: Mechanical Switch

Poles are the number of separate moving elements in a circuit that are used to complete or break the connecting by the same switching action.

Throws are the number of individual contact points for each pole. Debouncing is the main problem arises in the mechanical switch.

When a mechanical switch is switched to close or open the contacts, it also hits and bounces back to the other end as the contacting elements are elastic.

It may bounce a number of times before finally settling to its new state after, typically, some 20 ms.

To overcome, this problem either hardware or software can be used, With software, the microprocessor is programmed to detect, if the switch is closed / opened and then wait, say, 20 ms.

After checking, the bouncing has ceased and the switch is the same position, the next part of program can take place.

1.21 Optical Encoders

Optical Encoders are mainly used to measure the angular or linear displacement, position, velocity, acceleration and direction of movement of rotors, shafts particularly in machine tools, robots, rotary machines, and translational systems etc.,

Encoder is a circular device in the form of disk that provides a digital output in response of a movement.

Principle

An optical encoder is a device, that converts motion or any movement into a sequence of encoded pulsed digital signals by modulating (coding) the continuous optical signals from a light source.

The light source is received by a photo detector through a slotted disk containing coded patterns called track.

By counting or decoding these bits and the pulses can be converted into relative or absolute position measurements.

The number of pulses is being proportional to the position of the disk. The number of the pulses per second determines the velocity of the disk.

Classification of Optical Encoders may be classified as follows:

1. Linear Encoder
2. Rotary Encoder

    a) Incremental Encoder   b) Absolute Encoder

a) Incremental Encoder

An incremental encoder provides a simple pulse by which each time the object to be measured has moved a certain distance.

This encoder comparatively produces digital pulses as the shaft rotates, for the measurement of relative displacement of the shaft.

Incremental encoder also called as relative Encoder that detects changes in rotation from some datum position (reference position).

Principle

When a beam of light passes through slots in a disc, it is detected by a suitable light sensor places opposite to the light source.

When the disk is rotated, a pulsed output is produced by the sensor with the number of pulses being proportional to the position of the disk and the number of pulses per second determines the velocity of the disk.

Construction and Working

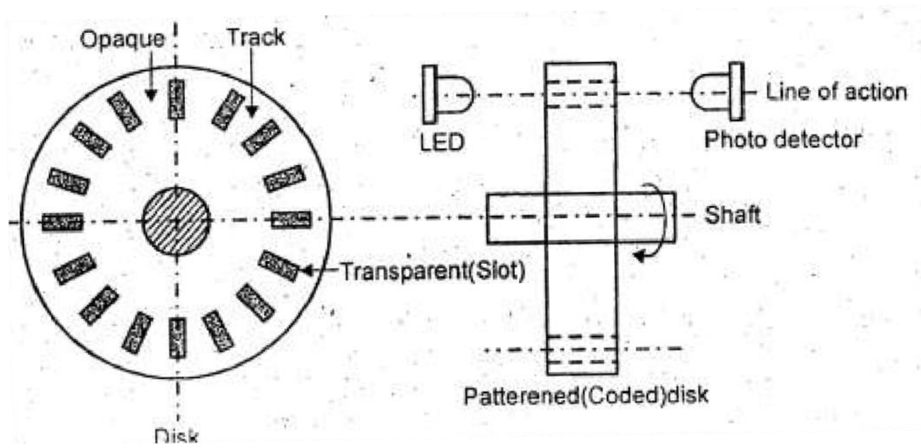


Figure 1.33: Classification of Optical Encoders

It consists of primarily three components: a light source, a coded disk and a photo detector.

A coded wheel is a specially designed rotating disk made of plastic or glass containing code patterns called 'track'.

The pattern or track on the disk consists of alternate appearance of opaque and transparent segment and the pattern is circular.

The coded wheel is mounted between the light source and a photo detector. The light source used here is light emitting diode (LED) to provide continuous light signal.

A photo diode or photo transistor is commonly used as a photo-detector.

The position of these three components should be such that their line, of action must be same. The disk is rigidly fixed with the rotor or shaft.

When the opaque section of the coded disk passes in front of the light, the detector does not receives any signal and hence no output.

Conversely, when the transparent section of the coded disk passes in front of the light, the detector receives light signal from the light source and hence there is an output.

Under these design criteria, if the disc is made to rotate, the photo detector will receive pulsed light signal for every time it sees the light source i.e. the LED.

The photo detector converts the light signal into electrical signal. The result is a series of signals corresponding to the rotation of the coded wheel.

By using a counter to count these signals, it is possible to find out how far the wheel has rotated. Velocity information can be obtained by differencing the pulses.

Classification of incremental Encoders

There are two types of Incremental Encoders.

They are

1) Tachometer type

2) Quadrature type

1) Tachometer Incremental Optical Encoder

Tachometer type encoders are incremental encoders with one output channel and are typically used in systems requiring velocity measurement. This is done by looking at the pulses during a certain interval of time.

2) Quadrature Incremental Optical Encoders

Quadrature Encoders are the more popular type having dual channels A and B.

The output waveform is arranged in such a way that channel A signal is 90° out of phase with channel B signal.

This systems are used to determine the direction of rotation or movement of a rotor. In practice, three concentric tracks with three sensors are used.

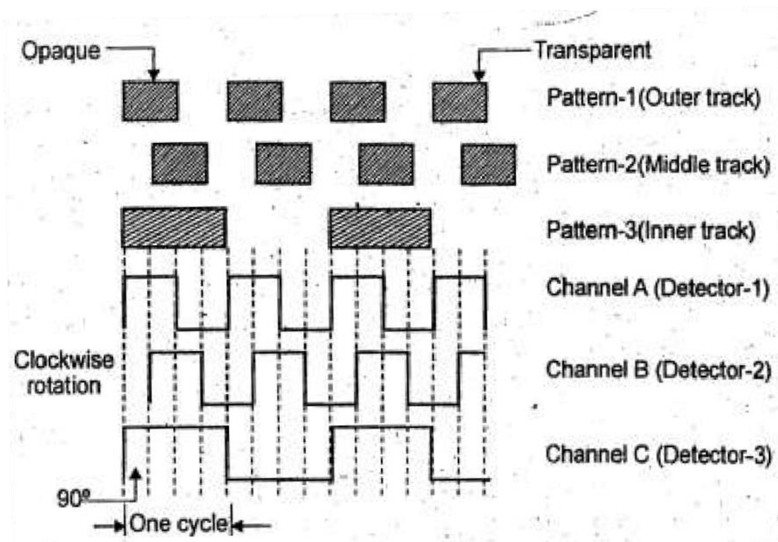


Figure 1.34: Quadrature Incremental Optical Encoder

The relative angular placements of transparent segments of these patterns are such that, the outputs of the three photo detectors are like as shown in figure.

In order to make it more clear an equivalent of the relative angular placements of two patterns have been shown in figure.

Such signals together are referred to as 'quadrature square waves', which means that two square waves that are phase-shifted with respect to each other by 90° electrical or one-quarter of a cycle and hence the name.

The phase relationship parameter, offset by 90° electrical, determines the direction. If channel a leads channel C than the direction of movement clockwise direction and vice versa.

The resolution is determined by the number of slots on the disk. With 90 slots, for 1 revolution the resolution is 360° /90° = 4°, for better resolution, disks having higher number of slots are preferred.

2) Absolute Encoders

As the name implies, absolute encoders provide actual positional information without using any external reference.

They are used where knowledge of position is required at all times.

However, when the encoder is required to operate over more than one complete revolution, a record of the number of completed Revolutions is required.

Principle

The principle of operation is that they provide a unique output (digital word) corresponds to each rotational position of the shaft.

The output is in the form of a binary number of several digits, each such number representing particular angular position.

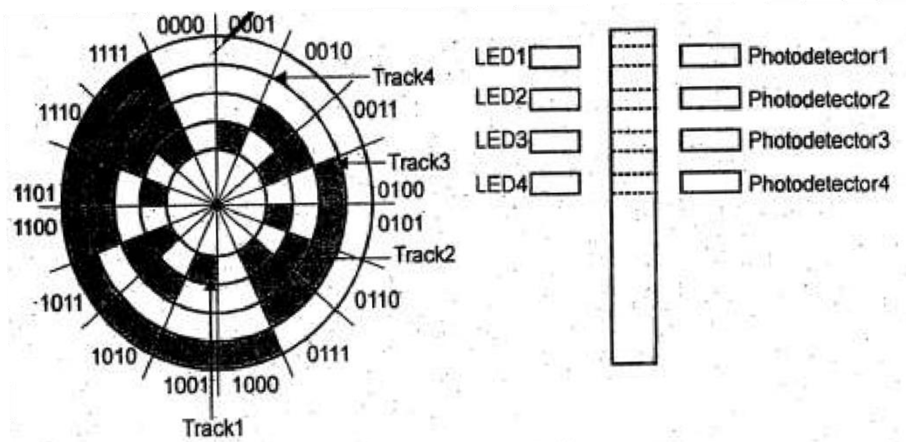
Construction and Working

The rotating disc consists of four concentric slots and four photo detectors to detect the light pulses. The slots are arranged in such a way that the sequential output from the sensors is a number in the binary code.

The optical rotating disc is designed to produce a digital word that distinguishes N distance positions of the shaft. The coded disk consists of a number of concentric patterns of opaque and transparent segments. The concentric patterns are called tracks.

Typical encoders have usually 8 to 14 slots. The number of track determines the resolution of the encoder.

The number of bits in binary number will be equal to the number of tracks.



	Normal	Binary	Gray	Code
0	0000		0000	
1	0001		0001	
2	0010		0011	
3	0011		0010	
4	0100		0110	
5	0101		0111	
6	0110		0101	
7	0111		0100	
8	1000		1100	
9	1001		1101	
10	1010		1111	

Figure1.35: Absolute Encoders

Thus with 12 tracks, there will be 12 bits and so the encoder will be able to detect 2^{12} = 4096 positions for the single rotation with a resolution of 360 / 4096= 0.0878°

Figure shows a 4 bit absolute encoder,

In practice, the normal binary coded techniques are not used because changing from one track (bit) to the next can result in multiple track change during count transitions.

This lead to false counting. To overcome this, Gray code is generally used. They are reliable and are as considered versatile error detecting codes. .

With is a code only one track change in moving from one number to the next.

The great merit of the absolute encoder is that if the power fails the exact position of the rotating disk can be known.

Interface Integrated circuits are also available to decode the encoder and give a binary output suitable for a microprocessor.

Advantages of Optical Encoders

- Incremental Encoder provide more resolution at lower cost than absolute Encoders
- Optical Encoders are the most reliable and least expensive motion feedback devices.
- Incremental Encoders are simple
- Highly accurate
- Suitable for sensitive applications
- Absolute Encoders measures absolute position as well as relative position

Applications

- Absolute Encoders are chosen where establishing a reference position is difficult or undesirable.
- Optical Encoders are used in velocity, displacement measurement etc;

Hall Effect Sensors

Hall effect sensors are used to measure proximity, position displacement, level and flow. They can be used as an analog motion. This transducer works on the principle of Hall Effect which was discovered by E.R. Hall in 1879.

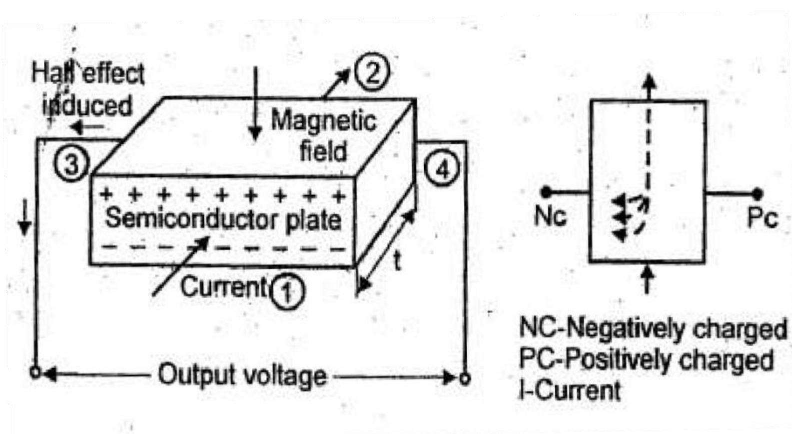


Figure 1.36: Hall Effect Sensors

Principle

When a current carrying semiconductor plate is placed in a transverse magnetic field, it experiences a force (Lorentz force).

Due to this action a beam of charged particles are forced to get displaced from its straight path. This is known as Hall Effect.

A current flowing in a semiconductor plate is like a beam of moving charged particles and thus can be deflected by a magnetic field.

The side towards which the moving electrons deflected becomes Negatively charged and the other side of the plate becomes positively charged or the electrons moving away from it.

This charge separation produces an electrical voltage which continues until the lorentz force on the charged particles from the electric field balances the forces produced by the magnetic field.

The result is a traverse potential difference known as Hall voltage.

Construction and Working

Current is passed through leads 1 and 2 of the semiconductor plate and the output leads are connected to the element faces 3 and 4.

These output faces are at same potential when there is no transverse magnetic field passing through the element and voltage 'V_n' known as Hall voltage appears when a transverse magnetic field is passing through the element.

This voltage is proportional to the current and the magnetic field.

The direction of deflection depends on the direction of applied current and the direction of magnetic field.

For optimum results, three quantities should be mutually perpendicular as illustrated in the figure.

Hall Effect is pragmatic in all metals, but semiconductor materials are used for transducer fabrication, because, controllable amount of charge carries can be doped in the semiconductor material determining the application of the transducer.

Magnetic field could be either positive or negative, if it is employed for measurement of current.

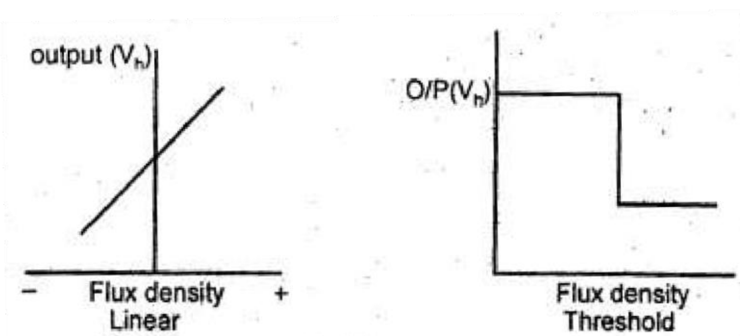


Figure 1.37: hall Effect

From the above equation, it is clear that the hall voltage is proportional to the current and the magnetic field at right angles to the plate.

Thus, if a constant current source is provided, the magnetic flux density can be measured.

The Hall Effect may be negative or positive which affects the overall sensitivity of the sensor.

Typical specifications are the power supply, temperature range, operating frequency and air gap.

Advantages of Hall Effect Sensors

- Hall Effect sensors are very fast and sensitive
- Able to operate as switches for repetition rates up to 100 KHz
- Cheaper than electromechanical switches
- No bouncing problems as occurs in case of electromechanical switches.
- Highly Immune to environmental Contaminants.
- It can be used under severe Service Conditions.

Applications

- They are widely used for measuring position, proximity, displacement, level and flow and used as proximity sensors, limit switches.
- They are also used for sensing deflections in biomedical implants.
- It can be used as a magnetic to electric Transducer
- It is used to measure current, power etc,
- It is used to check the alignment of windings in brushless DC motor.
- They are used in automotive, automation and control, robotics, valves, computers, motor communication, Security Systems, angular movement, length measurement, current sensing etc.

Tachogenerator

The tachogenerator is used to measure angular velocity. The tachogenerator, consists of a toothed wheel of ferromagnetic material which is attached to the rotating shaft.

A pick up coil is wound on a permanent magnet. As the wheel rotates, so the teeth move past the coil and the air gap between the coil and the ferromagnetic material changes

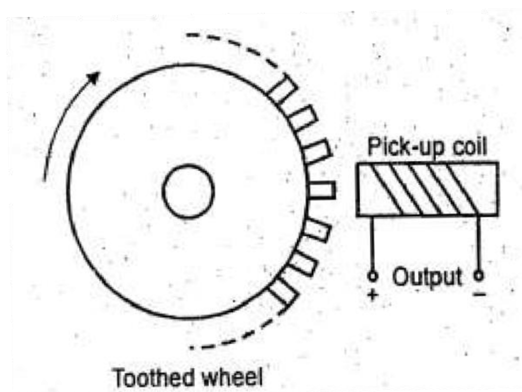


Figure 1.38: Variable reluctance tachogenerator

We have a magnetic circuit with an air gap which periodically changes. The resulting cyclic change in the flux linked produces an alternating e.m.f. in the coil.

Formula used

i) For finding flux in the coil:

$$\boxed{\Phi = \Phi_0 + \Phi_a \cos n\omega t}$$

where

Φ = flux in coil, Φ_0 = mean value of flux, Φ_a = amplitude of flux variation

n = No. of teeth, ω = angular velocity, t = time

ii) For finding induced emf in the coil:

$$e = -N\frac{d\Phi}{dt} = -N\frac{d}{dt}(\Phi_0 + \Phi_a \cos n\omega t) = N\Phi_a n\omega \sin n\omega t$$

$$\boxed{e = E_{max} \sin \omega t} \quad (\because \; E_{max} = N\Phi_a n\omega)$$

where

e = induced emf

N = No. of turns of the pickup coil

Motion sensors

Pyroelectric sensors

Lithium tantalate, are crystalline materials which generate charge in response to heat flow.

When such a material is heated to a temperature just below the Curie temperature, this being about 610°C for lithium tantalate, in an electric field and the material cooled while remaining in the field, electric dipoles within the material line up and it becomes polarized

When the field is then removed the material retains its polarization; the effect is rather like magnetizing a piece of iron by exposing it to a magnetic field.

When the pyroelectric material is exposed to infrared radiation, its temperature rises and this reduces the amount of Polarization in the material, the dipoles being shaken up more and losing their alignment

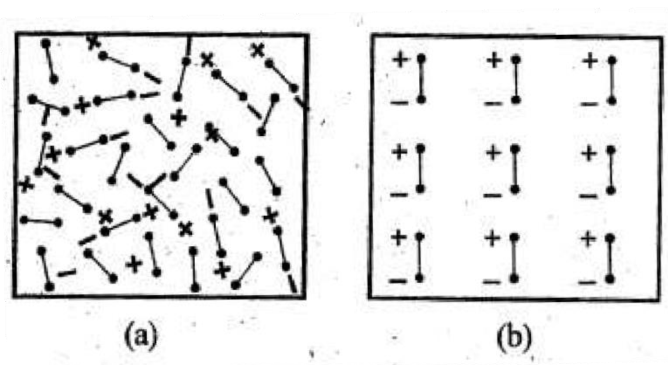


Figure 1.39 Polarizing a pyroelectric material

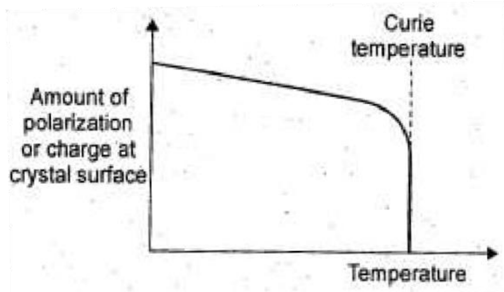


Figure 1.55 Effect of temperature on amount of polarization

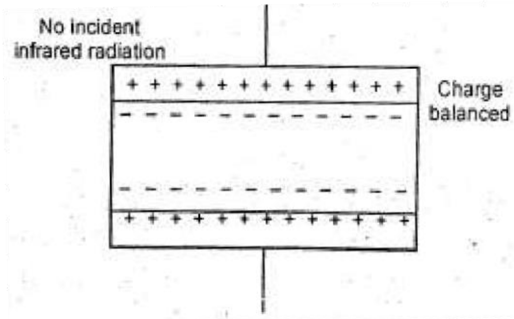


Figure 1.56 Pyroelectric sensor

Force Sensors

Strain gauge (or) Load cell

Commonly used form of force-measuring transducer is based on the use of electrical resistance strain gauges to monitor the strain produced in some member when stretched, compressed or bent by the application of the force.

The arrangement is generally referred to as a load cell. This is a cylindrical tube to which strain gauges have been attached.

When forces are applied to the cylinder to compress it, then the strain gauges give a resistance change which is a measure of the strain and hence the applied forces.

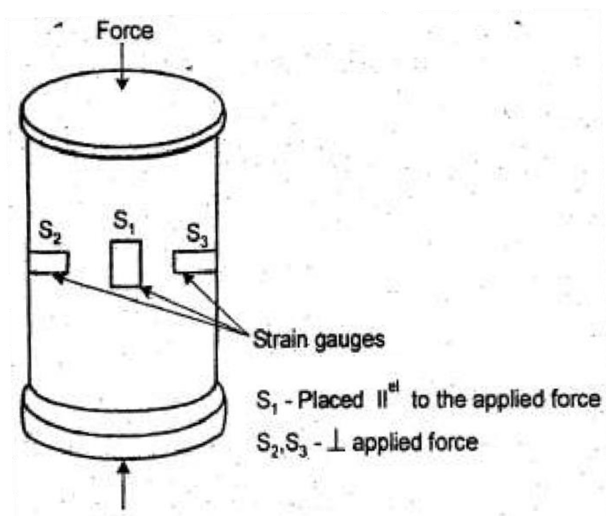


Figure1.40: Strain gauge load cell

Since temperature also produces a resistance change which is a measure of the strain and hence the applied forces.

Since temperature also produces a resistance change, the signal conditioning circuit used has to be able to eliminate the effects due to temperature.

Fluid pressure Sensor

a) Diaphragm Capsules, Bellows and Tube type sensors

The devices used to monitor fluid pressure involve the monitoring of the elastic deformation of diaphragms, capsules, bellows and tubes.

The type of pressure measurements that can be required are absolute pressure where the pressure is measured relative to zero-pressure, i.e. a vacuum, differential pressure where a pressure difference is measured and gauge pressure where the pressure is measured relative to the barometric pressure.

i) Diaphragm Type

In the diaphragm type sensor, when there is a difference in pressure between the two sides then the centre of the diaphragm becomes displaced. Corrugations in the diaphragm result in a greater sensitivity.

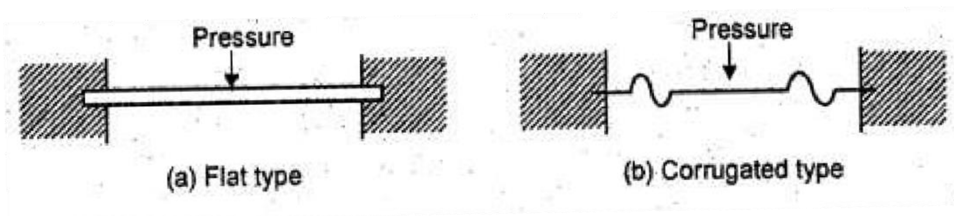


Figure 1.41: Diaphragm types

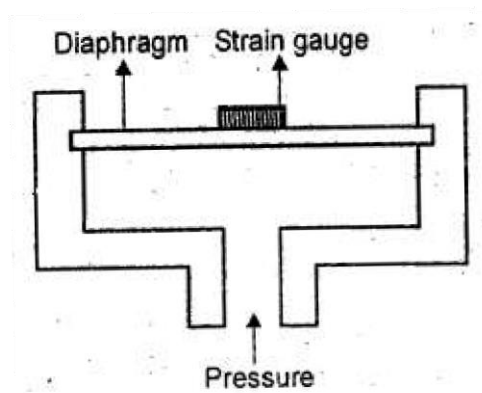


Figure 1.42 Diaphragm pressure gauge

This movement can be monitored by some form of displacement sensor, e.g. a strain gauge, as illustrated in figure.

A specially designed strain gauge is often used, consisting of four strain gauges with two measuring the strain in a circumferential direction while two measure strain in a radial direction.

The four strain gauges are then connected to form the arms of a Wheatstone bridge. While strain gauges cannot stuck on a diaphragm, an alternative is to create a silicon diaphragm with the strain gauges as specially doped areas of the diaphragm.

ii) Capsule and Bellow Types

Capsules can be considered to be just two corrugated diaphragms combined and give even greater sensitivity. A stack of capsules is just a bellows and even more sensitive.

Diaphragms, capsules and bellows are made from such materials as stainless steel, phosphor bronze, and nickel, with rubber and nylon also being used for some diaphragms. Pressures in the range of about 103 to 108 Pa can be monitored with such sensors.

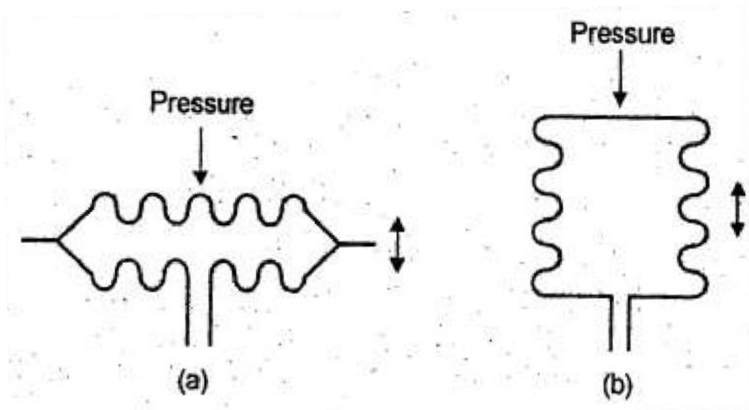


Figure 1.43(a) Capsule, (b) bellows

iii) Tube Pressure Sensor

A different form of deformation is obtained using a tube with an elliptical cross section increasing the pressure in such a tube causes it to tend to a more circular cross-section.

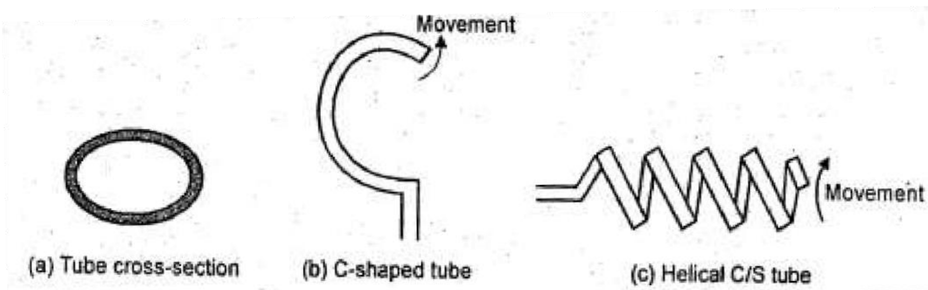


Figure 1.44: Tube pressure sensors

When such a tube is in the form of a C-shaped tube known as a Bourdon tube and the C opens up to some extent when the pressure in the tube increases.

A helical form of such a tube gives a greater sensitivity. The tubes are made from such materials as stainless steel and phosphor bronze.

Piezoelectric Sensors

Piezoelectric materials when stretched or compressed generate electric charges with one face of the managerial becoming positively charged and the opposite face negatively charged.

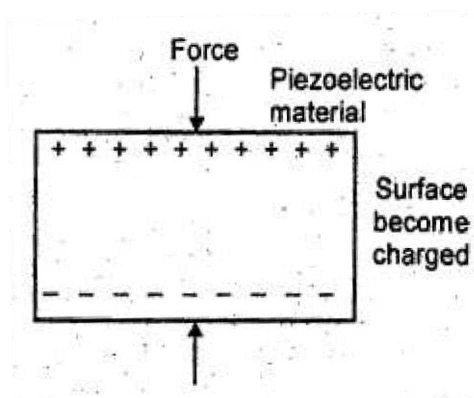


Figure 1.45: Piezoelectricity

As a result a voltage is produced. The net charge q on a surface is proportional to the amount x by which the charges have been displaced, and since the displacement is proportional to the applied force F. : $q = kx = SF$

where k is a constant and S a constant termed the charge sensitivity. The charge sensitivity depends on the material concerned and the orientation of its crystals.

Tactile sensor

A tactile sensor is a one form of pressure sensor. This sensor is used on the 'fingertips' of robotic 'hands' to determine when a 'hand' comes into contact with an object.

They are also used for 'touch display' screens where a physical contact has to be sensed.

One form of tactile sensor uses piezoelectric poly vinylidene fluoride (PVDF) film. Two layers of the film are used are separated by a soft film which transmits vibrations.

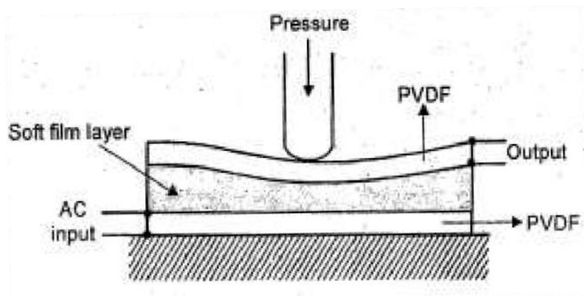


Figure 1.46: PVDF tactile sensor

The lower PVDF film has an alternating voltage applied to it and this results in mechanical oscillations of the film (the piezoelectric effect described above in reverse).

The intermediate film transmits these vibrations to the upper PVDF film. As a consequence of the piezoelectric effect, these vibrations are affected and the output alternating voltage is changed.

Liquid flow sensor

In the concept of measuring liquid flow involves the major role of Bernoulli's equation.

Since mass of liquid passing per second through the tube prior to the constriction must equal that passing through the tube at the constriction, we have $A_1 v_1 \rho = A_2 v_2 \rho$, But the quantity Q of liquid passing through the tube per second is $A_1 v_1 = A_2 v_2$

The quantity of fluid flowing through the pipe per second is proportional to √ (Pressure difference)

a) Orifice plate

The orifice plate is simply a disc, with a central hole, which is placed in the tube through which the fluid is flowing.

The pressure difference is measured between a point equal to the diameter of the tube upstream and a point equal to half the diameter downstream.

The orifice plate is simple, cheap with no moving parts, and is widely used.

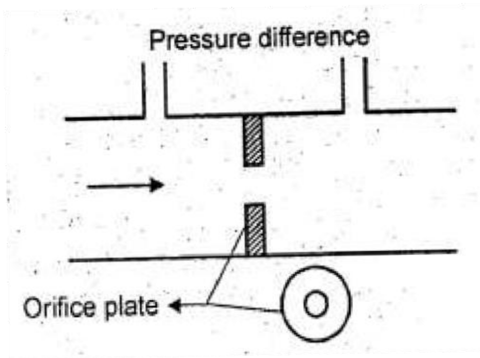


Figure 1.64 Orifice plate

b) Turbine meter

The turbine flow meter consists of a multi-bladed rotor that is supported centrally in the pipe along which the flow occurs.

The fluid flow results in rotation of the rotor, the angular velocity being approximately proportional to the flow rate.

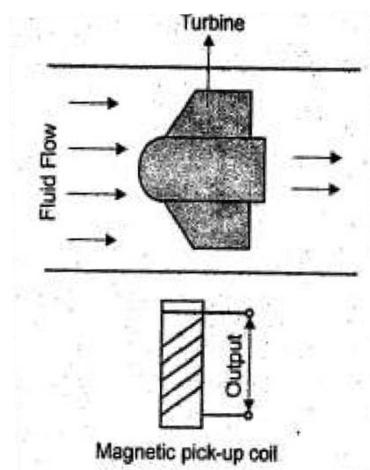


Figure 1.47: Turbine meter

The rate of revolution of the rotor can be determined using a magnetic pick-up. The pulses are counted and so the number of revolutions of the rotor can be determined.

1.30: Temperature Sensors

The measuring method of change in temperature in the form of expansion or contraction of solids, liquids or gases, is measured through the change in electrical resistance of conductor and semiconductors and thermoelectric e.m.f.s.

The following are some of the methods that are commonly used with temperature control systems.

a) Bimetallic Strips

This device consists of two different metal strips bonded together. The metals have different coefficients of expansion and when the temperature changes the composite strip bends into a curved strip, with the higher coefficient metal on the outside of the curve.

This deformation may be used as a temperature-controlled switch, as in the simple thermostat which was commonly used with domestic heating systems.

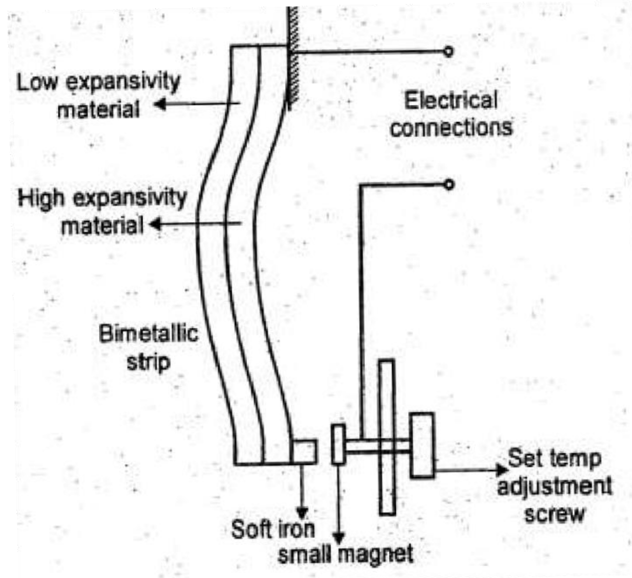


Figure 1.31: Bimetallic thermostat

The small magnet isso that the sensor exhibits hysteresis, this meaning that the switch contacts close at a different temperature from what at which they open.

b) Resistance Temperature Detectors (RTDs)

The resistance of most metals increases over a limited temperature range, in a reasonably linear way with temperature.

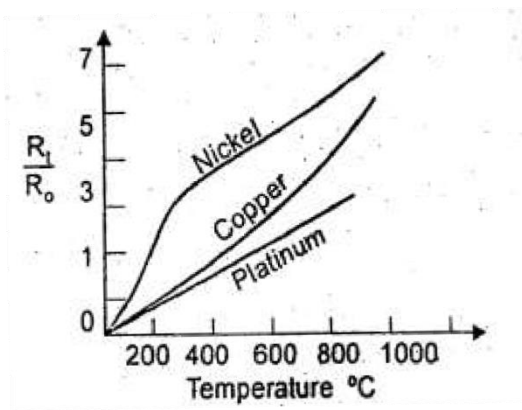


Figure 1.32: Variation of resistance with temperature for metals

$R_1 = R_o (I + \alpha t)$

Where R_1 is the resistance at a temperature t°C, R_o the resistance at 0° C and α a constant for the metal termed the temperature coefficient of resistance.

Resistance temperature detectors (RTDs) are simple resistive elements in the for of coils of wire of such metals as platinum, nickel or nickel-copper alloys and platinum is the most widely used.

Thin film platinum elements are often made by depositing the metal on a suitable substrate, wire wound elements involving a platinum wire held by a high temperature glass adhesive inside· a ceramic tube.

Such detectors are highly stable and give reproducible responses over long periods of time.

c) Thermistors

Thermistors are small pieces of material made from mixtures of metal oxides such as those of chromium, cobalt, iron, manganese and nickel. These oxides are semiconductors.

The material is formed into various forms of element, such as beads, discs and rods..

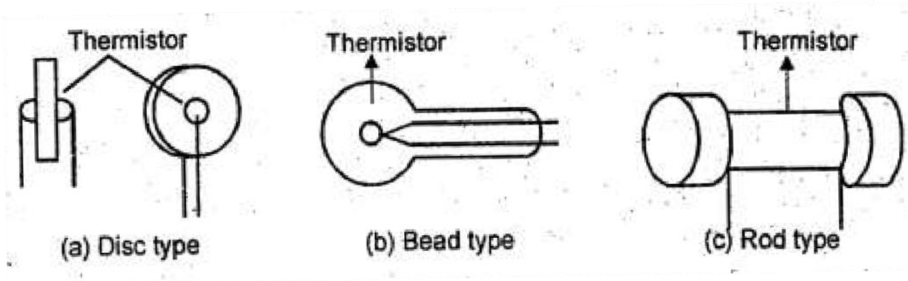


Figure 1.33:Thermistors

The resistance of conventional metal-oxide thermistors decreases in a very non linear manner with an increase in temperature.

The change in resistance per degree change in temperature is considerably larger than that which occurs with metals.

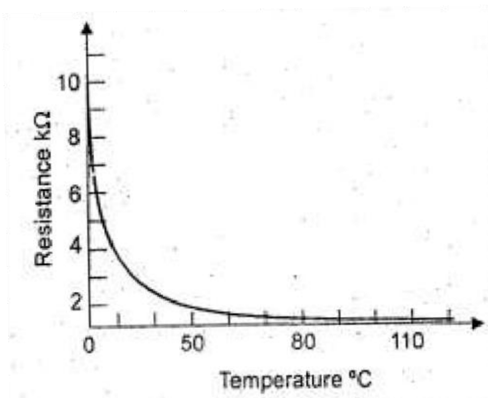


Figure 134: Variation of resistance with temperature for a typical thermistor

d) Thermodiodes and transistors

A junction semiconductor diode is widely used as a temperature sensor.

When the temperature of doped semiconductors changes, the mobility of their charge carriers changes and this affects the rate at which electrons and holes can diffuse across a p-n junction.

Thus when a p-n junction has a potential difference V across it, the current I through the junction is a function of the temperature.

e) Thermocouples

If two different metals are joined together, a potential difference occurs across the junction.

The potential difference depends on the metals used and the temperature of the junction. A thermocouple is a complete circuit involving two such junctions.

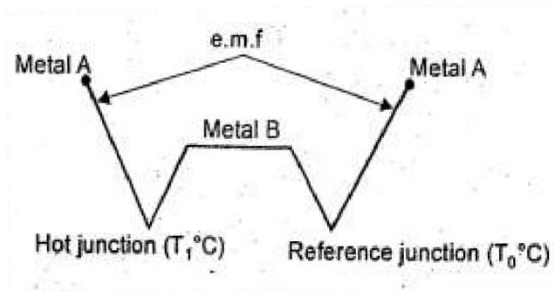


Figure 1.35

If both junctions are at the same temperature there is no net e.m.f. If, however, there is a difference in temperature between the two junctions, there is an e.m.f.

The value of this e.m.f. 'E' depends on the two metals concerned and the temperatures t of both junctions.

Usually one junction is held at 0° C and then, to a reasonable extent, the following relationship holds: $E=at+bt^2$

Where a and b are constants for the metals concerned.

Commonly used thermocouples are shown in table with the temperature ranges over which they are generally used and typical sensitivities.

These commonly used thermocouples are given reference letters. For example, the iron-constantan thermocouple is called a type J thermocouple. Figure shows how the e.m.f. varies with temperature for a number of commonly used pairs of metals.

Table 2.1 Thermocouples

Ref	*Materials*	*Range °C*
B	Platinum 30% rhodium / platinum 6% rhodium	0 to 1800
E	Chromel / constantan	−200 to 1000
J	Iron / constantan	−200 to 900
K	Chromel / alumel	−200 to 1300
N	Nirosil / nisil	−200 to 1300
R	Platinum / platinum 13% rhodium	0 to 1400
S	Platinum / platinum 10% rhodium	0 to 1400
T	Copper / constantan	−200 to 400

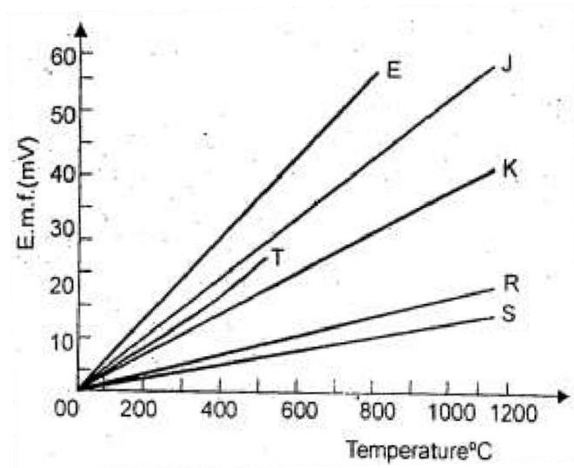


Figure 1.36 Thermoelectric EMF temperature graphs

Light Sensors

A photodiode can thus be used as a variable resistance device controlled by the light incident on it. Photodiodes have a very fast response to light.

Photodiodes are semiconductor junction diodes which are connected into a circuit in reverse bias, so giving a very high resistance, so that when light falls on the junction the diode resistance drops and the current in the circuit rises appreciably.

The phototransistors have a light-sensitive collector-base p-n junction. When there is no incident light there is a very small collector-to-emitter current.

When light is incident, a base current is produced thus is directly proportional to the light intensity.

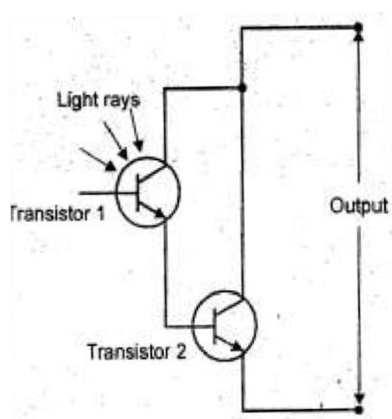


Figure 1.37: Photo Darlington

Phototransistors are often available as integrated packages with the phototransistor connected in a Darlington arrangement with a conventional transistor.

Because this arrangement gives a higher current gain, the device gives a much greater collector current for a given light intensity.

A photoresistor has a resistance which depends on the intensity of the light falling on it, decreasing linearly as the intensity increases.

The cadmium sulphide photoresistor is most responsive to light having wavelengths shorter than about 515 nm and the cadmium selenide photoresistor for wavelengths less than about 700 nm.

An array of light sensors is often required in a small space in order to determine the variations of light intensity across that space, e.g. in the automatic camera.

Selection of Sensors

There are a number of factors that need to be considered while selecting a sensor:

1. The nature of the measurement required, e.g., the variable to be measured, it nominal value, the range of values, the accuracy required, the required speed of measurement, the reliability required, the environmental conditions under which the measurement is to be made.

2. The nature of the output required from the sensor.

3. Then possible sensors can be identified, taking into account such factors as their range, accuracy, linearity, speed of response, reliability, maintainability, life, power supply requirements, ruggedness, availability, and cost.

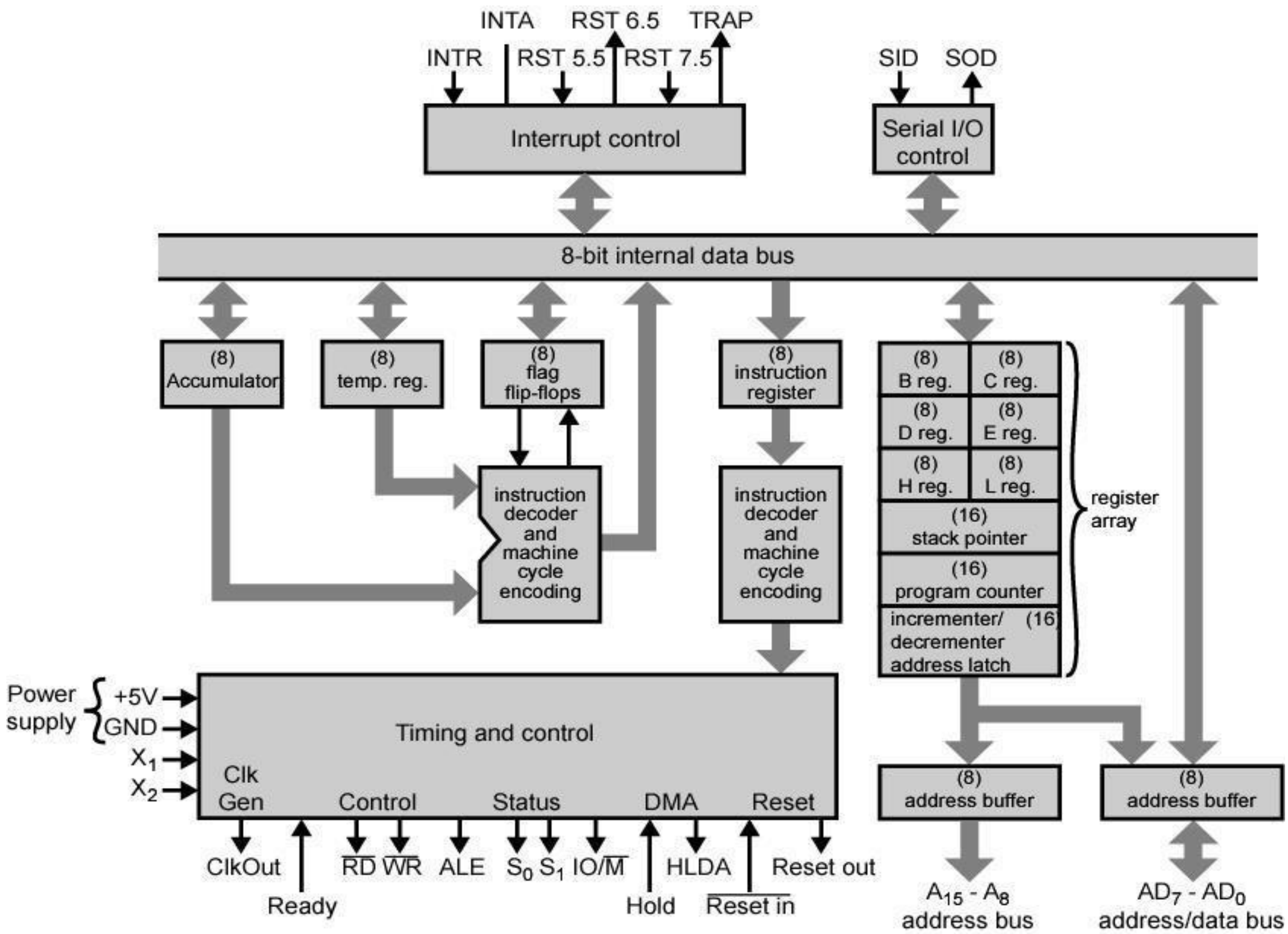
UNIT II

8085 MICRO PROCESSOR

8085 Architecture:

The architecture of 8085 consists of various components like:

1. Accumulator & Register sets.
2. Program counter and stack pointer.
3. Flag Register.
4. ALU.
5. Instruction decoder and machine cycle encoder.
6. Address buffer.
7. Address/data buffer.
8. Increment/Decrement latch.
9. Interrupt control.
10. Serial I/O like SOD,SID.
11. Timing and Control circuit.



8085 Architecture

Accumulator:

- The accumulator is an 8-bit register then is part of the arithmetic/logic unit(ALU).
- This register is used to store to store 8-bit data this data is used to perform arithmetic & logical operation.
- The result of an operation is stored in the accumulator.
- The accumulator is also identified as register A.
- The accumulator is used for data transfer between an I/O port and memory location.

Register sets:

- The 8085 simulator has six general-purpose registers to store 8-bit data; these are identified as **B**, **C**, **D**, **E**, **H** and **L**. They can be combined as register pair like**BC**, **DE** and **HL** – to perform some 16-bit operations.
- The programmer can use these registers to store or copy data into the registers by using data copy instructions.
- Out of these six registers, four 8-bit registers are scratch pad registers which are accessible to the programmer and hence can be used to temporarily store data during a program execution.
- And the two registers **H** and **L** are utilized in indirect addressing mode. In this mode, the memory location i.e. the address is specified by the contents of the registers.

Program Counter (PC):

- It is a 16 bit register which holds the memory address of the next instruction to be executed in the next step.
- This 16-bit register deals with sequencing the execution of instructions. This register is a memory pointer. Memory locations have 16-bit addresses, and that is why this is a 16-bit register.
- The microprocessor uses this register to sequence the execution of the instructions. The function of the program counter is to point to the memory address from which the next instruction is to be fetched. When a byte (machine code) is being fetched, the program counter is incremented by one to point to the next memory location.

Stack Pointer (SP):

- Stack pointer is used during subroutine calling and execution.
- The stack pointer is also a 16-bit register used as a memory pointer. It points to a memory location in R/W memory, called the stack.

Flag or status register:

- The ALU includes five flip-flops, which are set or reset after an operation according to data conditions of the result in the accumulator and other registers. They are called Zero(Z), Carry (CY), Sign (S), Parity (P), and Auxiliary Carry (AC) flags.
- The most commonly used flags are Zero, Carry, and Sign. The microprocessor uses these flags to test data conditions.
- For example, after an addition of two numbers, if the sum in the accumulator is larger than eight bits, the flip-flop uses to indicate a carry -- called the Carry flag (CY) -- is set to one.
- When an arithmetic operation results is zero, the flip-flop called the Zero(Z) flag is set to one.

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
S	Z		AC		P		CY

Bit positions of various flags in the flag register of 8085

- **Flag** is an 8-bit register containing 5no.s of 1-bit flags:
    1. Sign - If the result of the latest arithmetic operation is having MSB (most- significant bit) 1 (meaning it is a negative number), then the sign flag is set. Otherwise, it is reset to 0 which means it is a positive number.
    2. Zero - If the result of the latest operation is zero, then zero flag will be set; otherwise it be reset.
    3. Auxiliary carry - set if there was a carry out from bit 3 to bit 4 of the result.
    4. Parity - set if the parity (the number of set bits in the result) is even. i.e., If the result of the latest operation is having even number of „1s, then this flag will be set. Otherwise this will be reset to „0‟. This is used for error checking.
    5. Carry - set if there was a carry during addition, or borrow during subtraction/comparison. Otherwise it will be reset.

Instruction register or Decoder:-

- Instruction register holds the instruction that is currently being processed.
- Once the instruction is fetch from the memory, it is reloaded in the instruction register for some time, after the decoder decode the instruction performing some event or task.

Address buffer:

- The remaining higher order address lines form the address buffer ranging from [A8 - A15].This is having the unidirectional buffer.

Address/data buffer:

- The address bus will be having 16 address lines [A15 - A0] .In which A7-A0 are called as lower addressing lines and these are multiplexed with data lines [D7 - D0] to form multiplexed address /data buffer .The address/data buffer is the bidirectional bus.

Increment/Decrement Address Latch:

- It increments/ decrements the address before sent to the address buffer

Interrupts:

The processor has 5 interrupts. They are presented below in the order of theirpriority (from lowest to highest):

- **INTR** is maskable 8080A compatible interrupt. When the interrupt occurs, the processor fetches from the bus one instruction, usually one of these instructions: One of the 8 RST instructions (RST0 - RST7). The processor saves current program counter into stack and branches to memory location N * 8 (where N is a 3-bit number from 0 to 7 supplied with the RST instruction).
- CALL instruction (3 byte instruction). The processor calls the subroutine, address of which is specified in the second and third bytes of the instruction.

- **RST5.5** is a maskable interrupt. When this interrupt is received the processor saves the contents of the PC register into stack and branches to 2CH (hexadecimal) address.

- **RST6.5** is a maskable interrupt. When this interrupt is received the processor saves the contents of the PC register into stack and branches to 34H (hexadecimal) address.

- **RST7.5** is a maskable interrupt. When this interrupt is received the processor saves the contents of the PC register into stack and branches to 3CH (hexadecimal) address.
- **TRAP** is a non-maskable interrupt. When this interrupt is received the processorsaves the contents of the PC register into stack and branches to 24H (hexadecimal) address.
- All maskable interrupts can be enabled or disabled using EI and DI instructions. RST 5.5, RST6.5 and RST7.5 interrupts can be enabled or disabled individually using SIM Instruction

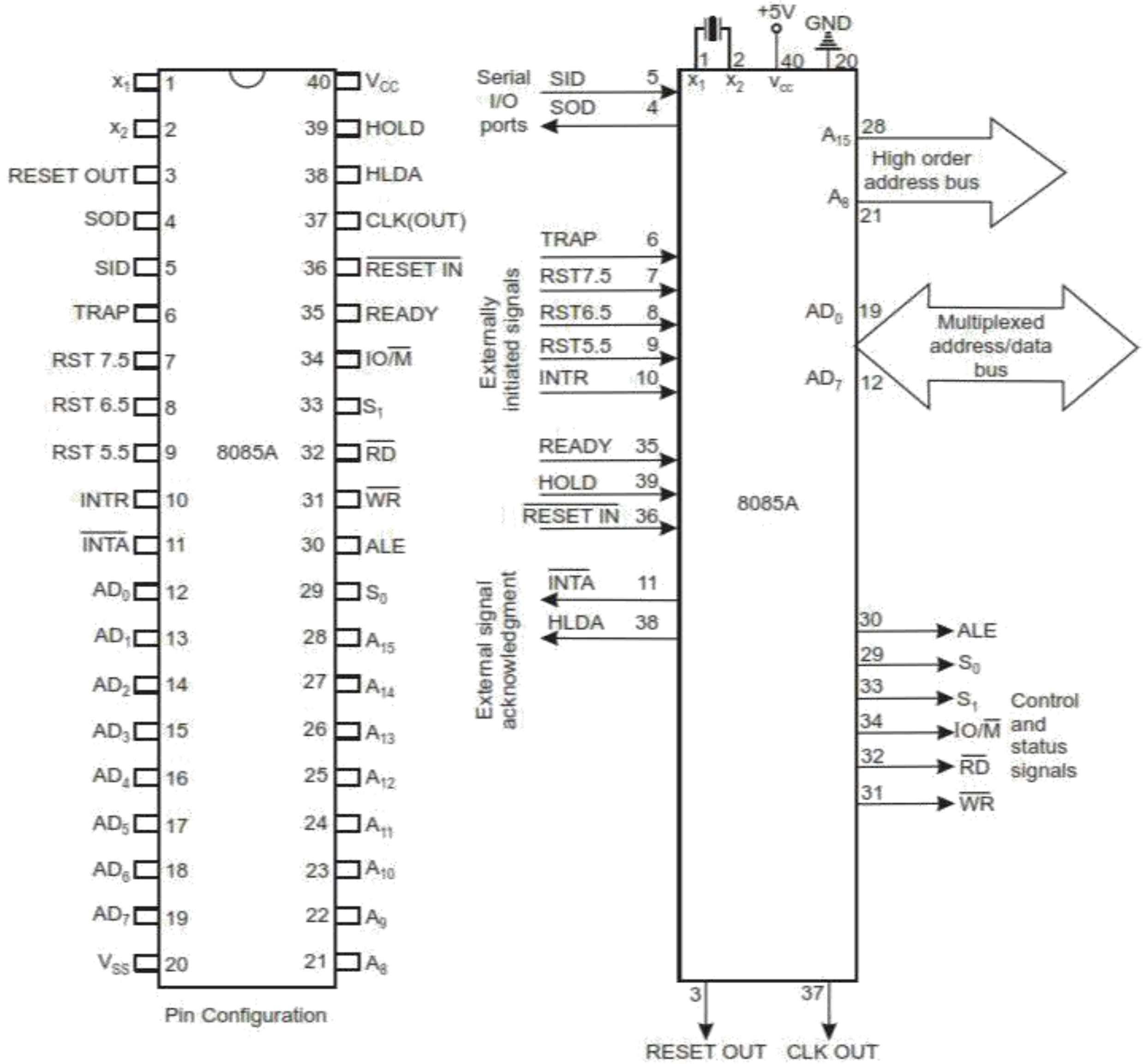
Serial I/O control

- These are control signals used for controlling 8085. These are subdivided into two types.

1. SID (Serial Input Data) – This is used for transferring of data into memory serially.
2. SOD (Serial Output Data) - This is used for transferring of data from memory to external devices

- Interrupt control is used to transfer the ISR to the CPU.

PIN DIAGRAM



Pin Diagram of 8085

A8 - A15 (Output 3 State):

Address Bus: The most significant 8 bits of the memory address or the 8 bits of the I/0 address,3 stated during Hold and Halt modes.

AD0 - AD7 (Input / Output 3 state):

Multiplexed Address/Data Bus; Lower 8 bits of the memory address (or I/0 address) appear on the bus during the first clock cycle of a machine state. It then becomes the data bus during the second and third clock cycles. 3 stated during Hold and Halt modes.

ALE (Output):

- Address Latch Enable: It occurs during the first clock cycle of a machine state and enables the address to get latched into the on chip latch of peripherals.
- The falling edge of ALE is set to guarantee setup and hold times for the address information. ALE can also be used to strobe the status information. ALE is never 3stated.

SO, S1 (Output): Data Bus Status. Encoded status of the bus cycle:

S1 S0

0 0 HALT
0 1 WRITE
1 0 READ
1 1 FETCH S1 can be used as an advanced R/W status.

RD (Output 3state):

READ: indicates the selected memory or I/0 device is to be read and that the Data Bus is available for the data transfer.

WR (Output 3state):

- WRITE: indicates the data on the Data Bus is to be written into the selected memory or I/0location.
- Data is set up at the trailing edge of WR. 3stated during Hold and Halt modes.

READY (Input):

- If Ready is high during a read or write cycle, it indicates that the memory or peripheral is readyto send or receive data.
- If Ready is low, the CPU will wait for Ready to go high before completing the read or write cycle.

HOLD (Input):

- HOLD: Indicates that another Master is requesting the use of the Address and Data Buses.
- The CPU, upon receiving the Hold request will relinquish the use of buses as soon as the completion of the current machine cycle.

- Internal processing can continue. The processor can regain the buses only after the Hold is removed. When the Hold is acknowledged, the Address, Data, RD, WR, and IO/M lines are 3stated.

HLDA (Output):

- HOLD ACKNOWLEDGE: indicates that the CPU has received the Hold request and that it willrelinquish the buses in the next clock cycle.

- HLDA goes low after the Hold request is removed. The CPU takes the buses one half clock cycle after HLDA goes low.

INTR (Input):

- INTERRUPT REQUEST is used as a general purpose interrupt. It is sampled only during the next clock cycle of the instruction. If it is active, the Program Counter (PC) will be inhibited from incrementing and an INTA will be issued.

- During this cycle a RESTART or CALL instruction can be inserted to jump to the interrupt service routine. The INTR is enabled and disabled by software. It is disabled by Reset and immediately after an interrupt is accepted.

INTA (Output):

- INTERRUPT ACKNOWLEDGE: is used instead of (and has the same timing as) RD during theInstruction cycle after an INTR is accepted.
- It can be used to activate the 8259 Interrupt chip or some other interrupt port.

RESTART INTERRUPTS:

These three inputs have the same timing as INTR except they cause an internal RESTART to be automatically inserted.

- RST 7.5 Highest Priority
- RST 6.5
- RST 5.5 Lowest Priority

TRAP (Input):

- Trap interrupt is a non maskable restart interrupt. It is recognized at the same time as INTR. It is unaffected by any mask or Interrupt Enable. It has the highest priority of any interrupt.

RESET IN (Input):

- Reset sets the Program Counter to zero and resets the Interrupt Enable and HLDA flip flops.
- None of the other flags or registers (except the instruction register) are affected. The CPU is held in the reset condition as long as Reset is applied.

RESET OUT (Output):

Indicates CPlJ is being reset. Can be used as a system RESET. The signal is synchronized to the processor clock.

X1, X2 (Input):

Crystal or R/C network connections to set the internal clock generator X1 can also be an external clock input instead of a crystal. The input frequency is divided by 2 to give the internal operating frequency.

CLK (Output):

Clock Output for use as a system clock when a crystal or R/ C network is used as an input to the CPU. The period of CLK is twice the X1, X2 input period.

IO/M (Output):

IO/M indicates whether the Read/Write is to memory or l/O Tristated during Hold and Halt modes.

SID (Input):

Serial input data line The data on this line is loaded into accumulator bit 7 whenever a RIM instruction is executed.

SOD (output):

Serial output data line. The output SOD is set or reset as specified by the SIM instruction.

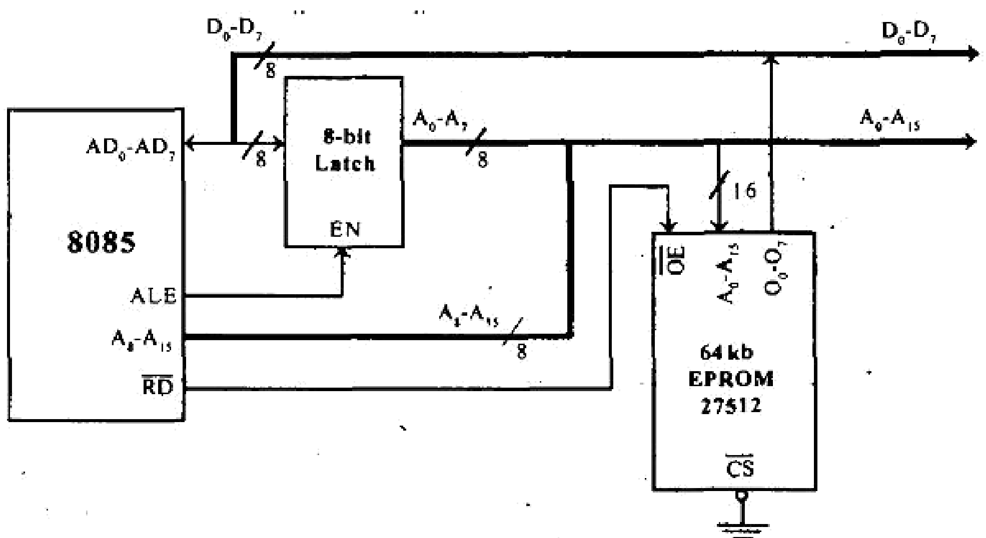
Vcc: +5 volt supply. **Vss:** Ground Reference.

MEMORY ORGANIZATION

Memory Interfacing

The memory is made up of semiconductor material used to store the programs and data. Three types of memory is,

- Process memory
- Primary or main memory
- Secondary memory



Memory Interfacing

Typical EPROM and Static RAM

A typical semiconductor memory IC will have n address pins, m data pins (or

output pins).

- Having two power supply pins (one for connecting required supply voltage V and the other for connecting ground).
- The control signals needed for static RAM are chip select (chip enable), read control (output enable) and write control (write enable).
- The control signals needed for read operation in EPROM are chip select (chip enable) and read control (output enable).

Decoder

It is used to select the memory chip of processor during the execution of a program. No of IC's used for decoder is,

2-4 decoder (74LS139)

3-8 decoder (74LS138)

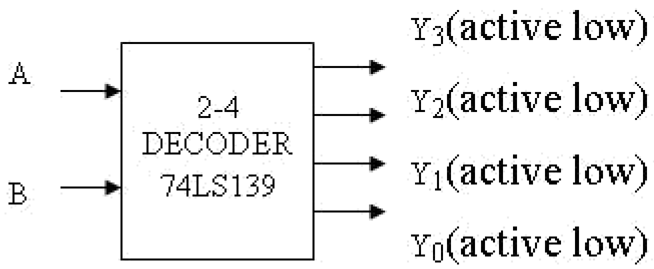


Fig 2.5 Block Diagram of 2-4 Decoder

Table 2.1 Truth Table for 2-4 Decoder

Input		Output			
B	A	$\overline{Y}_3$	$\overline{Y}_2$	$\overline{Y}_1$	$\overline{Y}_0$
0	0	1	1	1	0
0	1	1	1	0	1
1	0	1	0	1	1
1	1	0	1	1	1

Consider a system in which the full memory space 64kb is utilized for EPROM memory. Interface the EPROM with 8085 processor.

The memory capacity is 64 Kbytes. i.e 2^n = 64 x 1000 bytes where n = address lines.

So, n = 16. In this system the entire 16 address lines of the processor are connected to address input pins of memory IC in order to address the internal locations of memory. The chip select (CS) pin of EPROM is permanently tied to logic low (i.e., tied to ground).

Since the processor is connected to EPROM, the active low RD pin is connected to active low output enable pin of EPROM. The range of address for EPROM is 0000H to FFFFH.

TIMING DIAGRAM

Timing Diagram is a graphical representation. It represents the execution time taken by each instruction in a graphical format. The execution time is represented in T-states.

Instruction Cycle -The time required to execute an instruction is called instruction cycle.

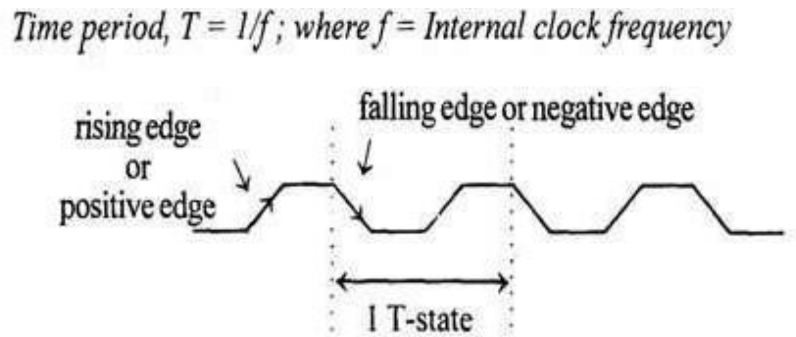
Machine Cycle - The time required to access the memory or input/output devices is called machine cycle.

T-State-The machine cycle and instruction cycle takes multiple clock periods. A portion of an operation carried out in one system clock period is called as T-state.

Machine cycles of 8085

The 8085 microprocessor has 5 (seven) basic machine cycles. They are

1. Opcode fetch cycle (4T)
2. Memory read cycle (3 T)
3. Memory write cycle (3 T)
4. I/O read cycle (3 T)
5. I/O write cycle (3 T)

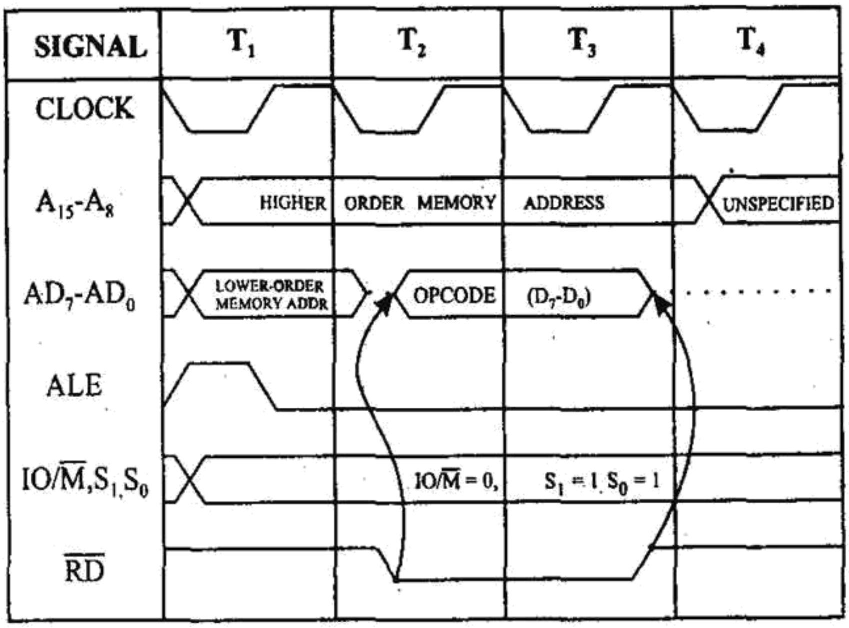


Clock Signal

1. Opcode fetch machine cycle of 8085

Each instruction of the processor has one byte opcode. The opcodes are stored in memory. So, the processor executes the opcode fetch machine cycle to fetch the opcode from memory. Hence, every instruction starts with opcode fetch machine cycle. The time taken by the processor to execute the opcode fetch cycle is 4T.

In this time, the first, 3 T-states are used for fetching the opcode from memory and the remaining T-states are used for internal operations by the processor.



Opcode fetch machine cycle

2. Memory Read Machine Cycle of 8085:

The memory read machine cycle is executed by the processor to read a data byte from memory. The processor takes 3T states to execute this cycle. The instructions which have more than one byte word size will use the machine cycle after the opcode fetch machine cycle.

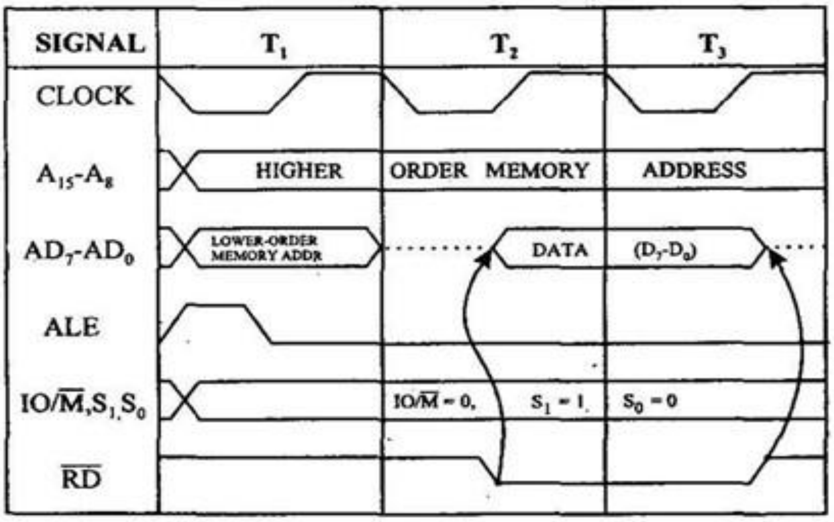
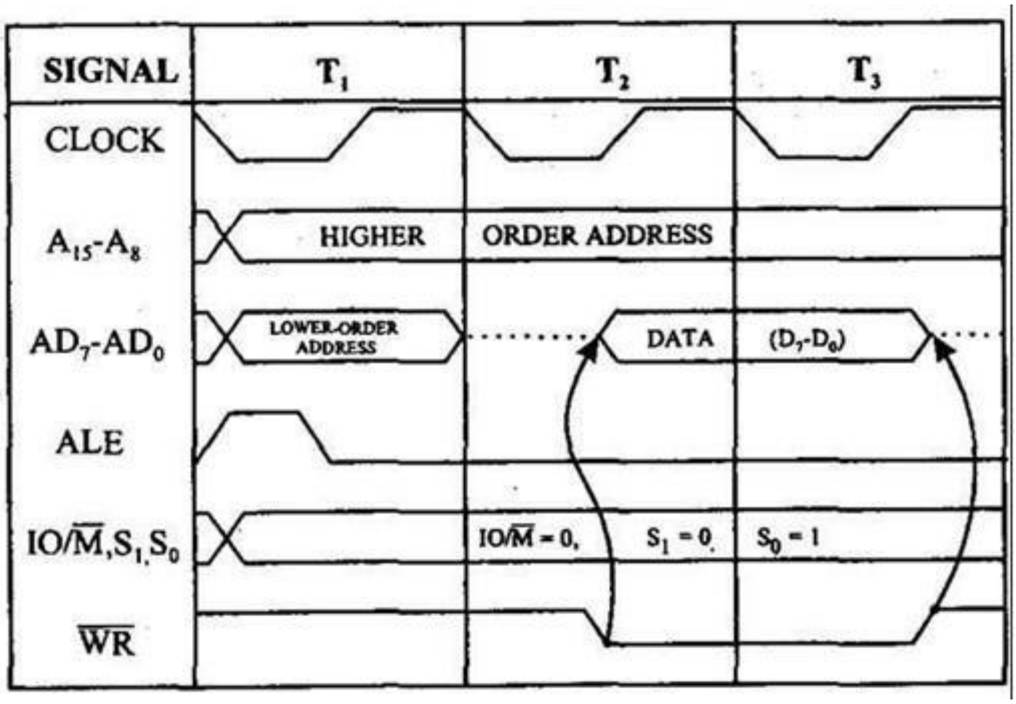


Fig 2.8 Memory Read Machine Cycle

3. Memory Write Machine Cycle of 8085

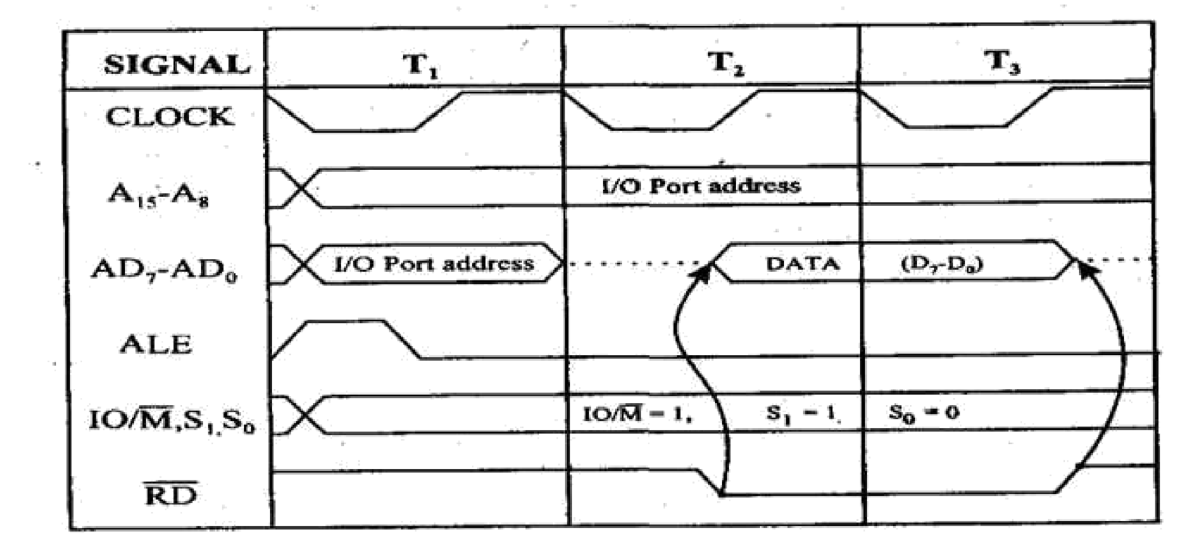
The memory write machine cycle is executed by the processor to write a data byte in a memory location. The processor takes, 3T states to execute this machine cycle.



Memory Write Machine Cycle

4. I/O Read Cycle of 8085

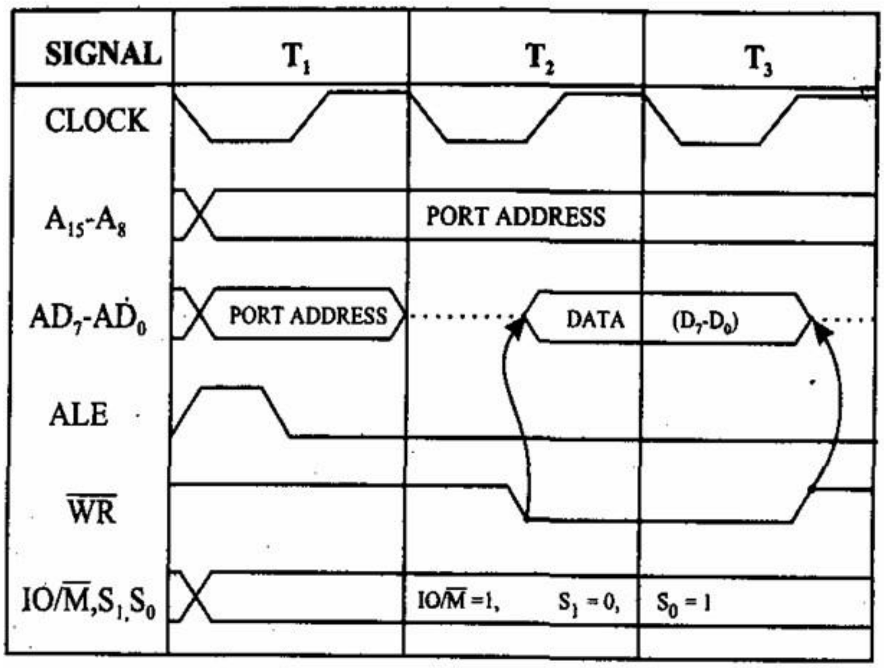
The I/O Read cycle is executed by the processor to read a data byte from I/O port or from the peripheral, which is I/O, mapped in the system. The processor takes 3T states to execute this machine cycle. The IN instruction uses this machine cycle during the execution.



I/O Read Cycle

5. I/O Write Cycle of 8085

The I/O write machine cycle is executed by the processor to write a data byte in the I/O port or to a peripheral, which is I/O, mapped in the system. The processor takes, 3T states to execute this machine cycle.



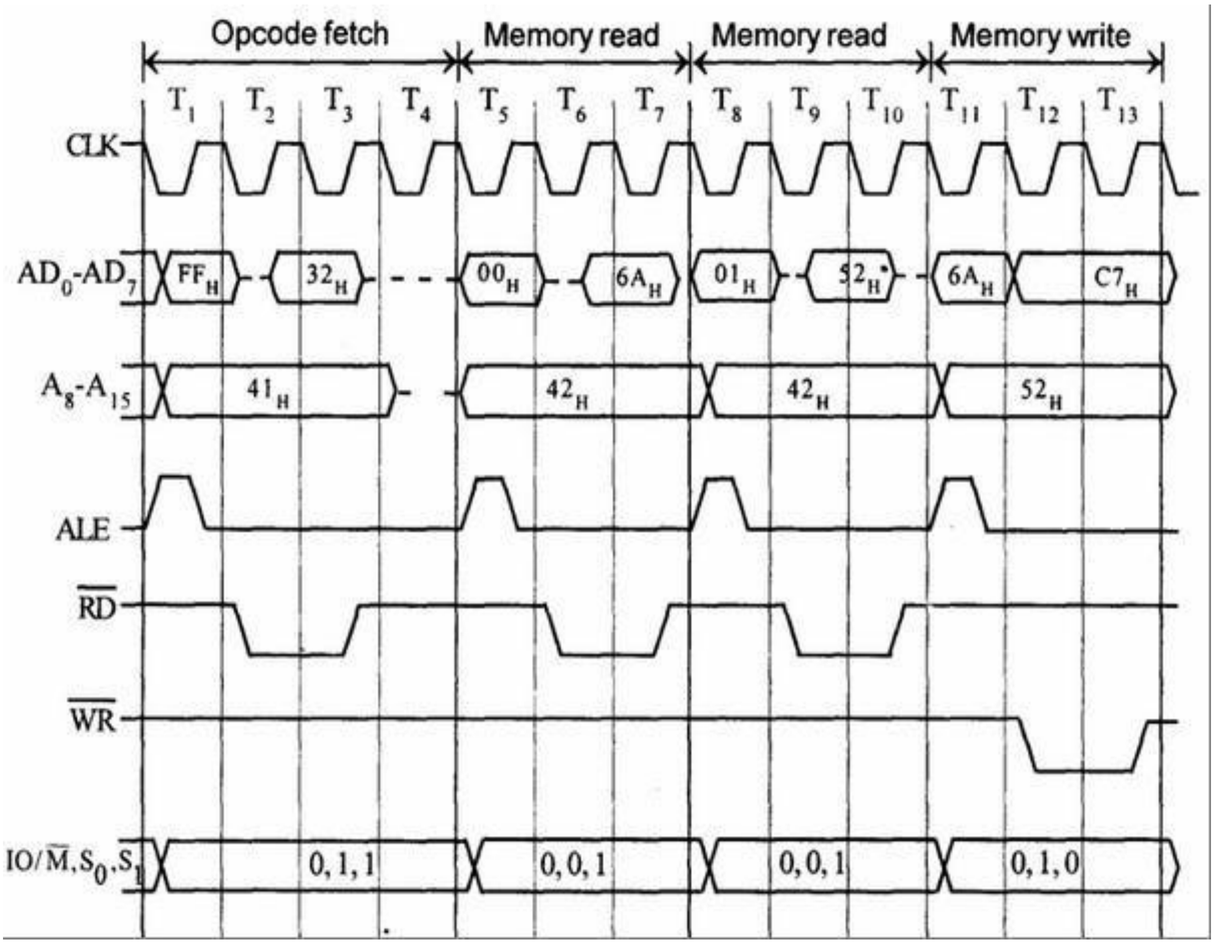
I/O Write Cycle

Timing diagram for STA 526AH

STA means Store Accumulator -The contents of the accumulator is stored in the specified address (526A). The opcode of the STA instruction is said to be 32H. It is fetched from the memory 41FFH of machine cycle. Then the lower order memory address is read(6A). - Memory Read Machine Cycle. Read the higher order memory address (52).- Memory Read Machine Cycle

The combination of both the addresses are considered and the content from accumulator is written in 526A. - Memory Write Machine Cycle Assume the memory address for the instruction and let the content of accumulator is C7H. So, C7H from accumulator is now stored in 526A.

Address	Mnemonics	Opcode
41FF	STA 526AH	32H
4200		6AH
4201		52H



Timing diagram for STA 526AH

INTERRUPTS:

Interrupt is signals send by an external device to the processor, to request the processor to perform a particular task or work.

- Mainly in the microprocessor based system the interrupts are used for data transfer between the peripheral and the microprocessor.
- The processor will check the interrupts always at the 2nd T-state of last machine cycle.
- If there is any interrupt it accept the interrupt and send the INTA (active low) signal to the peripheral.
- The vectored address of particular interrupt is stored in program counter.
- The processor executes an interrupt service routine (ISR) addressed in program counter.
- It returned to main program by RET instruction.

Types of Interrupts:

It supports two types of interrupts.

- Hardware
- Software

Software interrupts:

- The software interrupts are program instructions. These instructions are inserted at desired locations in a program.
- The 8085 has eight software interrupts from RST 0 to RST 7. The vector address for these interrupts can be calculated as follows.

Interrupt number * 8 = Vector address.

For RST 5,5 * 8 = 40 = 28H

Vector addresses of all interrupts

Interrupt	Vector address
RST 0	0000_H
RST 1	0008_H
RST 2	0010_H
RST 3	0018_H
RST 4	0020_H
RST 5	0028_H
RST 6	0030_H
RST 7	0038_H

Hardware interrupts:

An external device initiates the hardware interrupts and placing an appropriate signal at the interrupt pin of the processor. If the interrupt is accepted then the processor executes an interrupt service routine. The 8085 has five hardware interrupts

(1) TRAP (2) RST 7.5 (3) RST 6.5 (4) RST 5.5 (5) INTR

TRAP:

- This interrupt is a non-maskable interrupt. It is unaffected by any mask or interrupt enable.
- TRAP bas the highest priority and vectored interrupt.
- TRAP interrupt is edge and level triggered. This means hat the TRAP must go high and remain high until it is acknowledged.
- In sudden power failure, it executes a ISR and send the data from main memory to backup memory.
- The signal, which overrides the TRAP, is HOLD signal. (i.e., If the processor receives HOLD and TRAP at the same time then HOLD is recognized first and then TRAP is recognized).
- There are two ways to clear TRAP interrupt.

  1. By resetting microprocessor (External signal)
  2. By giving a high TRAP ACKNOWLEDGE (Internal signal)

RST 7.5:

- The RST 7.5 interrupt is a maskable interrupt.
- It has the second highest priority.

- It is edge sensitive. ie. Input goes to high and no need to maintain high state until it recognized.

Maskable interrupt. It is disabled by,

1. DI Instruction
2. System or processor reset.
3. After reorganization of interrupt.

It is Enabled by EI instruction**.**

RST 6.5 and 5.5:

The RST 6.5 and RST 5.5 both are level triggered. ie. Inputs goes to high and stay high until it recognized.

Maskable interrupt. It is disabled by,

1. DI, SIM instruction
2. System or processor reset.
3. After reorganization of interrupt.

It is Enabled by EI instruction**.**

The RST 6.5 has the third priority whereas RST 5.5 has the fourth priority.

INTR

INTR is a maskable interrupt. It is disabled by,

1. DI, SIM instruction
2. System or processor reset.
3. After reorganization of interrupt

INTR interrupt is Enabled by EI instruction.

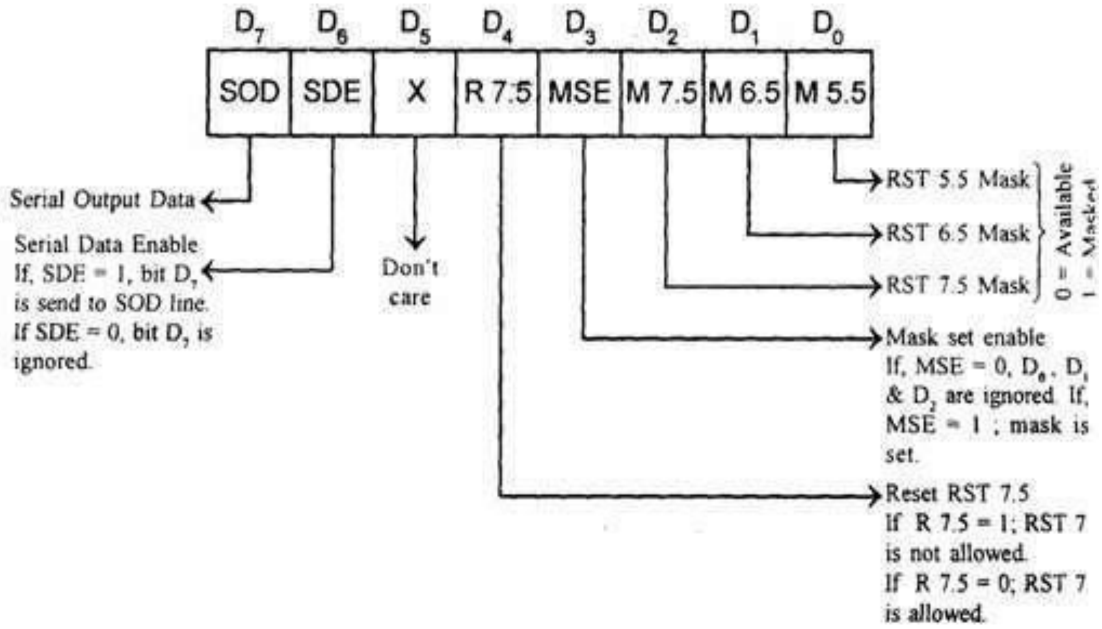
Non- vectored interrupt. After receiving INTA (active low) signal, it has to supply the address of ISR. It has lowest priority. It is a level sensitive interrupts. ie. Input goes to high and it is necessary to maintain high state until it recognized.

The following sequence of events occurs when INTR signal goes high.

1. The 8085 checks the status of INTR signal during execution of each instruction.
2. If INTR signal is high, then 8085 complete its current instruction and sends active low interrupt acknowledge signal, if the interrupt is enabled.
3. In response to the acknowledge signal, external logic places an instruction OPCODE on the data bus. In the case of multibyte instruction, additional interrupt acknowledge machine cycles are generated by the 8085 to transfer the additional bytes into the microprocessor.
4. On receiving the instruction, the 8085 save the address of next instruction on stack and execute received instruction.

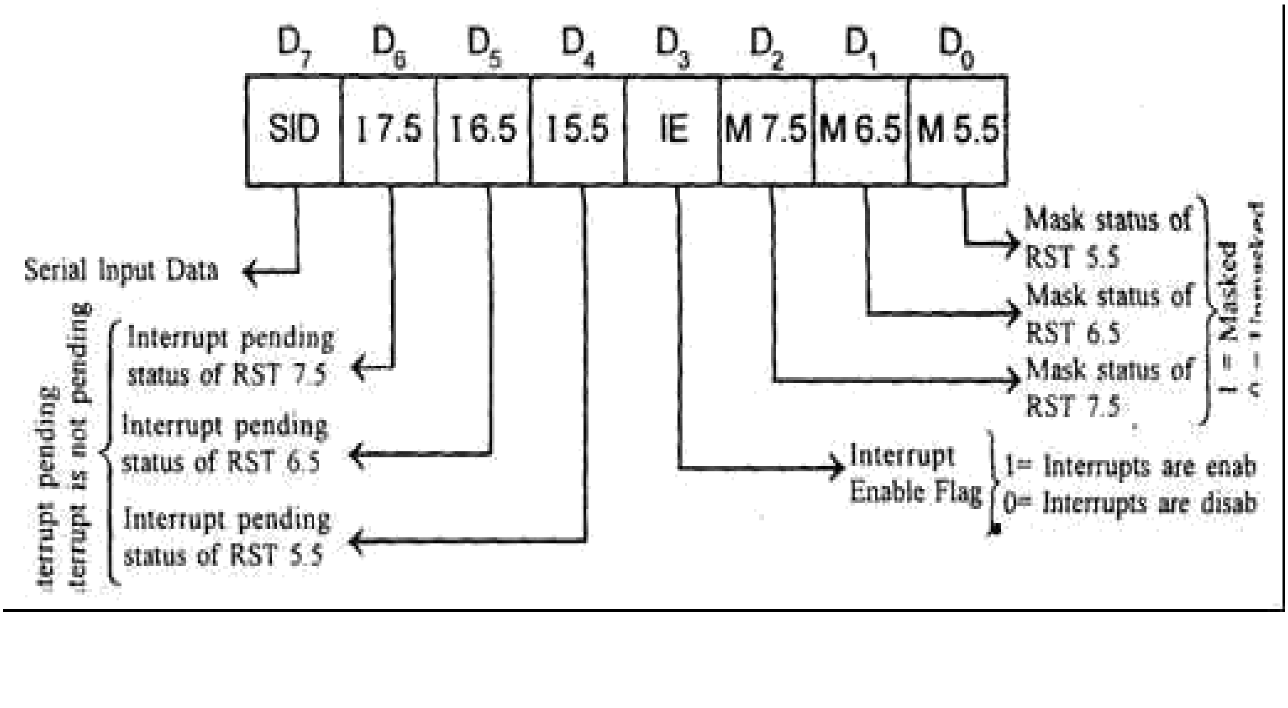
SIM and RIM for interrupts:

The 8085 provide additional masking facility for RST 7.5, RST 6.5 and RST 5.5 using SIM instruction. The status of these interrupts can be read by executing RIM instruction. The masking or unmasking of RST 7.5, RST 6.5 and RST 5.5 interrupts can be performed by moving an 8-bit data to accumulator and then executing SIM instruction.



Format of 8 bit data to be loaded into the Accumulator using SIM Instruction

The status of pending interrupts can be read from accumulator after executing RIM instruction. When RIM instruction is executed an 8-bit data is loaded in accumulator, which can be interpreted as shown in fig 1.14.



Format of 8 bit data in Accumulator after executing RIM

8051 MICRO CONTROLLER

Microprocessors Vs. Microcontrollers

Microprocessor

- CPU is stand-alone, RAM, ROM, I/O, timer are separate
- Designer can decide on the amount of ROM, RAM and I/O ports.
- Expensive
- Their instructions operate on nibbles, bytes, words, or even double words.
- Addressing modes provide access to large arrays of data using pointers and offsets.
- Versatility
- General-purpose.

Microcontroller

- CPU, RAM, ROM, I/O and timer are all on a single chip
- Fix amount of on-chip ROM, RAM, I/O ports
- They have instructions to set and clear individual bits and perform bit operations.
- They have instructions for input/output operations, event timing, enabling and setting priority levels for interrupts caused by external stimuli
- For applications in which cost, power and space are critical
- Single-purpose

8051 Architecture

Accumulator (ACC) :

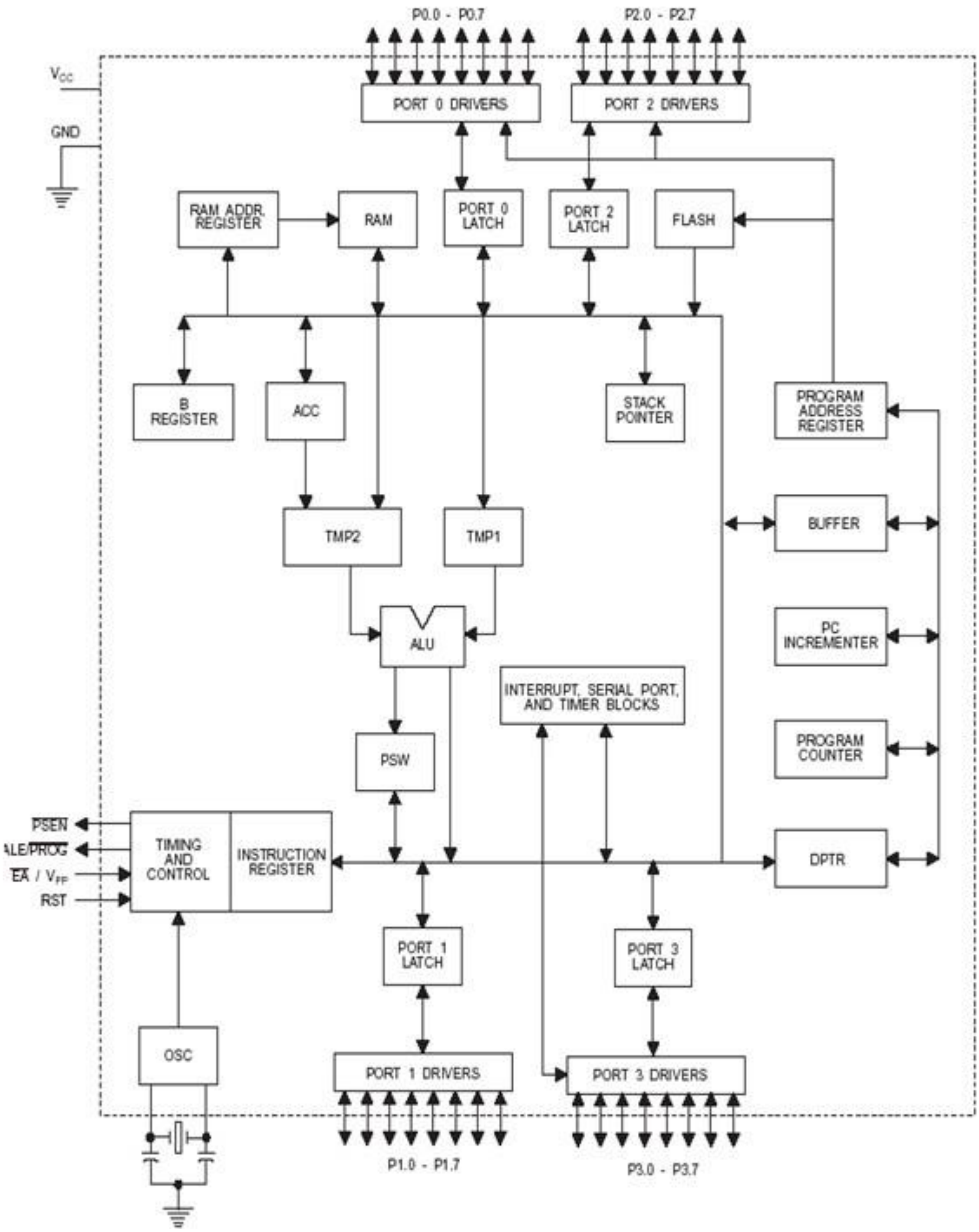
The accumulator register act as an operand register, in case of some instructions .This may either be implicit or specified in the instruction. The Acc register has been allotted and address in the on chip special function register bank.

B Register:

The register in used to store one of the operands for multiply and divide instructions . In other instructions, it may just be used as a scratch pad. This register is considered as a special faction register.

Program status word (PSW)

This set of flags contains the status information and is considered as one on of the special registers.



Architecture of 8051

Stack pointer (Sp) :

This 8 bit wide register is incremented before the data is stored on to the stack using push or call instructions. The register contains 8 bit stack top address. This stack may be defined anywhere in the on chip 128 by the RAM. After reset, the SP register is initialized to 07. After each write to stack operation, the 8 bit contents of the operand are stored on to the stack after incrementing the SP register by one . Thus if SP contains 07H, the forthcoming PUSH operation will store the data at address 08 H in the internal RAM .The SP content will be incremented to 08.The 8051 stack is not a top down data structure, like other Intel processors This register has also been allotted an address in the special function register bank .

Data Pointer (DTPR)

This 16 bit register contains a higher byte (DPH) and the lower byte (DPL) of a 16 bit external data RAM address. It is accessed as a 16 bit register or two 8bit register as specified above. It has been allotted two address in the special Function register bank for its two bytes DPH and DPL

Port 0 to 3 latches and Drivers:

These four latches and drivers pairs are allotted to each of the four on chip I/O Ports. These latches have been allotted addresses in the special function register bank using the allotted address the user can communicate with these ports. These are identified as P0, P1, P2 and P3

Serial data buffer:

The serial data buffer internally contains two independent registers. one of them is a transmit buffer which is necessarily a parallel .

Timing and control unit :

This unit derives all the necessary timing and control signal required for the internal operation of the circuit It also derives control signal required for controlling the external system bus oscillator : This circuit generates the basic timing clock signal for the operation of the circuit using crystal oscillator .

Instruction Register :

This register decodes the opcode of an instruction to be executed and gives information to the timing and control unit to generate necessary signals for the execution of the instruction

EPROM and Program Address Register :

These blocks provide an on chip EPROM and a mechanism to internally adders it Note that EPROM is not available in all 8051 versions.

RAM and RAM address Register .

This block provide internal 128 bytes of RAM and mechanism to address it internally .

ALU

The arithmetic and logic unit performs 8 bit arithmetic and logical operations over the operands held by the temporary registers TMPI and TMP2 .Users cannot access these temporary registers .

SFR Register Bank :

This is a set of special function registers which can be addressed using their respective address which lie in the range 80 H to FFH . Finally the interrupt , serial port and timer units control and perform their special functions under the control of the timing and control unit in serial out register . The other is called receive butter which in a serial in parallel out register. Loading a byte to the transmit buffer initiates serial transmission of that byte. The serial data butter in identified as SBUF and is one of the special function registers. If a byte is written to SBUF, it initiates serial transmission and if the SBUF is read, it reads received serial data .

Timer Register :

These two 16 bit register can be accessed as their lower and upper bytes. For example TL0 represents the lower byte of the timing register 0, while TH0 represents higher bytes of the timing register 0. Similarly TL1 and TH1 represents lower and higher bytes of timing register 1. All these registers can be accessed using the 4 addresses allotted to them which lies in the special function registers. SFR address range, ie 80H to FFH .

Control Registers :

The special function registers IP, IE, TMOD, TCON, SCON and PCON contain control and status information for interrupt timer/ counters and serial port. These register have been allotted address in the SFR bank of 8051.

Program Status Word Register(PSW): -

D7	D6	D5	D4	D3	D2	D1	D0
CY	AC	F0	RS1	RS0	OV	----	PF

It contains several status bits that reflect the current state of the CPU. Besides, this register contains four mathematical flags (Carry flag, Auxiliary Carry, Overflow flag, parity bit) two register bank select bits (RS1 & RS0), and one user-definable status flag (F0) and one bit is not defined.

P - Parity bit: - If a number stored in the accumulator A contains even number of 1’s then this bit will be automatically set (1), otherwise it will be cleared (0). It is mainly used during data transmit and receive via serial communication.

OV Overflow: - Overflow occurs when the result of an arithmetical operation is larger than 255 and cannot be stored in one register. Overflow condition causes the OV bit to be set (1). Otherwise, it will be cleared (0).

RS0, RS1 - Register bank select bits. These two bits are used to select one of four register banks of RAM. By setting and clearing these bits, registers R0-R7 are stored in one of four banks of RAM.

RS1	RS0	Space in RAM
0	0	Bank0 (00H-07H)
0	1	Bank1 (08H-0FH)
1	0	Bank2 (10H-17H)
1	1	Bank3 (18H-1FH)

F0 - Flag 0. This is a general-purpose user defined flag.

AC - Auxiliary Carry Flag: - It is used for BCD operations only. This flag is set to '1' when in the addition operation the carry is generated at bit position D3 or in subtraction operation borrow is needed at the bit position D3.

CY - Carry Flag: **-** This flag is set to '1' when in the addition operation the final carry is generated or in subtraction operation the Minuend is less than the Subtrahend.

PC (Program Counter): -It addresses the next instruction byte address in the program memory. Program memory is on chip i.e. is 0000H to 0FFFH, external to the chip for addresses that exceeds 0FFFH or total external memory 0000h to 0FFFFH. The content of the PC is automatically incremented after fetching of the instruction byte from the memory and some instructions also change the value in the PC. The specialty of this register is it **doesn't have any internal address.**

DPTR (Data Pointer): - It is made up of two 8-bit registers those are DPH & DPL. This register gives the memory addresses for internal and external code access and external data access. The DPTR has two independent internal addresses, one for DPL and another for DPH.

Internal Memory: - The 8051 Microcontroller has internal program memory (ROM) and internal data memory (RAM). Due to this 8051 has a Harvard architecture, which uses a same address in different memories, for code and data.

Internal RAM: - The 8051 microcontroller has 128 bytes of internal RAM, its address range from 00H to 07FH. From 80H to 0FFH addresses are assigned to SFRs (Special Function Registers). The internal RAM 128Bytes can divide into three parts. Those are

1. Register Banks – 32 Bytes (00H – 1FH)
2. Bit/Byte addressable memory – 16 Bytes (20H – 2FH)
3. User memory or General purpose memory—80 Bytes (30H – 7FH)

PIN Diagram

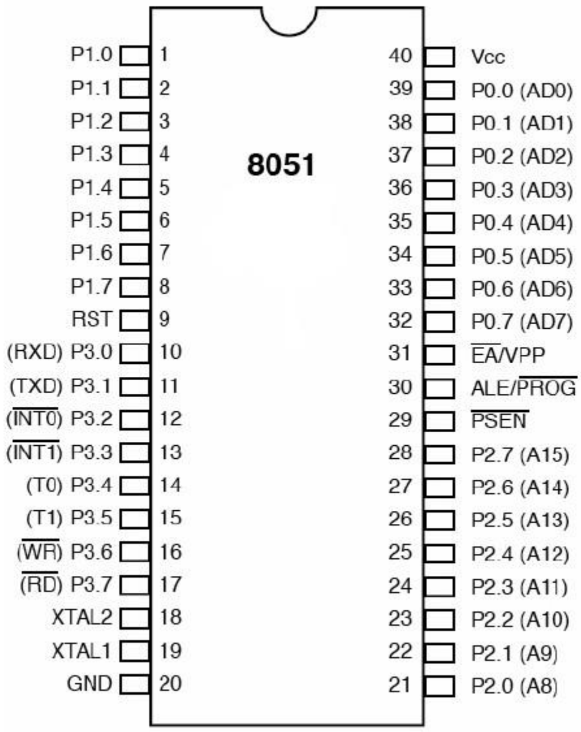
Pins 1-8: Port 1 Each of these pins can be configured as an input or an output.

Pin 9: RS A logic one on this pin disables the microcontroller and clears the contents of most registers. In other words, the positive voltage on this pin resets the microcontroller. By applying logic zero to this pin, the program starts execution from the beginning.

Pins10-17: Port 3 Similar to port 1, each of these pins can serve as general input or output. Besides, all of them have alternative functions:

Pin 10: RXD Serial asynchronous communication input or Serial synchronous communication output.
Pin 11: TXD Serial asynchronous communication output or Serial synchronous communication clock output.

Pin 12: INT0 Interrupt 0 input.



Pin diagram of 8051

Pin 13: INT1 Interrupt 1 input.

Pin 14: T0 Counter 0 clock input.

Pin 15: T1 Counter 1 clock input.

Pin 16: WR Write to external (additional) RAM.

Pin 17: RD Read from external RAM.

Pin 18, 19: X2, X1 Internal oscillator input and output. A quartz crystal which specifies operating frequency is usually connected to these pins.

Pin 20: GND Ground.

Pin 21-28: Port 2 If there is no intention to use external memory then these port pins are configured as general inputs/outputs. In case external memory is used, the higher address byte, i.e. addresses A8-A15 will appear on this port. Even though memory with capacity of 64Kb is not used,

Pin 29: PSEN If external ROM is used for storing program then a logic zero (0) appears on it every time the microcontroller reads a byte from memory.

Pin 30: ALE Prior to reading from external memory, the microcontroller puts the lower address byte (A0-A7) on P0 and activates the ALE output. After receiving signal from the ALE pin, the external register (usually 74HCT373 or 74HCT375 add-on chip) memorizes the state of P0 and uses it as a memory chip address.

Pin 31: EA By applying logic zero to this pin, P2 and P3 are used for data and address transmission with no regard to whether there is internal memory or not. It means that even there is a program written to the microcontroller, it will not be executed. Instead, the program written to external ROM will be executed. By applying logic one to the EA pin, the microcontroller will use both memories, first internal then external (if exists).

Pin 32-39: Port 0 Similar to P2, if external memory is not used, these pins can be used as general inputs/outputs. Otherwise, P0 is configured as address output (A0-A7) when the ALE pin is driven high (1) or as data output (Data Bus) when the ALE pin is driven low (0).

Pin 40: VCC +5V power supply.

Memory Organization

The 8051 microcontroller utilizes the Harvard architecture, with separate code and data spaces. Memory organization in 8051 is similar to that of the industry standard 8051. There are three memory areas, as shown.

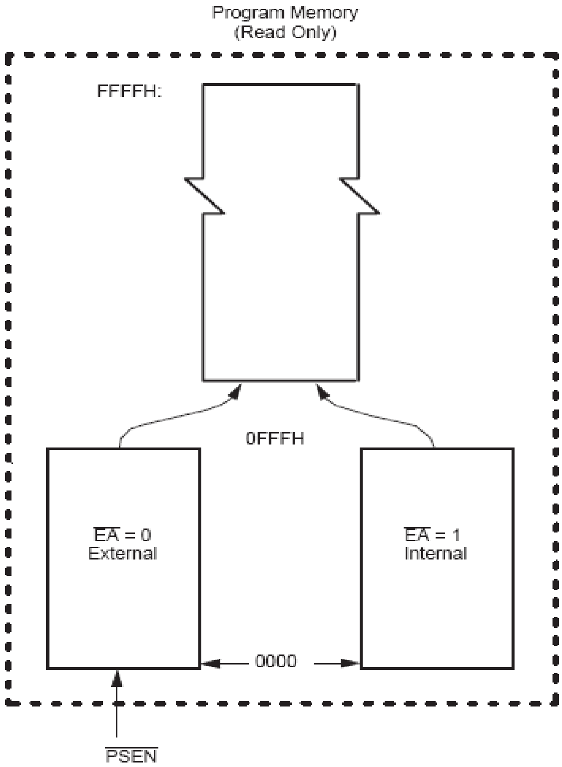
• Program Memory (Internal RAM, External RAM, or External ROM)

• External Data Memory (External RAM)

• Internal Data Memory (Internal RAM)

Program Memory

8051 can address up to 64kB of program memory space, from 0000H to FFFFH. The External Bus Interface services program memory when the MEMPSRD signal is active. Program memory is read when the CPU performs fetching instructions or MOVC. After reset, the CPU starts program execution from location 0000H. The lower part of the program memory includes interrupt and reset vectors. The interrupt vectors are spaced at eight-byte intervals, starting from 0003H. Program memory can be implemented as Internal RAM, External RAM, External ROM, or a combination of all three.



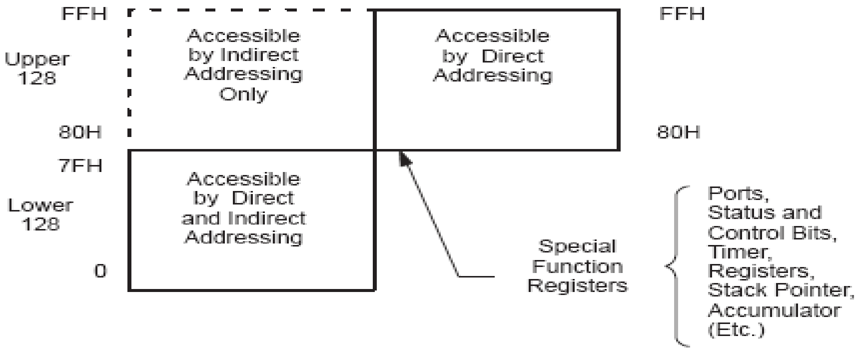
Program memory

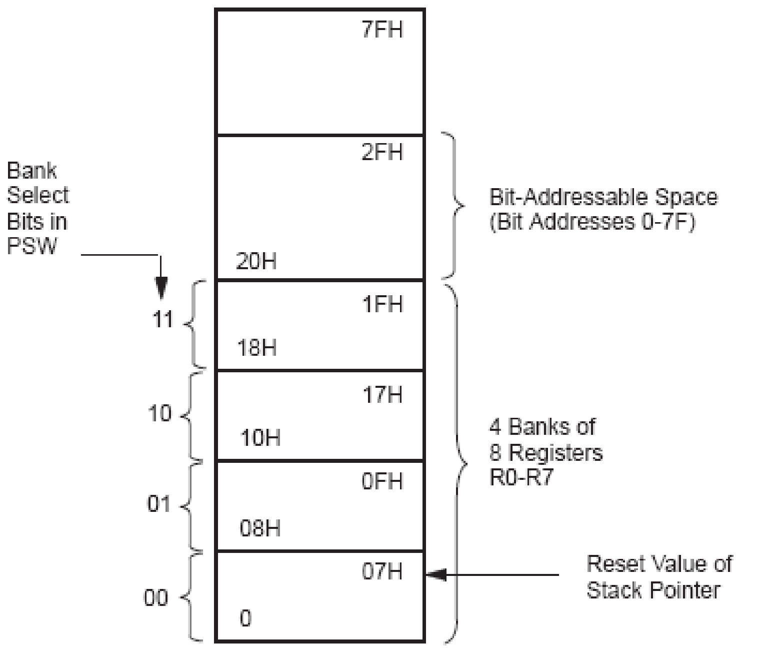
External Data Memory

8051 can address up to 64kB of external data memory space, from 0000H to FFFFH. The External Bus Interface services data memory when the MEMRD signal is active. Writing to external program memory is only supported in debug mode using the OCI logic block and external debugger hardware and software. 8051 writes into external data memory when the CPU executes MOVX @Ri ,A or MOVX @DPTR,A instructions.

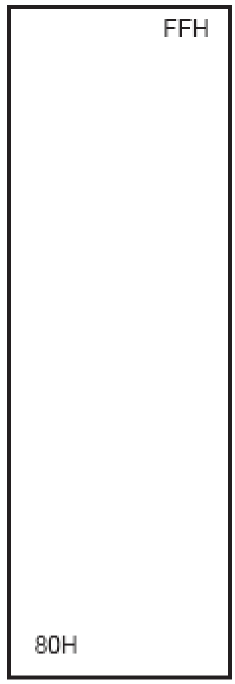
Internal Data Memory

The internal data memory interface services up to 256 bytes of off-core data memory. The internal data memory address is always one byte wide. The memory space is 256 bytes large (00H to FFH) and can be accessed by direct or indirect addressing.





Lower 128 Bytes of Internal RAM

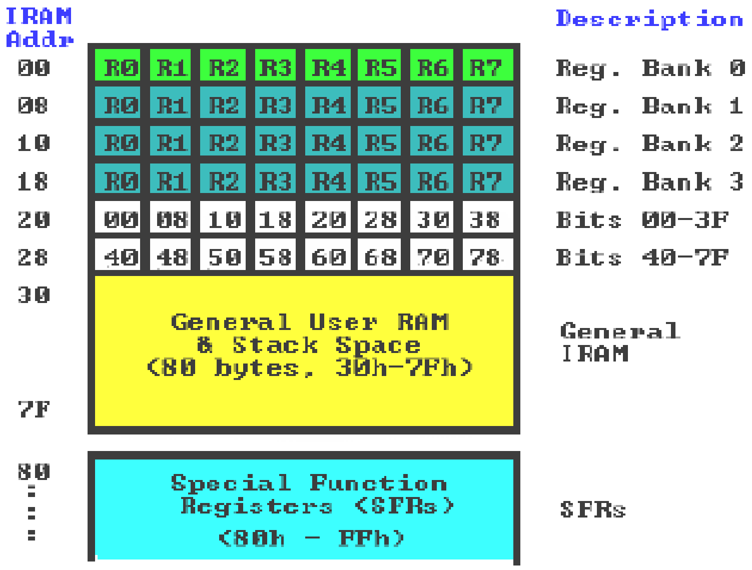


Upper 128 Bytes of Internal RAM

Internal Data Memory

On-Chip Memory.

The 8051 includes a certain amount of on chip memory. On-chip memory is really one of two (SFR) memory. The layout of the 8051's internal memory is presented in the following memory map:



On-Chip Memory

The Internal RAM is found *on-chip* on the 8051 so it is the fastest RAM available, and it is also the most flexible in terms of reading, writing, and modifying it's contents.

Bit Memory

The 8051, being a communications oriented microcontroller, gives the user the ability to access a number of *bit variables*. These variables may be either 1 or 0. There are 128 bit variables available to the user, numbered 00h through 7Fh. The user may make use of these variables with commands such as SETB and CLR.

Bit variables 00h through 7Fh are for user defined functions in their programs. However, bit variables 80h and above are actually used to access certain SFRs on a bit-by-bit basis.

Special Function Register (SFR) Memory

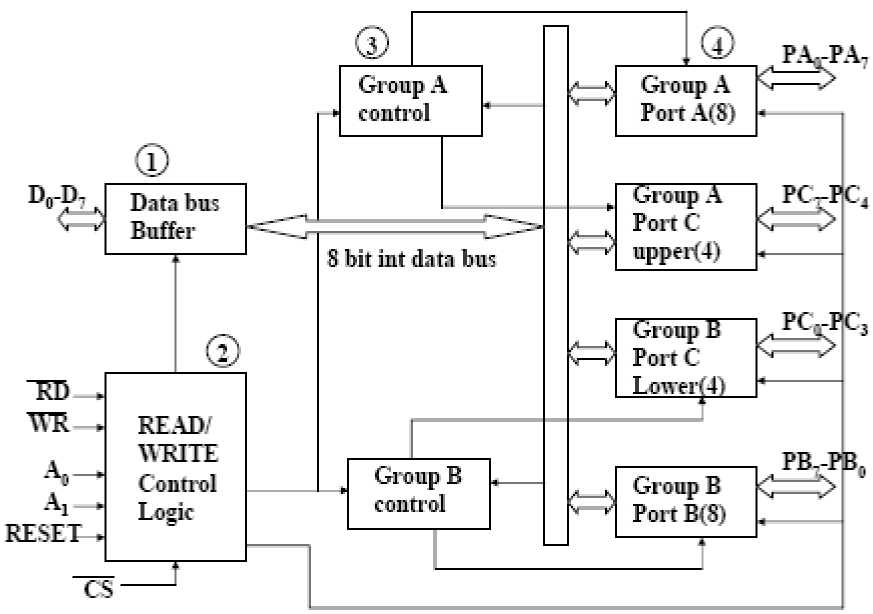
Special Function Registers (SFRs) are areas of memory that control specific functionality of the 8051 processor. For example, four SFRs permit access to the 8051's 32 input/output lines. Another SFR allows a program to read or write to the 8051's serial port. Other SFRs allow the user to set the serial baud rate, control and access timers, and configure the 8051's interrupt system. When programming, SFRs have the illusion of being Internal Memory. When using this method of memory access (it's called direct address), any instruction that has an address of 00h through 7Fh refers to an Internal RAM memory address; any instruction with an address of 80h through FFh refers to an SFR control register.

UNIT III

PROGRAMMABLE PERIPHERAL INTERFACING

8255 Programmable Peripheral Input-Output port

The parallel input-output port chip 8255 is also called as programmable peripheral input-output port. The Intel's 8255 is designed for use with Intel's 8- bit, 16-bit and higher capability microprocessors. It has 24 input/output lines which may be individually programmed in two groups of twelve lines each, or three groups of eight lines. The two groups of I/O pins are named as Group A and Group B. Each of these two groups contains a subgroup of eight I/O lines called as 8-bit port and another subgroup of four lines or a 4-bit port. Thus Group A contains an 8-bit port A along with a 4-bit port. C upper. The port A lines are identified by symbols PA0-PA7 while the port C lines are identified as PC4-PC7. Similarly, Group B contains an 8-bit port B, containing lines PB0-PB7 and a 4-bit port C with lower bits PC0- PC3. The port C upper and port C lower can be used in combination as an 8-bit port C. Both the port C are assigned the same address. Thus one may have either three 8- bit I/O ports or two 8-bit and two 4-bit ports from 8255. All of these ports can function independently either as input or as output ports. This can be achieved by programming the bits of an internal register of 8255 called as control word register (CWR).



Block Diagram of 8255 (Architecture)

The 8-bit data bus buffer is controlled by the read/write control logic. The read/write control logic manages all of the internal and external transfers of both data and control words. RD, WR, A1, A0 and RESET are the inputs provided by the microprocessor to the READ/ WRITE control logic of 8255. The 8-bit, 3-state bidirectional buffer is used to interface the 8255 internal data bus with the external system data bus. This buffer receives or transmits data upon the execution of input or output instructions by the microprocessor. The control words or status information is also transferred through the buffer.

Block Diagram of 8255

It has

1. Data bus buffer
2. Read Write control logic
3. Group A and Group B controls
4. Port A, B and C

Data bus buffer: This is a tri state bidirectional buffer used to interface the 8255 to system data bus. Data is transmitted or received by the buffer on execution of input or output instruction by the CPU. Control word and status information are also transferred through this unit.

Read/Write control logic: This unit accepts control signals (RD, WR) and also inputs from address bus and issues commands to individual group of control blocks (Group A, Group B).

It has the following pins.

- **CS** – Chip select : A low on this PIN enables the communication between CPU and 8255.
- **RD** (Read) – A low on this pin enables the CPU to read the data in the ports or the status word through data bus buffer.
- **WR** (Write) : A low on this pin, the CPU can write data on to the ports or on to the control register through the data bus buffer.
- **RESET**: A high on this pin clears the control register and all ports are set to the input mode
- **A0** and **A1** (Address pins): These pins in conjunction with RD and WR pins control the selection of one of the 3 ports.

Group A and Group B controls : These block receive control from the CPU and issues commands to their respective ports. Group A - PA and PCU (PC7 –PC4) Group B - PCL (PC3 – PC0) Control word register can only be written into no read operation of the CW register is allowed.

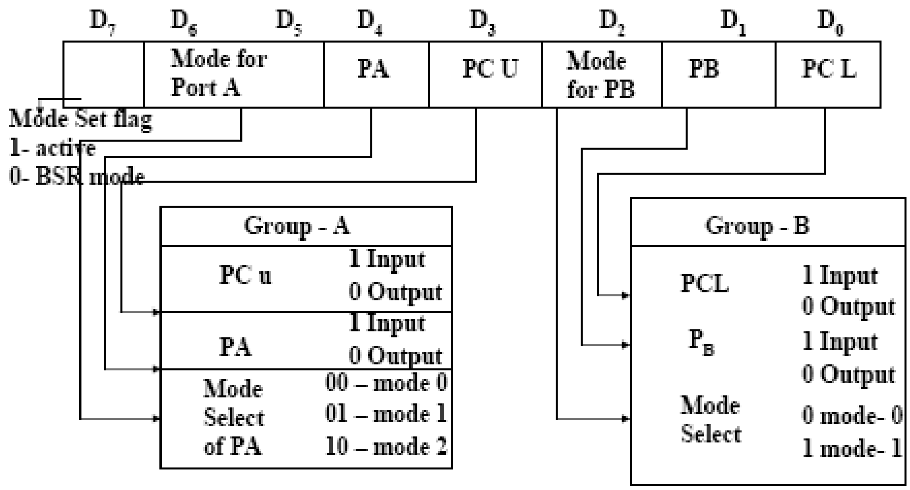
- **Port A**: This has an 8 bit latched/buffered O/P and 8 bit input latch. It can be programmed in 3 modes – mode 0, mode 1, mode 2.
- **Port B**: This has an 8 bit latched / buffered O/P and 8 bit input latch. It can be programmed in mode 0, mode1.
- **Port C** : This has an 8 bit latched input buffer and 8 bit out put latched/buffer. This port can be divided into two 4 bit ports and can be used as control signals for port A and port B. it can be programmed in mode 0.

Modes of Operation of 8255

These are two basic modes of operation of 8255. **I/O mode and Bit Set-Reset mode (BSR).**

In I/O mode, the 8255 ports work as programmable I/O ports, while in BSR mode only port C (PC0-PC7) can be used to set or reset its individual port bits.

Under the I/O mode of operation, further there are three modes of operation of 8255, so as to support different types of applications, mode 0, mode 1 and mode 2.



Control Word Format of 8255

BSR Mode:

In this mode any of the 8-bits of port C can be set or reset depending on D0 of the control word. The bit to be set or reset is selected by bit select flags D3, D2 and D1 of the CWR as given in table.

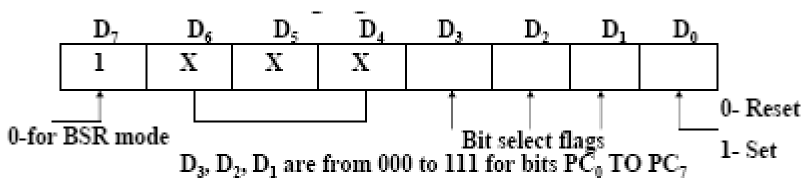


Fig. 4.3 BSR Mode Control Word Register Format

D3	D2	D1	Selected bits of port C
0	0	0	D0
1	0	0	D1
0	1	1	D2
0	1	1	D3
0	0	0	D4
1	0	1	D5
1	1	0	D6
1	1	1	D7

I/O Modes :

a) Mode 0 (Basic I/O mode):

This mode is also called as basic input/output mode. This mode provides simple input and output capabilities using each of the three ports. Data can be simply read from and written to the input and output ports respectively, after appropriate initialization.

The salient features of this mode are as listed below:

1. Two 8-bit ports (port A and port B)and two 4-bit ports (port C upper and lower) are available. The two 4-bit ports can be combinedly used as a third 8-bit port. 2. Any port can be used as an input or output port.
2. Output ports are latched. Input ports are not latched.
3. A maximum of four ports are available so that overall 16 I/O configuration are possible.

All these modes can be selected by programming a register internal to 8255 known as CWR. The control word register has two formats. The first format is valid for I/O modes of operation, i.e. modes 0, mode 1 and mode 2 while the second format is valid for bit set/reset (BSR) mode of operation.

Mode 0 Control Word Register Format

- Port A and Port C acting as O/P.
- Port B acting as I/P

D7	D6	D5	D4	D3	D2	D1	D0
1	0	0	0	0	0	1	0

D7 – set Mode set flag , 1 – I/O Mode

D6,D5 - set either Mode 0 , Mode 1 , Mode 2

0 0 – Mode 0

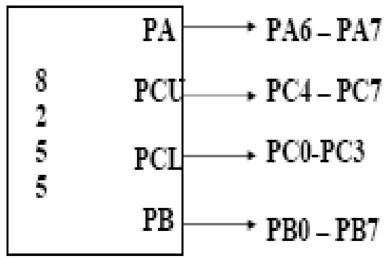
if D4 is 0 - PA as output

if D3 is 0 - PCU as output

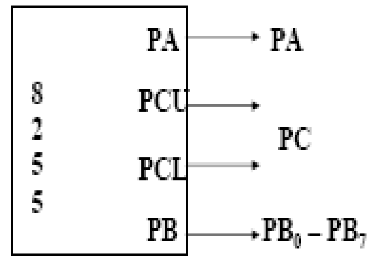
if D2 is 0 - set mode 0 of PB

if D1 is 1 - PB as input

if D0 is 0 - PCL as output



All Output



Port A and Port C acting as O/P. Port B acting as I/P

b) Mode 1: (Strobed input/output mode)

In this mode the handshaking control the input and output action of the specified port. Port C lines PC0-PC2, provide strobe or handshake lines for port B. This group which includes port B and PC0-PC2 is called as group B for Strobed data input/output. Port C lines PC3-PC5 provide strobe lines for port A. This group including port A and PC3-PC5 from group A. Thus port C is utilized for generating handshake signals. The

Salient Features Of Mode 1:

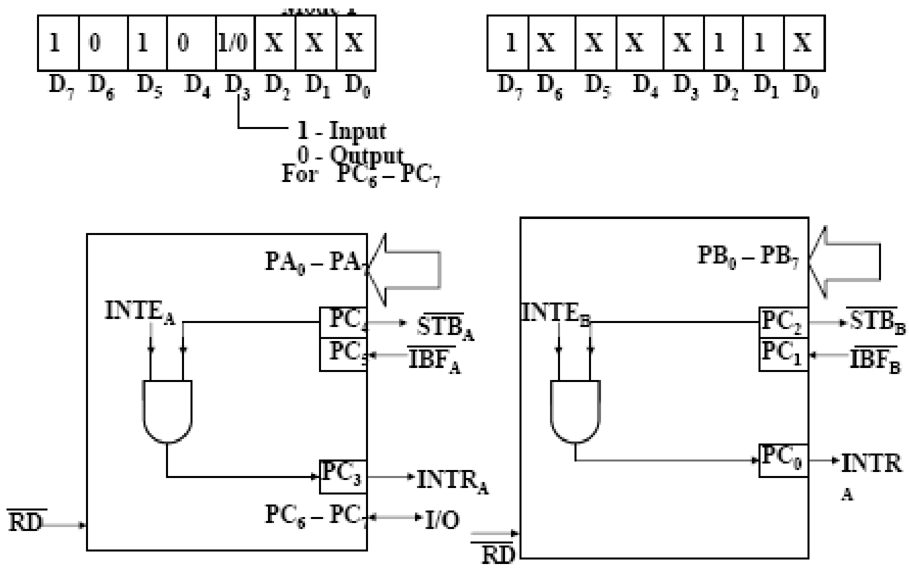
1. Two groups – group A and group B are available for strobed data transfer.
2. Each group contains one 8-bit data I/O port and one 4-bit control/data port.
3. The 8-bit data port can be either used as input and output port. The inputs and outputs both are latched.
4. Out of 8-bit port C, PC0-PC2 are used to generate control signals for port B and PC3-PC5 are used to generate control signals for port A. the lines PC6, PC7 may be used as independent data lines.

Input control signal definitions (mode 1):

STB(Strobe input) – If this lines falls to logic low level, the data available at 8- bit input port is loaded into input latches.

IBF (Input buffer full) – If this signal rises to logic 1, it indicates that data has been loaded into latches, i.e. it works as an acknowledgement. IBF is set by a low on STB and is reset by the rising edge of RD input.

INTR (Interrupt request) – This active high output signal can be used to interrupt the CPU whenever an input device requests the service. INTR is set by a high STB pin and a high at IBF pin. INTE is an internal flag that can be controlled by the bit set/reset mode of either PC4(INTEA) or PC2(INTEB) as shown in Figure 7. INTR is reset by a falling edge of RD input. Thus an external input device can be request the service of the processor by putting the data on the bus and sending the strobe signal.



Mode 1 Control Word Group A I/P

Mode 1 Control Word Group B I/P

Input control signal definitions in Mode 1

Output control signal definitions (mode 1) :

OBF (Output buffer full) – This status signal, whenever falls to low, indicates that CPU has written data to the specified output port. The OBF flip-flop will be set by a rising edge of WR signal and reset by a low going edge at the ACK input.

ACK (Acknowledge input) – ACK signal acts as an acknowledgement to be given by an output device. ACK signal, whenever low, informs the CPU that the data transferred by the CPU to the output device through the port is received by the output device.

INTR (Interrupt request) – Thus an output signal that can be used to interrupt the CPU when an output device acknowledges the data received from the CPU. INTR is set when ACK, OBF and INTE are 1. It is reset by a falling edge on WR input. The INTEA and INTEB flags are controlled by the bit set-reset mode of PC6 and PC2 respectively.

C) Mode 2 (Strobed bidirectional I/O):

This mode of operation of 8255 is also called as strobed bidirectional I/O. This mode of operation provides 8255 with an additional features for communicating with a peripheral device on an 8-bit data bus. Handshaking signals are provided to maintain proper data flow and synchronization between the data transmitter and receiver. The interrupt generation and other functions are similar to mode 1.

In this mode, 8255 is a bidirectional 8-bit port with handshake signals. The Rd and WR signals decide whether the 8255 is going to operate as an input port or output port.

The Salient features of Mode 2 of 8255 are listed as follows:

1. The single 8-bit port in group A is available.
2. The 8-bit port is bidirectional and additionally a 5-bit control port is available.
3. Three I/O lines are available at port C.(PC2 – PC0)
4. Inputs and outputs are both latched.

5. The 5-bit control port C (PC3-PC7) is used for generating / accepting handshake signals for the 8-bit data transfer on port A.

Control signal definitions in mode 2:

INTR – (Interrupt request) As in mode 1, this control signal is active high and is used to interrupt the microprocessor to ask for transfer of the next data byte to/from it. This signal is used for input (read) as well as output (write) operations.

Control Signals for Output operations:

OBF (Output buffer full) – This signal, when falls to low level, indicates that the CPU has written data to port A.

ACK (Acknowledge) This control input, when falls to logic low level, acknowledges that the previous data byte is received by the destination and next byte may be sent by the processor. This signal enables the internal tristate buffers to send the next data byte on port A.

INTE1 (A flag associated with OBF) This can be controlled by bit set/reset mode with PC6.

8279 – Keyboard / Display Controller

While studying 8255, we have explained the use of 8255 in interfacing keyboards and displays with 8086. The disadvantages of this method of interfacing keyboard and display with 8086 is that the processor has to refresh the display and check the status of the keyboard periodically using polling technique. Thus a considerable amount of CPU time is wasted, reducing the system operating speed. Intel's 8279 is a general purpose keyboard display controller that simultaneously drives the display of a system and interfaces a keyboard with the CPU, leaving it free for its routine task.

Architecture of 8279

The keyboard display controller chip 8279 provides:

a) a set of four scan lines and eight return lines for interfacing keyboards
b) A set of eight output lines for interfacing display.

I/O Control and Data Buffers : The I/O control section controls the flow of data to/from the 8279. The data buffers interface the external bus of the system with internal bus of 8279.

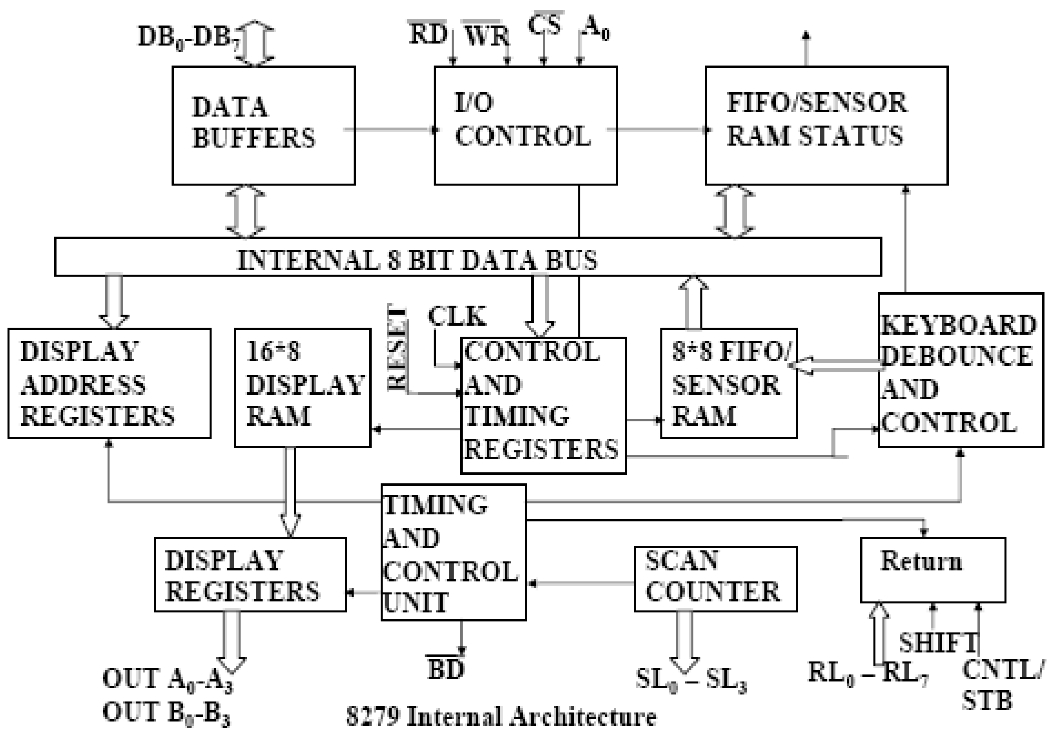
Control and Timing Register and Timing Control : These registers store the keyboard and display modes and other operating conditions programmed by CPU. The registers are written with A0=1 and WR=0.

Scan Counter : The scan counter has two modes to scan the key matrix and refresh the display. In the encoded mode, the counter provides binary count that is to be externally decoded to provide the scan lines for keyboard and display (Four externally decoded scan lines may drive up to 16 displays). In the decode scan mode, the counter internally decodes the least significant 2 bits and provides a decoded 1 out of 4 scan on SL0-SL3(Four internally decoded scan lines may drive up to 4 displays). The keyboard and display both are in the same mode at a time.

Return Buffers and Keyboard Debounce and Control: This section for a key closure row wise. If a key closer is detected, the keyboard debounce unit debounces the key entry (i.e. wait for 10 ms).

FIFO/Sensor RAM and Status Logic: In keyboard or strobed input mode, this block acts as 8-byte first-in-first-out (FIFO) RAM. Each key code of the pressed key is entered in the order of the entry and in the mean time read by the CPU, till the RAM become empty. • The status logic generates an interrupt after each FIFO read operation till the

Display Address Registers and Display RAM : The display address register holds the address of the word currently being written or read by the CPU to or from the display RAM. The contents of the registers are automatically updated by 8279 to accept the next data entry by CPU.



8279 Internal Architecture

Modes of Operation of 8279

The modes of operation of 8279 are as follows :

1. Input (Keyboard) modes.

2. Output (Display) modes.

Input (Keyboard) Modes :

8279 provides three input modes. These modes are as follows

1. **Scanned Keyboard Mode** : This mode allows a key matrix to be interfaced using either encoded or decoded scans. In encoded scan, an 8*8 keyboard or in decoded scan, a 4*8 keyboard can be interfaced. The code of key pressed with SHIFT and CONTROL status is stored into the FIFO RAM.
2. **Scanned Sensor Matrix** : In this mode, a sensor array can be interfaced with 8279 using either encoded or decoded scans. With encoded scan 8*8 sensor matrix or with decoded scan 4*8 sensor matrix can be interfaced. The sensor codes are stored in the CPU addressable sensor RAM.
3. **Strobed input**: In this mode, if the control lines goes low, the data on return lines, is stored in the FIFO byte by byte.

Output (Display) Modes : 8279 provides two output modes for selecting the display options. These are discussed briefly.

1. **Display Scan** : In this mode 8279 provides 8 or 16 character multiplexed displays those can be organized as dual 4- bit or single 8-bit display units.
2. **Display Entry** : (right entry or left entry mode) 8279 allows options for data entry on the displays. The display data is entered for display either from the right side or from the left side.

Display Modes

There are various options of data display. For example, the command number of characters can be 8 or 16, with each character organized as single 8-bit or dual 4- bit codes.

<u>A/D and D/A converters</u>

Interfacing Analog to Digital Data Converters

- In most of the cases, the PIO 8255 is used for interfacing the analog to digital converters with microprocessor.
- The analog to digital converters is treated as an input device by the microprocessor that sends an initializing signal to the ADC to start the analogy to digital data conversation process.

General algorithm for ADC interfacing contains the following steps:

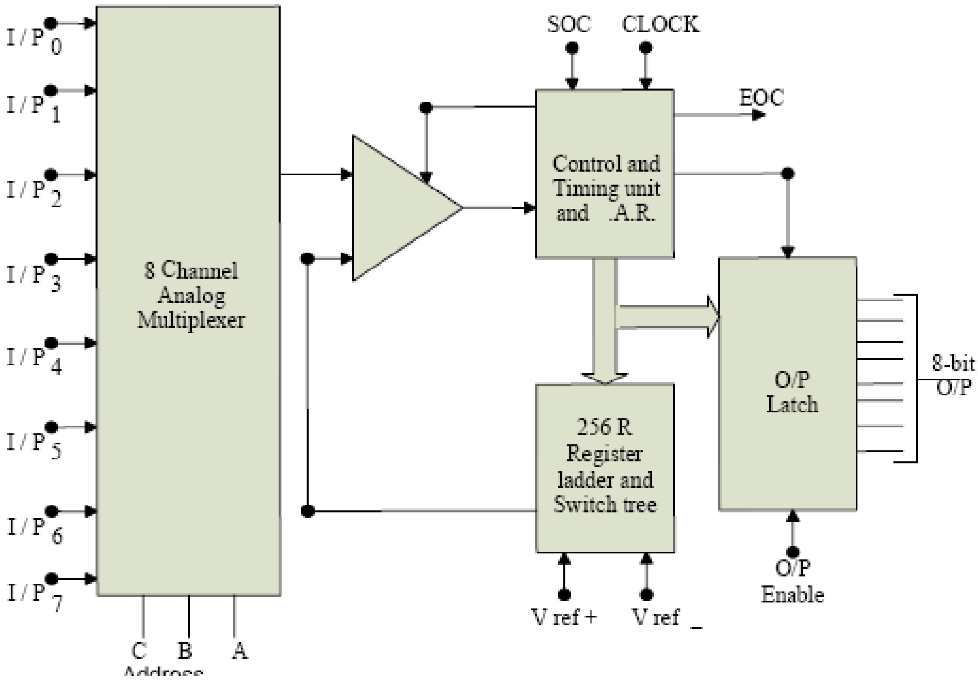
- Ensure the stability of analog input, applied to the ADC.
- Issue start of conversion pulse to ADC
- Read end of conversion signal to mark the end of conversion processes.
- Read digital data output of the ADC as equivalent digital output.
- Analog input voltage must be constant at the input of the ADC right from the start of conversion till the end of the conversion to get correct results. This may be ensured by a sample and hold circuit which samples the analog signal and holds it constant for specific time duration. The microprocessor may issue a hold signal to the sample and hold circuit.
- If the applied input changes before the complete conversion process is over, the digital equivalent of the analog input calculated by the ADC may not be correct.

ADC 0808/0809

- The analog to digital converter chips 0808 and 0809 are 8-bit CMOS, successive approximation converters.
- This technique is one of the fast techniques for analog to digital conversion.
- The conversion delay is 100µs at a clock frequency of 640 KHz, which is quite low as compared to other converters. These converters do not need any external zero or full scale adjustments as they are already taken care of by internal circuits.
- These converters internally have a 3:8 analog multiplexer so that at a time eight different analog conversion by using address lines - ADD A, ADD B, ADD C.
- Using these address inputs, multi channel data acquisition system can be designed using a single ADC.
- The CPU may drive these lines using output port lines in case of multi channel applications.
- In case of single input applications, these may be hardwired to select the proper input.
- There are unipolar analog to digital converters, i.e. they are able to convert only positive analog input voltage to their digital equivalent. These chips do no contain any internal sample and hold circuit.

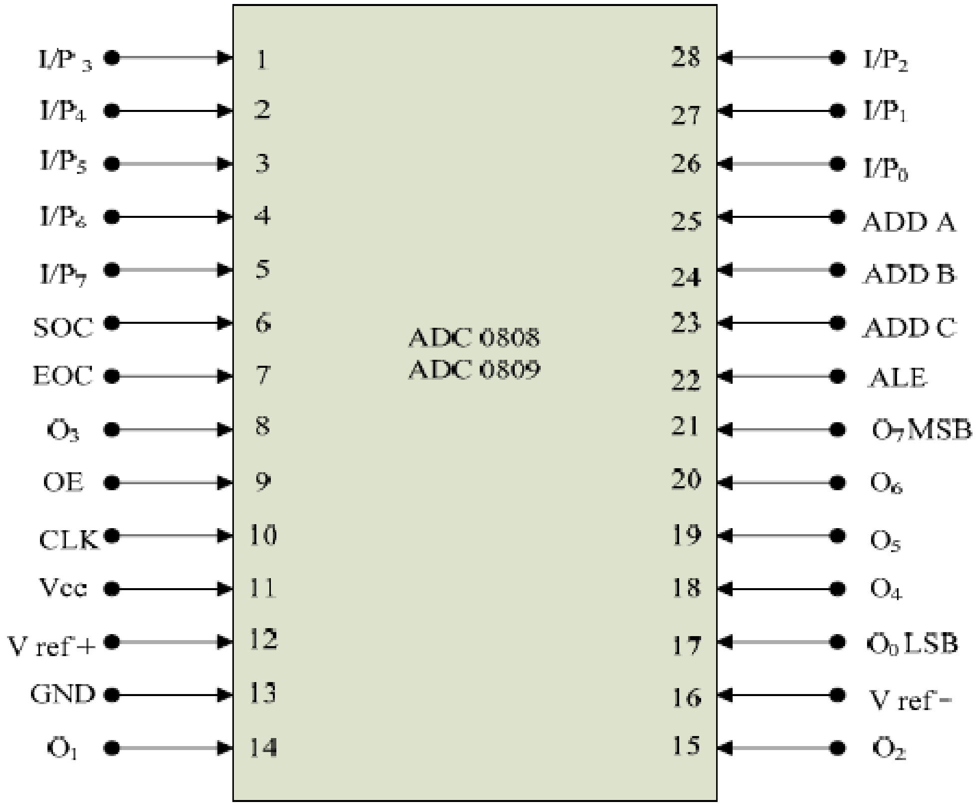
Analog / select	Address lines		
	C	B	A
I / P 0	0	0	0
I / P 1	0	0	1
I / P 2	0	1	0
I / P 3	0	1	1
I / P 4	1	0	0
I / P 5	1	0	1
I / P 6	1	1	0
I / P 7	1	1	1

Block Diagram of ADC 0808/0809



Block Diagram of ADC 0808/0809

Pin Diagram of ADC 0808/0809



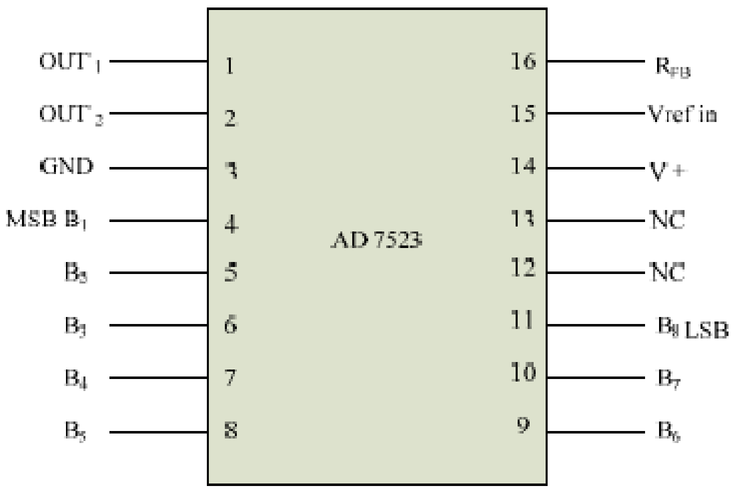
Pin diagram of ADC 0808/0809

Vcc	**:**	Supply pins +5V
GND	**:**	GND
Vref+	:	Reference voltage positive +5 Volts maximum.
Vref_	:	Reference voltage negative 0Volts minimum.
I/P0 –I/P7	**:**	Analog inputs
ADD A,B,C	**:**	Address lines for selecting analog inputs.
O7-00	**:**	Digital 8-bit output with O7 MSB and O0 LSB
SOC	**:**	Start of conversion signal pin
EOC	**:**	End of conversion signal pin
OE	**:**	Output latch enable pin, if high enables output
CLK	**:**	Clock input for ADC

Interfacing Digital to Analog Converters

- The digital to analog converters convert binary number into their equivalent voltages.
- The DAC find applications in areas like digitally controlled gains, motors speed controls, programmable gain amplifiers etc.AD 7523 8-bit Multiplying DAC:
- This is a 16 pin DIP, multiplying digital to analog converter, containing R-2R ladder for D-A conversion along with single pole double thrown NMOS switches to connect the digital inputs to the ladder.

Pin Diagram



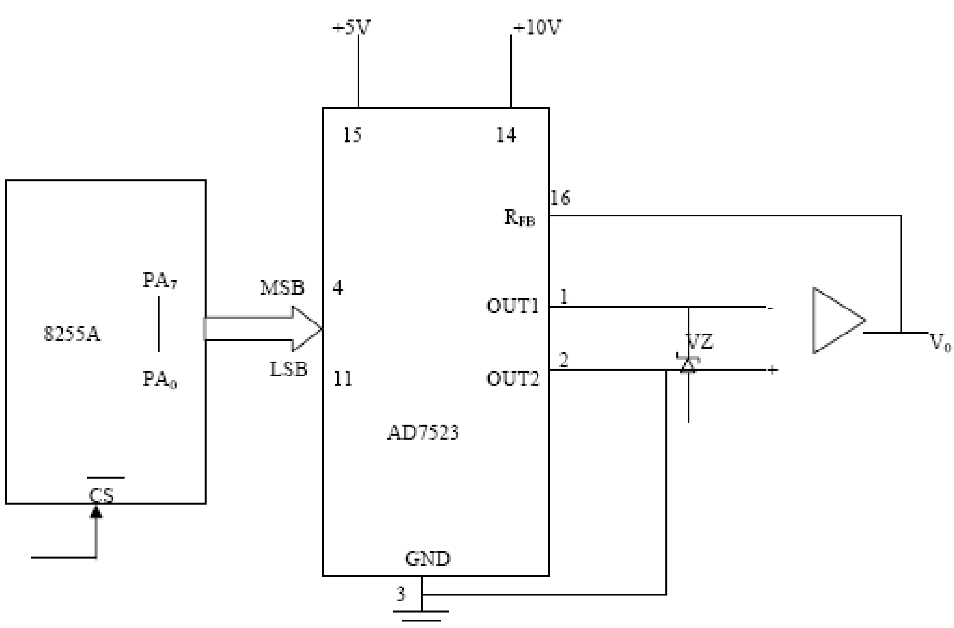
Pin diagram of AD7523

- The pin diagram of AD7523 is shown in Fig, the supply range is from +5V to +15V, while Vref may be any where between -10V to +10V.
- The maximum analog output voltage will be any where between -10V to +10V, when all the digital inputs are at logic high state.
- Usually a zener is connected between OUT1 and OUT2 to save the DAC from negative transients.
- An operational amplifier is used as a current to voltage converter at the output of AD to convert the current out put of AD to a proportional output voltage. It also offers additional drive capability to the DAC output.
- An external feedback resistor acts to control the gain. One may not connect any external feedback resistor, if no gain control is required.

Example:

- Interfacing DAC AD7523 with an 8086 CPU running at 8MHZ and write an assembly language program to generate a saw tooth waveform of period 1ms with Vmax 5V.
- Solution*:* Figure 3.17 shows the interfacing circuit of AD 74523 with 8086 using 8255.
- Program gives an ALP to generate a saw tooth waveform using circuit.

```
ASSUME CS:CODE
CODE SEGMENT
START: MOV AL,80h  ;make all ports output
OUT CW, AL
AGAIN: MOV AL, 00h            ;start voltage for ramp
BACK: OUT PA, AL
INC AL
CMP AL, 0FFh
JB BACK
JMP  AGAIN
CODE ENDS
END START
```



Interfacing of AD7523

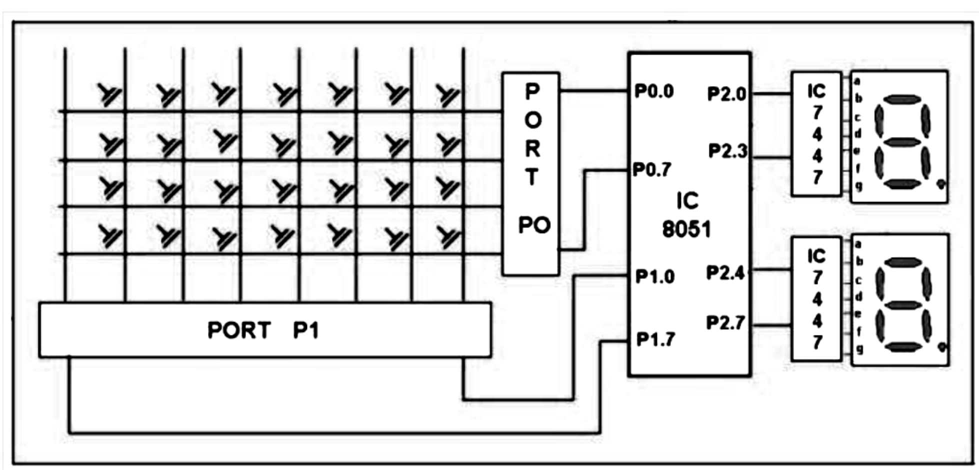
- In the above program, port A is initialized as the output port for sending the digital data as input to DAC. The ramp starts from the 0V (analog), hence AL starts with 00H.
- To increment the ramp, the content of AL is increased during each execution of loop till it reaches F2H. After that the saw tooth wave again starts from 00H, i.e. 0V(analog) and the procedure is repeated.
- The ramp period given by this program is precisely 1.000625 ms. Here the count F2H has been calculated by dividing the required delay of 1ms by the time required for the execution of the loop once.
- The ramp slope can be controlled by calling a controllable delay after the OUT instruction.

Keyboard Interfacing

Interfacing the Keyboard to 8051 microcontroller

The contents of the counter is then compared and displayed in the display. This display is designed using a seven segment display and a BCD to seven segment decoder IC 7447.

The BCD equivalent number of counter is sent through output part of 8051 displays the number of pressed key.



Block Diagram of Keyboard Interfacing

Keyboard is organized in a matrix of rows and columns as shown in the figure. The microcontroller accesses both rows and columns through the port.

1. The 8051 has 4 I/O ports P0 to P3 each with 8 I/O pins, P0.0 to P0.7,P1.0 to P1.7, P2.0 to P2.7, P3.0 to P3.7. The one of the port P1 (it understood that P1 means P1.0 to P1.7) as an I/P port for microcontroller 8051, port P0 as an O/P port of

microcontroller 8051 and port P2 is used for displaying the number of pressed key.

2. Make all rows of port P0 high so that it gives high signal when key is pressed.

3. See if any key is pressed by scanning the port P1 by checking all columns for non zero condition.

4. If any key is pressed, to identify which key is pressed make one row high at a time.

5. Initiate a counter to hold the count so that each key is counted.

6. Check port P1 for nonzero condition. If any nonzero number is there in [accumulator], start column scanning by following step 9.

7. Otherwise make next row high in port P1.

8. Add a count of 08h to the counter to move to the next row by repeating steps from step 6.

9. If any key pressed is found, the [accumulator] content is rotated right through the carry until carry bit sets, while doing this increment the count in the counter till carry is found.

10. Move the content in the counter to display in data field or to memory location

11. To repeat the procedures go to step 2.

Start of main program: to check that whether any key is pressed

```
start: mov a,#00h
mov p1,a ;making all rows of port p1 zero mov a,#0fh
mov p1,a ;making all rows of port p1 high
press: mov a,p2
jz press ;check until any key is pressed
```

after making sure that any key is pressed

```
mov a,#01h ;make one row high at a time mov r4,a
mov r3,#00h ;initiating counter
next: mov a,r4
mov p1,a ;making one row high at a time mov a,p2 ;taking input from port A
jnz colscan ;after getting the row jump to check column
mov a,r4
rl a ;rotate left to check next row mov r4,a
mov a,r3
add a,#08h ;increment counter by 08 count mov r3,a
sjmp next ;jump to check next row
```

after identifying the row to check the colomn following steps are followed

```
colscan: mov r5,#00h
in: rrc a ;rotate right with carry until get the carry jc out ;jump on getting carry
inc r3 ;increment one count jmp in
out: mov a,r3
da a ;decimal adjust the contents of counter before display
mov p2,a
jmp start ;repeat for check next key
```

INTERFACING STEPPER MOTOR WITH 8051

- A Stepper Motor is a brushless, synchronous DC Motor.
- It has many applications in the field of robotics and mechatronics.
- The total rotation of the motor is divided into steps.
- The angle of a single step is known as the stepper angle of the motor.
- There are two types of stepper motors **Unipolar** and **Bipolar**.
- Unipolar stepper motor is commonly used by electronics hobbyists.
- Stepper Motors can be easily interfaced with a microcontroller using driver ICs such as L293D or ULN2003.

Stepper motor Interfacing/Control using 8085 and 8051

Stepper Motor

A stepper motor is a device that translates electrical pulses into mechanical movement in steps of fixed step angle.

- The stepper motor rotates in steps in response to the applied signals.
- It is mainly used for position control.
- It is used in disk drives, dot matrix printers, plotters and robotics and process control circuits.

Structure

Stepper motors have a permanent magnet called rotor (also called the shaft) surrounded by a stator. The most common stepper motors have four stator windings that are paired with a center-tap. This type of stepper motor is commonly referred to as a four-phase or unipolar stepper motor. The center tap allows a change of current direction in each of two coils when a winding is grounded, thereby resulting in a polarity change of the stator.

Interfacing

Even a small stepper motor require a current of 400 mA for its operation. But the ports of the microcontroller cannot source this much amount of current. If such a motor is directly connected to the microprocessor/microcontroller ports, the motor may draw large current from the ports and damage it. So a suitable driver circuit is used with the microprocessor/microcontroller to operate the motor.

Motor Driver Circuit (ULN2003)

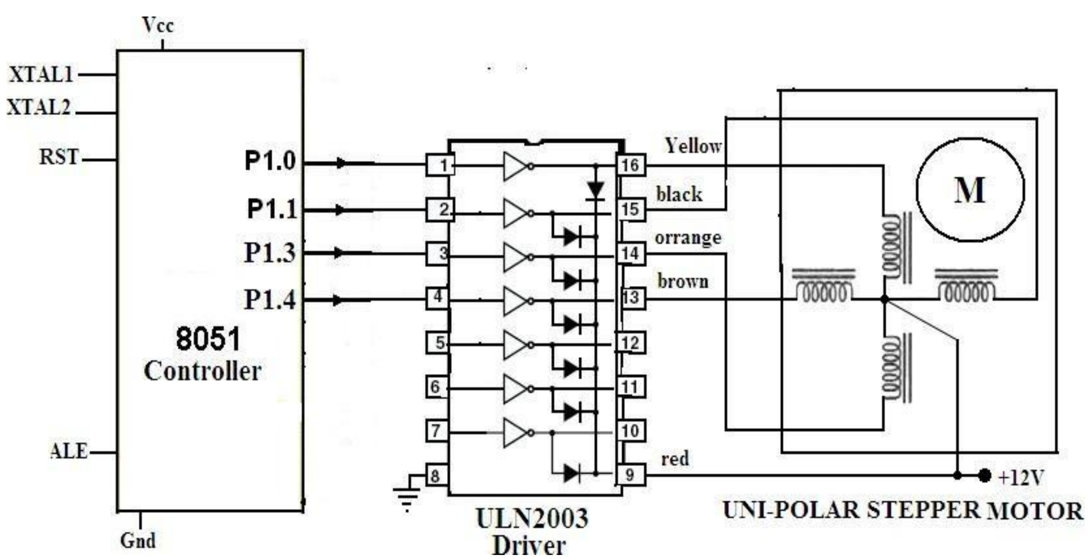
Stepper motor driver circuits are available readily in the form of ICs. ULN2003 is one such driver IC which is a High-Voltage High-Current Darlington transistor array and can give a current of 500mA.This current is sufficient to drive a small stepper motor. Internally, it has protection diodes used to protect the motor from damage due to back emf and large eddy currents. So, this ULN2003 is used as a driver to interface the stepper motor to the microcontroller.

Operation

The important parameter of a stepper motor is the step angle. It is the minimum angle through which the motor rotates in response to each excitation pulse. In a four phase motor if there are 200 steps in one complete rotation then then the step angle is 360/200 = 1.8^{O} . So to rotate the stepper motor we have to apply the excitation pulse. For this the controller should send a hexa decimal code through one of its ports. The hex code mainly depends on the construction of the stepper motor. So, all the stepper motors do not have the same Hex code for their rotation. (refer the operation manual supplied by the manufacturer.)

For example, let us consider the hex code for a stepper motor to rotate in clockwise direction is 77H , BBH , DDH and EEH. This hex code will be applied to the input terminals of the driver through the assembly language program. To rotate the stepper motor in anti-clockwise direction the same code is applied in the reverse order.

Stepper Motor interface- Schematic Diagram (for 8051)



The assembly language program for 8051 is given below.

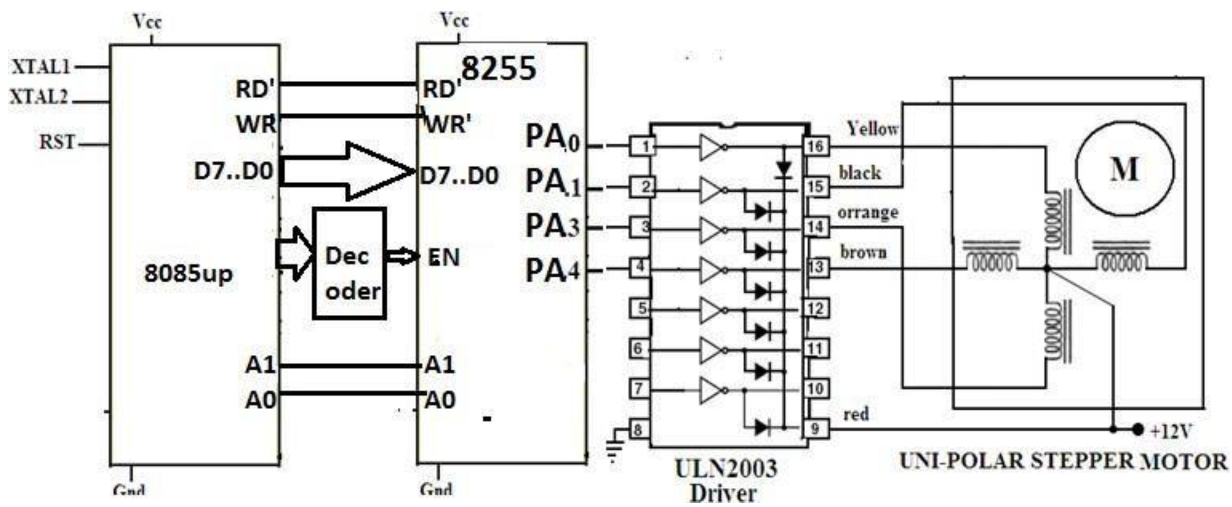
ASSEMBLY LANGUAGE PROGRAM (8051)

```
Main  : MOV A, # 0FF H        ;  Initialization of Port 1
        MOV P1, A             ;
        MOV A, #77 H          ; Code for the Phase 1
        MOV P1, A             ;
        ACALL DELAY           ; Delay subroutine
        MOV A, # BB H         ; Code for the Phase II
        MOV P1, A             ;
        ACALL DELAY           ; Delay subroutine.
        MOV A, # DD H         ; Code for the Phase III
        MOV P1, A             ;
        ACALL DELAY           ; Delay subroutine
        MOV A, # EE H         ; Code for the Phase 1
        MOV P1, A             ;
        ACALL DELAY           ; Delay subroutine SJMP
        MAIN; Keep the motor rotating continuously.
```

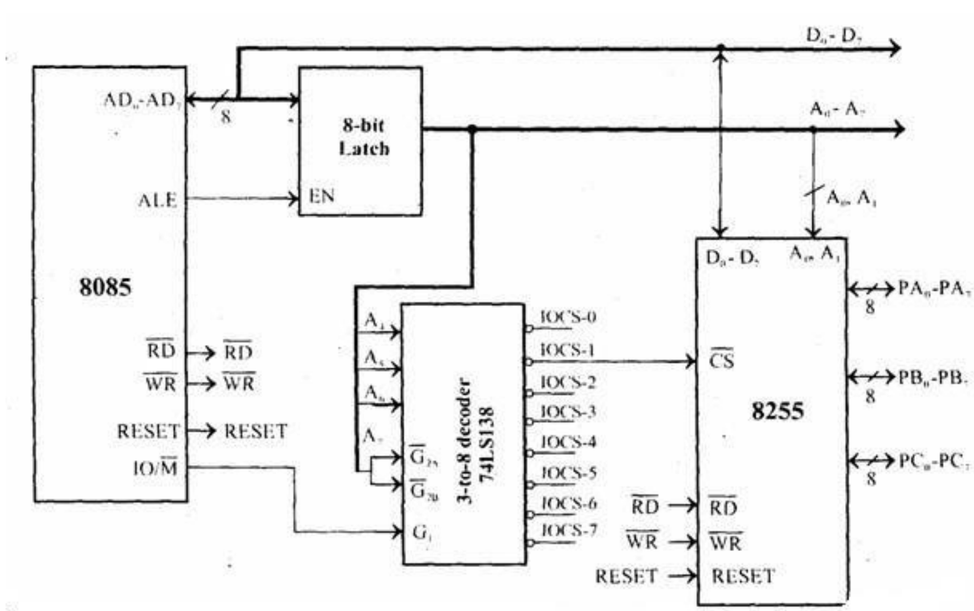
DELAY Subroutine

```
        MOV R4, #0FF H        ;  Load R4 with FF
        MOV R5, # 0FF         ; Load R5 with FF
LOOP1:  DJNZ R4, LOOP1        ; Decrement R4 until zero,wait
LOOP2:  DJNZ R5, LOOP2        ; Decrement R5 until zero,wait
        RET                   ; Return to main program .
```

Stepper Motor interface - Schematic Diagram for (8085)



Detailed Connection diagram between 8085 and 8255



ASSEMBLY LANGUAGE PROGRAM (8085)

```
Main   : MVI A, 80            ;  80H → Control word to configure PA,PB,PC in O/P
         OUT CWR_Address      ; Write control word in CWR of 8255
         MVI A, 77            ; Code for the Phase 1
         OUT PortA_Address    ; sent to motor via port A of 8255        ;
         CALL DELAY           ; Delay subroutine
         MVI A, BB            ; Code for the Phase II
         OUT PortA_Address    ; sent to motor via port A of 8255
         CALL DELAY           ; Delay subroutine.
         MVI A, DD            ; Code for the Phase III
         OUT PortA_Address    ; sent to motor via port A of 8255;
         CALL DELAY           ; Delay subroutine
         MVI A, EE H          ; Code for the Phase 1
         OUT PortA_Address    ; sent to motor via port A of 8255                  ;
         CALL DELAY           ; Delay subroutine
         JMP MAIN             ; Keep the motor rotating continuously.
```

DELAY Subroutine

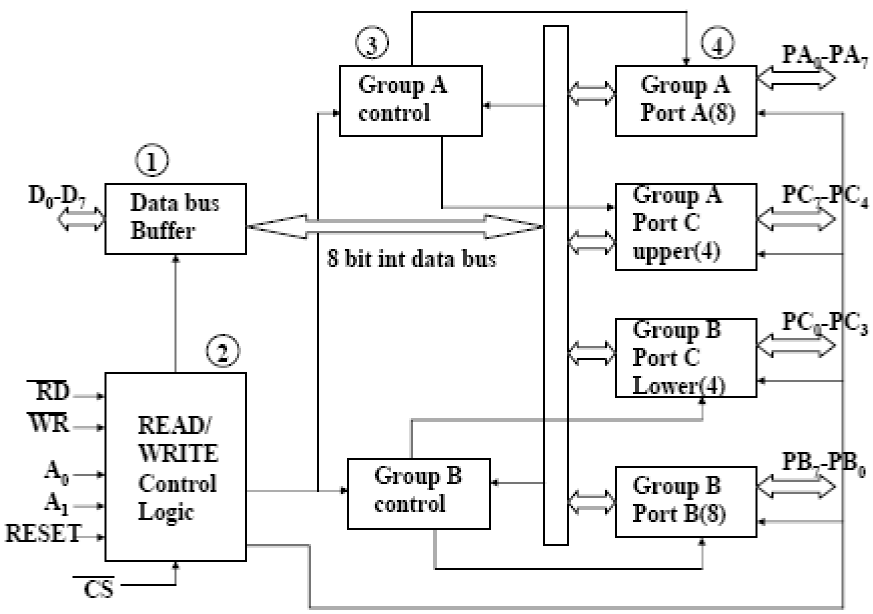
```
         MVI C, FF            ; Load C with FF -- Change it for the speed variation
LOOP1:  MVI D,FF              ; Load D with FF
LOOP2:  DCR D
         JNZ LOOP2
         DCR C
         JNZ LOOP1
         RET                  ; Return to main program .
```

UNIT III

PROGRAMMABLE PERIPHERAL INTERFACING

8255 Programmable Peripheral Input-Output port

The parallel input-output port chip 8255 is also called as programmable peripheral input-output port. The Intel's 8255 is designed for use with Intel's 8- bit, 16-bit and higher capability microprocessors. It has 24 input/output lines which may be individually programmed in two groups of twelve lines each, or three groups of eight lines. The two groups of I/O pins are named as Group A and Group B. Each of these two groups contains a subgroup of eight I/O lines called as 8-bit port and another subgroup of four lines or a 4-bit port. Thus Group A contains an 8-bit port A along with a 4-bit port. C upper. The port A lines are identified by symbols PA0-PA7 while the port C lines are identified as PC4-PC7. Similarly, Group B contains an 8-bit port B, containing lines PB0-PB7 and a 4-bit port C with lower bits PC0- PC3. The port C upper and port C lower can be used in combination as an 8-bit port C. Both the port C are assigned the same address. Thus one may have either three 8- bit I/O ports or two 8-bit and two 4-bit ports from 8255. All of these ports can function independently either as input or as output ports. This can be achieved by programming the bits of an internal register of 8255 called as control word register (CWR).



Block Diagram of 8255 (Architecture)

The 8-bit data bus buffer is controlled by the read/write control logic. The read/write control logic manages all of the internal and external transfers of both data and control words. RD, WR, A1, A0 and RESET are the inputs provided by the microprocessor to the READ/ WRITE control logic of 8255. The 8-bit, 3-state bidirectional buffer is used to interface the 8255 internal data bus with the external system data bus. This buffer receives or transmits data upon the execution of input or output instructions by the microprocessor. The control words or status information is also transferred through the buffer.

Block Diagram of 8255

It has

1. Data bus buffer
2. Read Write control logic
3. Group A and Group B controls
4. Port A, B and C

Data bus buffer: This is a tri state bidirectional buffer used to interface the 8255 to system data bus. Data is transmitted or received by the buffer on execution of input or output instruction by the CPU. Control word and status information are also transferred through this unit.

Read/Write control logic: This unit accepts control signals (RD, WR) and also inputs from address bus and issues commands to individual group of control blocks (Group A, Group B).

It has the following pins.

- **CS** – Chip select : A low on this PIN enables the communication between CPU and 8255.
- **RD** (Read) – A low on this pin enables the CPU to read the data in the ports or the status word through data bus buffer.
- **WR** (Write) : A low on this pin, the CPU can write data on to the ports or on to the control register through the data bus buffer.
- **RESET**: A high on this pin clears the control register and all ports are set to the input mode
- **A0** and **A1** (Address pins): These pins in conjunction with RD and WR pins control the selection of one of the 3 ports.

Group A and Group B controls : These block receive control from the CPU and issues commands to their respective ports. Group A - PA and PCU (PC7 –PC4) Group B - PCL (PC3 – PC0) Control word register can only be written into no read operation of the CW register is allowed.

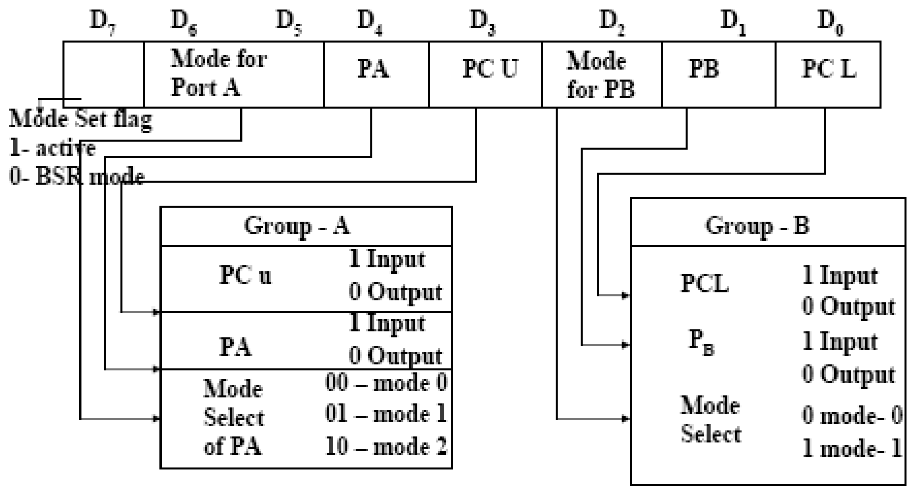
- **Port A**: This has an 8 bit latched/buffered O/P and 8 bit input latch. It can be programmed in 3 modes – mode 0, mode 1, mode 2.
- **Port B**: This has an 8 bit latched / buffered O/P and 8 bit input latch. It can be programmed in mode 0, mode1.
- **Port C** : This has an 8 bit latched input buffer and 8 bit out put latched/buffer. This port can be divided into two 4 bit ports and can be used as control signals for port A and port B. it can be programmed in mode 0.

Modes of Operation of 8255

These are two basic modes of operation of 8255. **I/O mode and Bit Set-Reset mode (BSR).**

In I/O mode, the 8255 ports work as programmable I/O ports, while in BSR mode only port C (PC0-PC7) can be used to set or reset its individual port bits.

Under the I/O mode of operation, further there are three modes of operation of 8255, so as to support different types of applications, mode 0, mode 1 and mode 2.



Control Word Format of 8255

BSR Mode:

In this mode any of the 8-bits of port C can be set or reset depending on D0 of the control word. The bit to be set or reset is selected by bit select flags D3, D2 and D1 of the CWR as given in table.

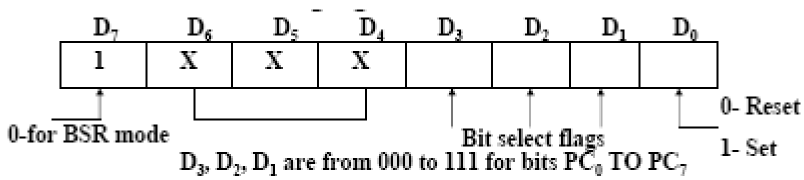


Fig. 4.3 BSR Mode Control Word Register Format

D3	D2	D1	Selected bits of port C
0	0	0	D0
1	0	0	D1
0	1	1	D2
0	1	1	D3
0	0	0	D4
1	0	1	D5
1	1	0	D6
1	1	1	D7

I/O Modes :

a) Mode 0 (Basic I/O mode):

This mode is also called as basic input/output mode. This mode provides simple input and output capabilities using each of the three ports. Data can be simply read from and written to the input and output ports respectively, after appropriate initialization.

The salient features of this mode are as listed below:

1. Two 8-bit ports (port A and port B)and two 4-bit ports (port C upper and lower) are available. The two 4-bit ports can be combinedly used as a third 8-bit port. 2. Any port can be used as an input or output port.
2. Output ports are latched. Input ports are not latched.
3. A maximum of four ports are available so that overall 16 I/O configuration are possible.

All these modes can be selected by programming a register internal to 8255 known as CWR. The control word register has two formats. The first format is valid for I/O modes of operation, i.e. modes 0, mode 1 and mode 2 while the second format is valid for bit set/reset (BSR) mode of operation.

Mode 0 Control Word Register Format

- Port A and Port C acting as O/P.
- Port B acting as I/P

D7	D6	D5	D4	D3	D2	D1	D0
1	0	0	0	0	0	1	0

D7 – set Mode set flag , 1 – I/O Mode

D6,D5 - set either Mode 0 , Mode 1 , Mode 2

0 0 – Mode 0

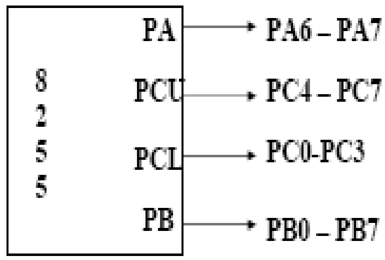
if D4 is 0 - PA as output

if D3 is 0 - PCU as output

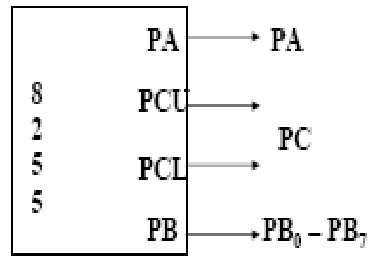
if D2 is 0 - set mode 0 of PB

if D1 is 1 - PB as input

if D0 is 0 - PCL as output



All Output



Port A and Port C acting as O/P. Port B acting as I/P

b) Mode 1: (Strobed input/output mode)

In this mode the handshaking control the input and output action of the specified port. Port C lines PC0-PC2, provide strobe or handshake lines for port B. This group which includes port B and PC0-PC2 is called as group B for Strobed data input/output. Port C lines PC3-PC5 provide strobe lines for port A. This group including port A and PC3-PC5 from group A. Thus port C is utilized for generating handshake signals. The

Salient Features Of Mode 1:

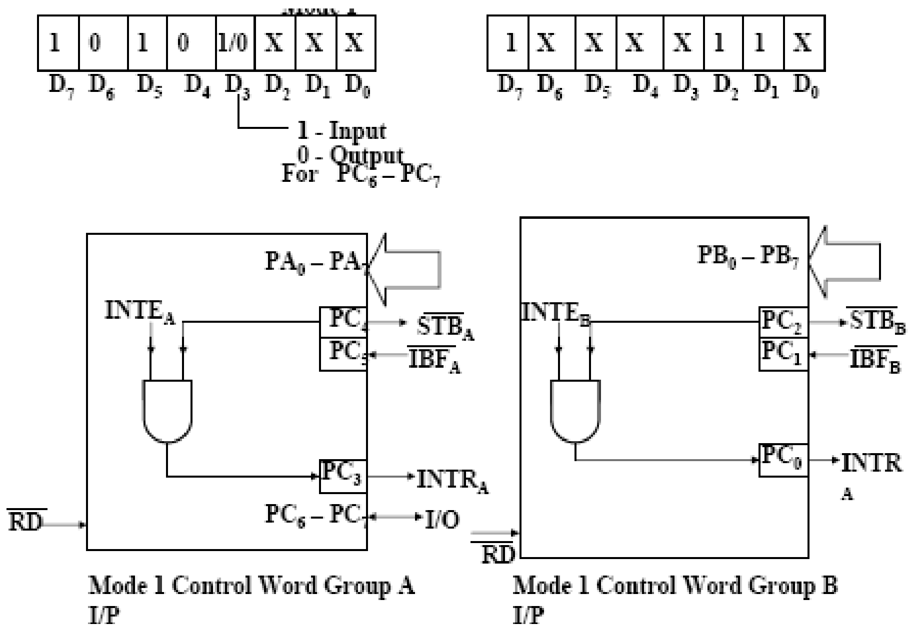
1. Two groups – group A and group B are available for strobed data transfer.
2. Each group contains one 8-bit data I/O port and one 4-bit control/data port.
3. The 8-bit data port can be either used as input and output port. The inputs and outputs both are latched.
4. Out of 8-bit port C, PC0-PC2 are used to generate control signals for port B and PC3-PC5 are used to generate control signals for port A. the lines PC6, PC7 may be used as independent data lines.

Input control signal definitions (mode 1):

STB(Strobe input) – If this lines falls to logic low level, the data available at 8- bit input port is loaded into input latches.

IBF (Input buffer full) – If this signal rises to logic 1, it indicates that data has been loaded into latches, i.e. it works as an acknowledgement. IBF is set by a low on STB and is reset by the rising edge of RD input.

INTR (Interrupt request) – This active high output signal can be used to interrupt the CPU whenever an input device requests the service. INTR is set by a high STB pin and a high at IBF pin. INTE is an internal flag that can be controlled by the bit set/reset mode of either PC4(INTEA) or PC2(INTEB) as shown in Figure 7. INTR is reset by a falling edge of RD input. Thus an external input device can be request the service of the processor by putting the data on the bus and sending the strobe signal.



Input control signal definitions in Mode 1

Output control signal definitions (mode 1) :

OBF (Output buffer full) – This status signal, whenever falls to low, indicates that CPU has written data to the specified output port. The OBF flip-flop will be set by a rising edge of WR signal and reset by a low going edge at the ACK input.

ACK (Acknowledge input) – ACK signal acts as an acknowledgement to be given by an output device. ACK signal, whenever low, informs the CPU that the data transferred by the CPU to the output device through the port is received by the output device.

INTR (Interrupt request) – Thus an output signal that can be used to interrupt the CPU when an output device acknowledges the data received from the CPU. INTR is set when ACK, OBF and INTE are 1. It is reset by a falling edge on WR input. The INTEA and INTEB flags are controlled by the bit set-reset mode of PC6 and PC2 respectively.

C) Mode 2 (Strobed bidirectional I/O):

This mode of operation of 8255 is also called as strobed bidirectional I/O. This mode of operation provides 8255 with an additional features for communicating with a peripheral device on an 8-bit data bus. Handshaking signals are provided to maintain proper data flow and synchronization between the data transmitter and receiver. The interrupt generation and other functions are similar to mode 1.

In this mode, 8255 is a bidirectional 8-bit port with handshake signals. The Rd and WR signals decide whether the 8255 is going to operate as an input port or output port.

The Salient features of Mode 2 of 8255 are listed as follows:

1. The single 8-bit port in group A is available.
2. The 8-bit port is bidirectional and additionally a 5-bit control port is available.
3. Three I/O lines are available at port C.(PC2 – PC0)
4. Inputs and outputs are both latched.

5. The 5-bit control port C (PC3-PC7) is used for generating / accepting handshake signals for the 8-bit data transfer on port A.

Control signal definitions in mode 2:

INTR – (Interrupt request) As in mode 1, this control signal is active high and is used to interrupt the microprocessor to ask for transfer of the next data byte to/from it. This signal is used for input (read) as well as output (write) operations.

Control Signals for Output operations:

OBF (Output buffer full) – This signal, when falls to low level, indicates that the CPU has written data to port A.

ACK (Acknowledge) This control input, when falls to logic low level, acknowledges that the previous data byte is received by the destination and next byte may be sent by the processor. This signal enables the internal tristate buffers to send the next data byte on port A.

INTE1 (A flag associated with OBF) This can be controlled by bit set/reset mode with PC6.

8279 – Keyboard / Display Controller

While studying 8255, we have explained the use of 8255 in interfacing keyboards and displays with 8086. The disadvantages of this method of interfacing keyboard and display with 8086 is that the processor has to refresh the display and check the status of the keyboard periodically using polling technique. Thus a considerable amount of CPU time is wasted, reducing the system operating speed. Intel's 8279 is a general purpose keyboard display controller that simultaneously drives the display of a system and interfaces a keyboard with the CPU, leaving it free for its routine task.

Architecture of 8279

The keyboard display controller chip 8279 provides:

a) a set of four scan lines and eight return lines for interfacing keyboards
b) A set of eight output lines for interfacing display.

I/O Control and Data Buffers : The I/O control section controls the flow of data to/from the 8279. The data buffers interface the external bus of the system with internal bus of 8279.

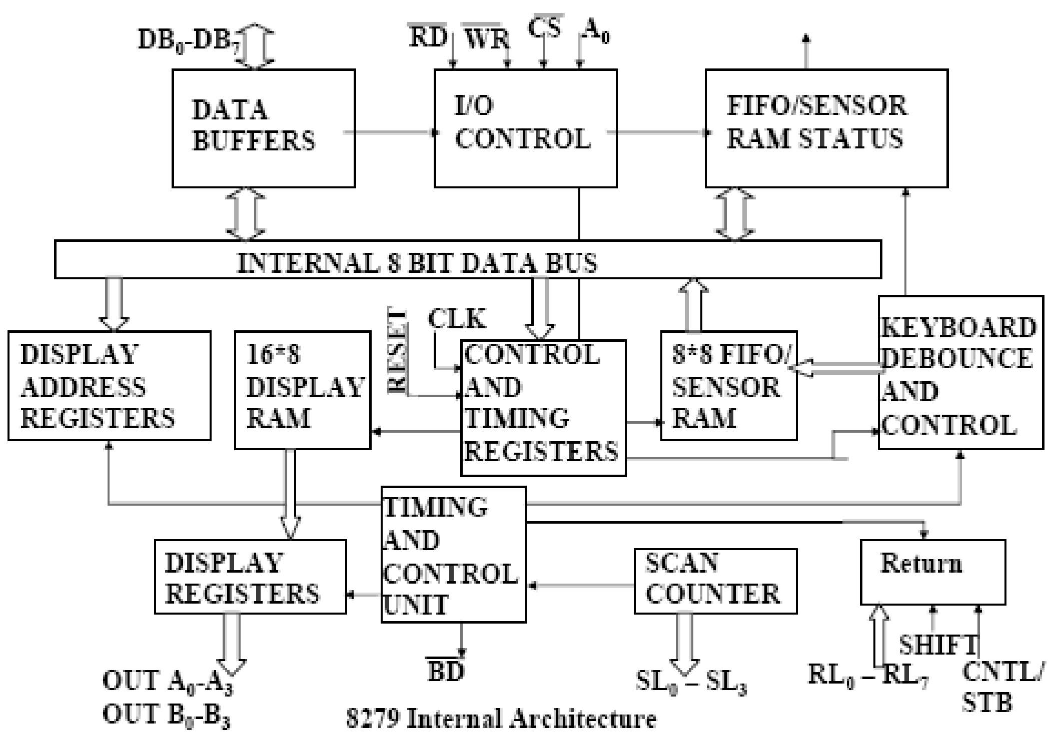
Control and Timing Register and Timing Control : These registers store the keyboard and display modes and other operating conditions programmed by CPU. The registers are written with A0=1 and WR=0.

Scan Counter : The scan counter has two modes to scan the key matrix and refresh the display. In the encoded mode, the counter provides binary count that is to be externally decoded to provide the scan lines for keyboard and display (Four externally decoded scan lines may drive up to 16 displays). In the decode scan mode, the counter internally decodes the least significant 2 bits and provides a decoded 1 out of 4 scan on SL0-SL3(Four internally decoded scan lines may drive up to 4 displays). The keyboard and display both are in the same mode at a time.

Return Buffers and Keyboard Debounce and Control: This section for a key closure row wise. If a key closer is detected, the keyboard debounce unit debounces the key entry (i.e. wait for 10 ms).

FIFO/Sensor RAM and Status Logic: In keyboard or strobed input mode, this block acts as 8-byte first-in-first-out (FIFO) RAM. Each key code of the pressed key is entered in the order of the entry and in the mean time read by the CPU, till the RAM become empty. • The status logic generates an interrupt after each FIFO read operation till the

Display Address Registers and Display RAM : The display address register holds the address of the word currently being written or read by the CPU to or from the display RAM. The contents of the registers are automatically updated by 8279 to accept the next data entry by CPU.



8279 Internal Architecture

Modes of Operation of 8279

The modes of operation of 8279 are as follows :

1. Input (Keyboard) modes.

2. Output (Display) modes.

Input (Keyboard) Modes :

8279 provides three input modes. These modes are as follows

1. **Scanned Keyboard Mode** : This mode allows a key matrix to be interfaced using either encoded or decoded scans. In encoded scan, an 8*8 keyboard or in decoded scan, a 4*8 keyboard can be interfaced. The code of key pressed with SHIFT and CONTROL status is stored into the FIFO RAM.
2. **Scanned Sensor Matrix** : In this mode, a sensor array can be interfaced with 8279 using either encoded or decoded scans. With encoded scan 8*8 sensor matrix or with decoded scan 4*8 sensor matrix can be interfaced. The sensor codes are stored in the CPU addressable sensor RAM.
3. **Strobed input**: In this mode, if the control lines goes low, the data on return lines, is stored in the FIFO byte by byte.

Output (Display) Modes : 8279 provides two output modes for selecting the display options. These are discussed briefly.

1. **Display Scan** : In this mode 8279 provides 8 or 16 character multiplexed displays those can be organized as dual 4- bit or single 8-bit display units.
2. **Display Entry** : (right entry or left entry mode) 8279 allows options for data entry on the displays. The display data is entered for display either from the right side or from the left side.

Display Modes

There are various options of data display. For example, the command number of characters can be 8 or 16, with each character organized as single 8-bit or dual 4- bit codes.

<u>A/D and D/A converters</u>

Interfacing Analog to Digital Data Converters

- In most of the cases, the PIO 8255 is used for interfacing the analog to digital converters with microprocessor.
- The analog to digital converters is treated as an input device by the microprocessor that sends an initializing signal to the ADC to start the analogy to digital data conversation process.

General algorithm for ADC interfacing contains the following steps:

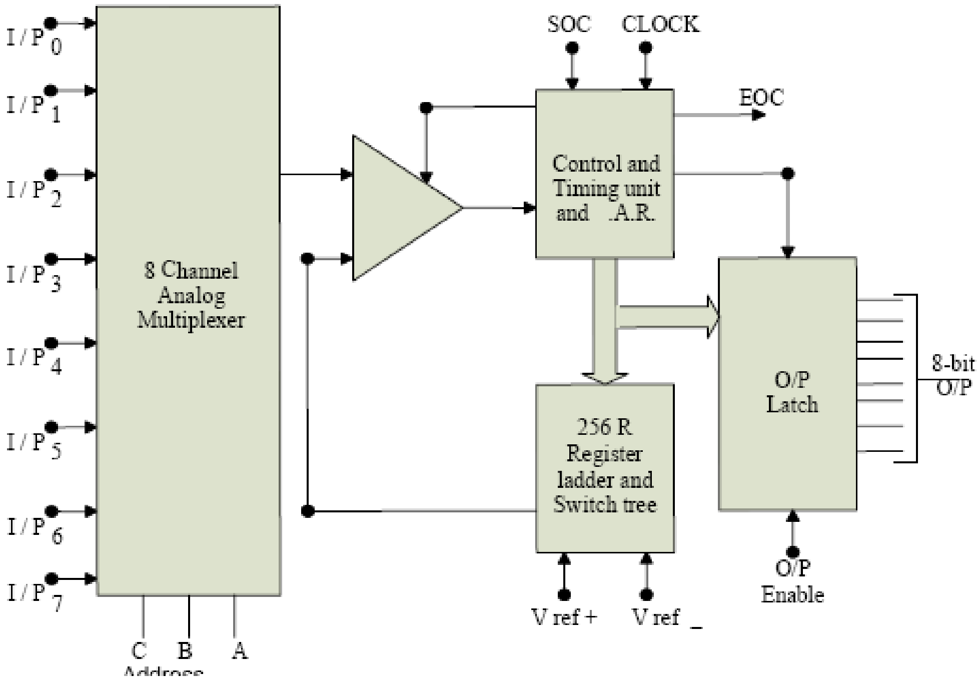
- Ensure the stability of analog input, applied to the ADC.
- Issue start of conversion pulse to ADC
- Read end of conversion signal to mark the end of conversion processes.
- Read digital data output of the ADC as equivalent digital output.
- Analog input voltage must be constant at the input of the ADC right from the start of conversion till the end of the conversion to get correct results. This may be ensured by a sample and hold circuit which samples the analog signal and holds it constant for specific time duration. The microprocessor may issue a hold signal to the sample and hold circuit.
- If the applied input changes before the complete conversion process is over, the digital equivalent of the analog input calculated by the ADC may not be correct.

ADC 0808/0809

- The analog to digital converter chips 0808 and 0809 are 8-bit CMOS, successive approximation converters.
- This technique is one of the fast techniques for analog to digital conversion.
- The conversion delay is 100µs at a clock frequency of 640 KHz, which is quite low as compared to other converters. These converters do not need any external zero or full scale adjustments as they are already taken care of by internal circuits.
- These converters internally have a 3:8 analog multiplexer so that at a time eight different analog conversion by using address lines - ADD A, ADD B, ADD C.
- Using these address inputs, multi channel data acquisition system can be designed using a single ADC.
- The CPU may drive these lines using output port lines in case of multi channel applications.
- In case of single input applications, these may be hardwired to select the proper input.
- There are unipolar analog to digital converters, i.e. they are able to convert only positive analog input voltage to their digital equivalent. These chips do no contain any internal sample and hold circuit.

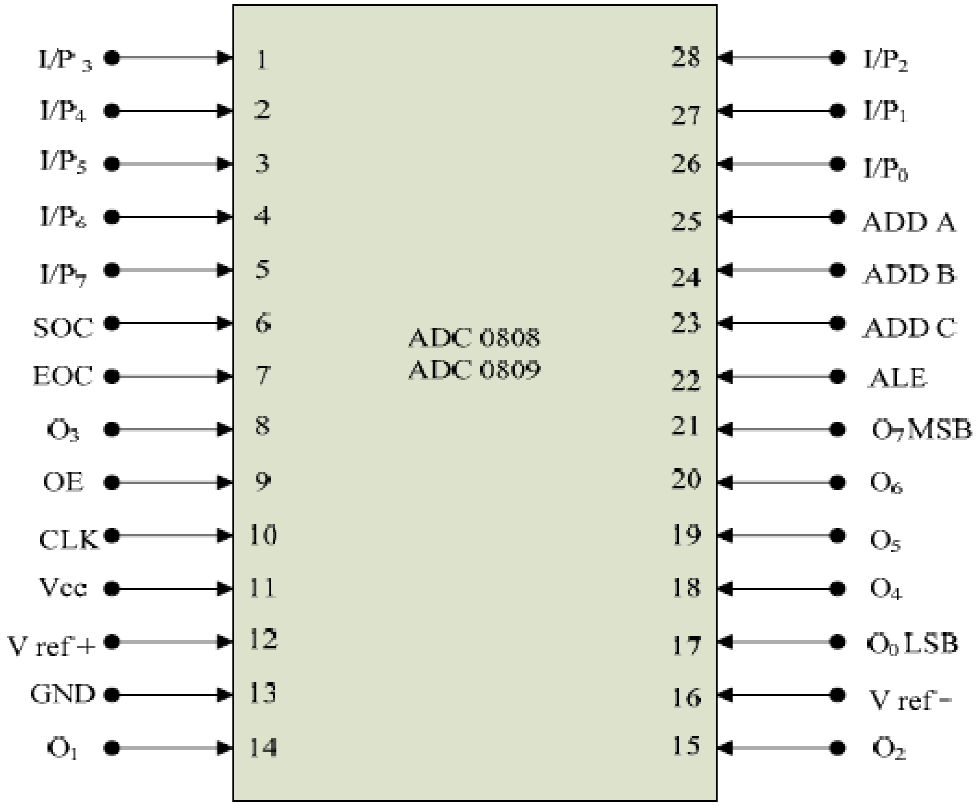
Analog / select	**Address lines**		
	C	**B**	**A**
I / P 0	0	0	0
I / P 1	0	0	1
I / P 2	0	1	0
I / P 3	0	1	1
I / P 4	1	0	0
I / P 5	1	0	1
I / P 6	1	1	0
I / P 7	1	1	1

Block Diagram of ADC 0808/0809



Block Diagram of ADC 0808/0809

Pin Diagram of ADC 0808/0809



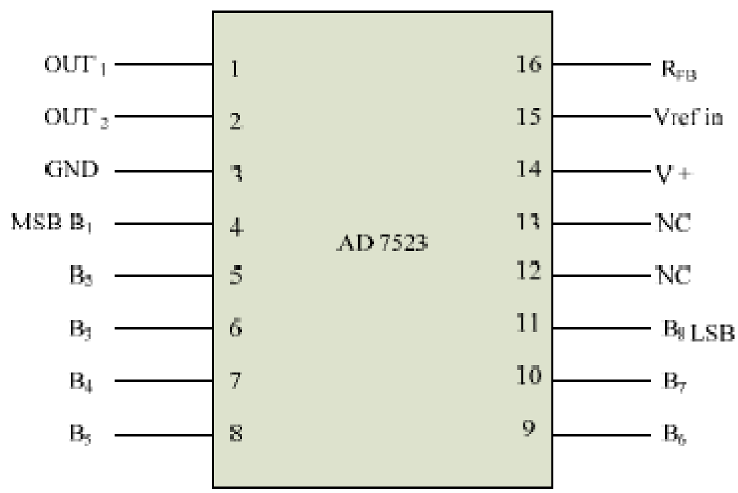
Pin diagram of ADC 0808/0809

Vcc	**:**	Supply pins +5V
GND	**:**	GND
Vref+	:	Reference voltage positive +5 Volts maximum.
Vref_	:	Reference voltage negative 0Volts minimum.
I/P0 –I/P7	**:**	Analog inputs
ADD A,B,C	**:**	Address lines for selecting analog inputs.
O7-00	**:**	Digital 8-bit output with O7 MSB and O0 LSB
SOC	**:**	Start of conversion signal pin
EOC	**:**	End of conversion signal pin
OE	**:**	Output latch enable pin, if high enables output
CLK	**:**	Clock input for ADC

Interfacing Digital to Analog Converters

- The digital to analog converters convert binary number into their equivalent voltages.
- The DAC find applications in areas like digitally controlled gains, motors speed controls, programmable gain amplifiers etc.AD 7523 8-bit Multiplying DAC:
- This is a 16 pin DIP, multiplying digital to analog converter, containing R-2R ladder for D-A conversion along with single pole double thrown NMOS switches to connect the digital inputs to the ladder.

Pin Diagram



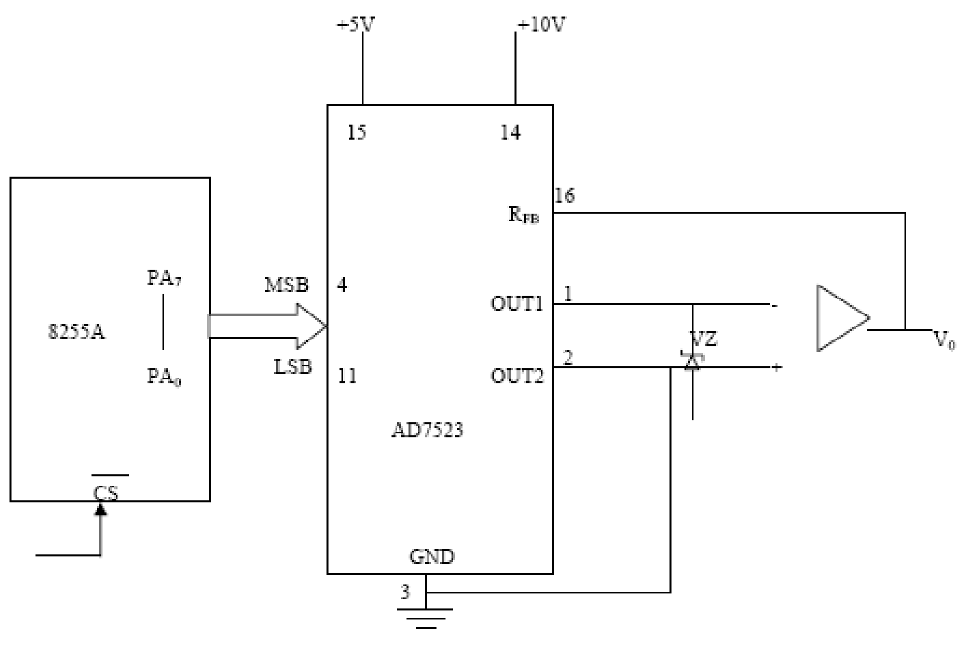
Pin diagram of AD7523

- The pin diagram of AD7523 is shown in Fig, the supply range is from +5V to +15V, while Vref may be any where between -10V to +10V.
- The maximum analog output voltage will be any where between -10V to +10V, when all the digital inputs are at logic high state.
- Usually a zener is connected between OUT1 and OUT2 to save the DAC from negative transients.
- An operational amplifier is used as a current to voltage converter at the output of AD to convert the current out put of AD to a proportional output voltage. It also offers additional drive capability to the DAC output.
- An external feedback resistor acts to control the gain. One may not connect any external feedback resistor, if no gain control is required.

Example:

- Interfacing DAC AD7523 with an 8086 CPU running at 8MHZ and write an assembly language program to generate a saw tooth waveform of period 1ms with Vmax 5V.
- Solution*:* Figure 3.17 shows the interfacing circuit of AD 74523 with 8086 using 8255.
- Program gives an ALP to generate a saw tooth waveform using circuit.

```
ASSUME CS:CODE
CODE SEGMENT
START: MOV AL,80h  ;make all ports output
OUT CW, AL
AGAIN: MOV AL, 00h            ;start voltage for ramp
BACK: OUT PA, AL
INC AL
CMP AL, 0FFh
JB BACK
JMP  AGAIN
CODE ENDS
END START
```



Interfacing of AD7523

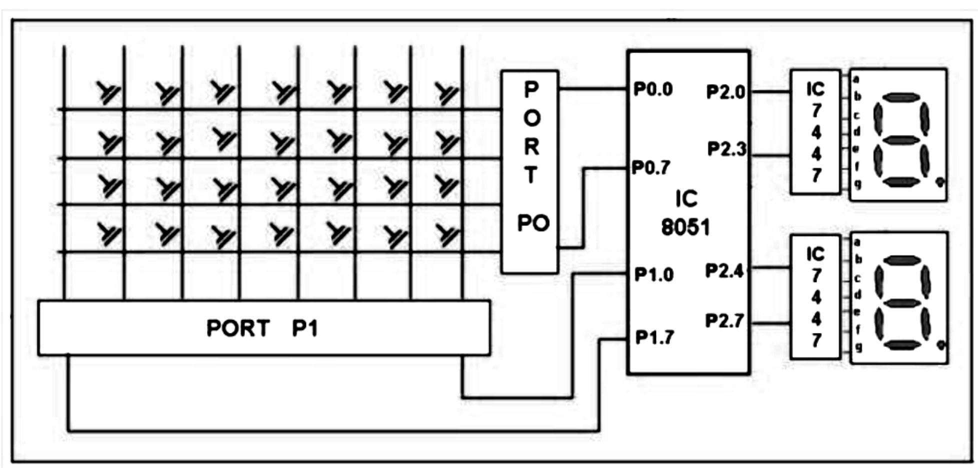
- In the above program, port A is initialized as the output port for sending the digital data as input to DAC. The ramp starts from the 0V (analog), hence AL starts with 00H.
- To increment the ramp, the content of AL is increased during each execution of loop till it reaches F2H. After that the saw tooth wave again starts from 00H, i.e. 0V(analog) and the procedure is repeated.
- The ramp period given by this program is precisely 1.000625 ms. Here the count F2H has been calculated by dividing the required delay of 1ms by the time required for the execution of the loop once.
- The ramp slope can be controlled by calling a controllable delay after the OUT instruction.

Keyboard Interfacing

Interfacing the Keyboard to 8051 microcontroller

The contents of the counter is then compared and displayed in the display. This display is designed using a seven segment display and a BCD to seven segment decoder IC 7447.

The BCD equivalent number of counter is sent through output part of 8051 displays the number of pressed key.



Block Diagram of Keyboard Interfacing

Keyboard is organized in a matrix of rows and columns as shown in the figure. The microcontroller accesses both rows and columns through the port.

1. The 8051 has 4 I/O ports P0 to P3 each with 8 I/O pins, P0.0 to P0.7,P1.0 to P1.7, P2.0 to P2.7, P3.0 to P3.7. The one of the port P1 (it understood that P1 means P1.0 to P1.7) as an I/P port for microcontroller 8051, port P0 as an O/P port of

microcontroller 8051 and port P2 is used for displaying the number of pressed key.

2. Make all rows of port P0 high so that it gives high signal when key is pressed.

3. See if any key is pressed by scanning the port P1 by checking all columns for non zero condition.

4. If any key is pressed, to identify which key is pressed make one row high at a time.

5. Initiate a counter to hold the count so that each key is counted.

6. Check port P1 for nonzero condition. If any nonzero number is there in [accumulator], start column scanning by following step 9.

7. Otherwise make next row high in port P1.

8. Add a count of 08h to the counter to move to the next row by repeating steps from step 6.

9. If any key pressed is found, the [accumulator] content is rotated right through the carry until carry bit sets, while doing this increment the count in the counter till carry is found.

10. Move the content in the counter to display in data field or to memory location

11. To repeat the procedures go to step 2.

Start of main program: to check that whether any key is pressed

```
start: mov a,#00h
mov p1,a ;making all rows of port p1 zero mov a,#0fh
mov p1,a ;making all rows of port p1 high
press: mov a,p2
jz press ;check until any key is pressed
```

after making sure that any key is pressed

```
mov a,#01h ;make one row high at a time mov r4,a
mov r3,#00h ;initiating counter
next: mov a,r4
mov p1,a ;making one row high at a time mov a,p2 ;taking input from port A
jnz colscan ;after getting the row jump to check column
mov a,r4
rl a ;rotate left to check next row mov r4,a
mov a,r3
add a,#08h ;increment counter by 08 count mov r3,a
sjmp next ;jump to check next row
```

after identifying the row to check the colomn following steps are followed

```
colscan: mov r5,#00h
in: rrc a ;rotate right with carry until get the carry jc out ;jump on getting carry
inc r3 ;increment one count jmp in
out: mov a,r3
da a ;decimal adjust the contents of counter before display
mov p2,a
jmp start ;repeat for check next key
```

INTERFACING STEPPER MOTOR WITH 8051

- A Stepper Motor is a brushless, synchronous DC Motor.
- It has many applications in the field of robotics and mechatronics.
- The total rotation of the motor is divided into steps.
- The angle of a single step is known as the stepper angle of the motor.
- There are two types of stepper motors **Unipolar** and **Bipolar**.
- Unipolar stepper motor is commonly used by electronics hobbyists.
- Stepper Motors can be easily interfaced with a microcontroller using driver ICs such as L293D or ULN2003.

Stepper motor Interfacing/Control using 8085 and 8051

Stepper Motor

A stepper motor is a device that translates electrical pulses into mechanical movement in steps of fixed step angle.

- The stepper motor rotates in steps in response to the applied signals.
- It is mainly used for position control.
- It is used in disk drives, dot matrix printers, plotters and robotics and process control circuits.

Structure

Stepper motors have a permanent magnet called rotor (also called the shaft) surrounded by a stator. The most common stepper motors have four stator windings that are paired with a center-tap. This type of stepper motor is commonly referred to as a four-phase or unipolar stepper motor. The center tap allows a change of current direction in each of two coils when a winding is grounded, thereby resulting in a polarity change of the stator.

Interfacing

Even a small stepper motor require a current of 400 mA for its operation. But the ports of the microcontroller cannot source this much amount of current. If such a motor is directly connected to the microprocessor/microcontroller ports, the motor may draw large current from the ports and damage it. So a suitable driver circuit is used with the microprocessor/microcontroller to operate the motor.

Motor Driver Circuit (ULN2003)

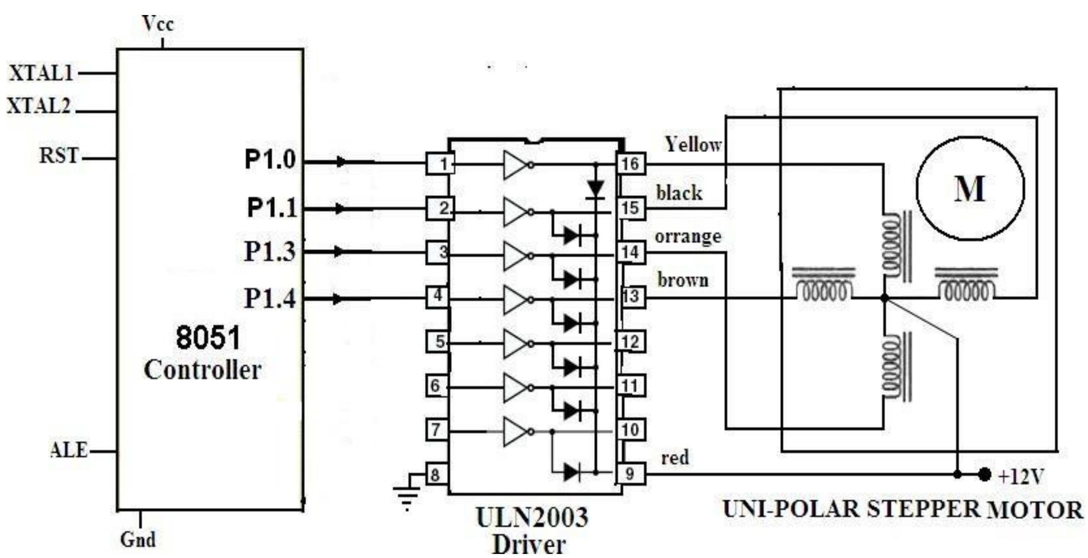
Stepper motor driver circuits are available readily in the form of ICs. ULN2003 is one such driver IC which is a High-Voltage High-Current Darlington transistor array and can give a current of 500mA.This current is sufficient to drive a small stepper motor. Internally, it has protection diodes used to protect the motor from damage due to back emf and large eddy currents. So, this ULN2003 is used as a driver to interface the stepper motor to the microcontroller.

Operation

The important parameter of a stepper motor is the step angle. It is the minimum angle through which the motor rotates in response to each excitation pulse. In a four phase motor if there are 200 steps in one complete rotation then then the step angle is 360/200 = 1.8^{O} . So to rotate the stepper motor we have to apply the excitation pulse. For this the controller should send a hexa decimal code through one of its ports. The hex code mainly depends on the construction of the stepper motor. So, all the stepper motors do not have the same Hex code for their rotation. (refer the operation manual supplied by the manufacturer.)

For example, let us consider the hex code for a stepper motor to rotate in clockwise direction is 77H , BBH , DDH and EEH. This hex code will be applied to the input terminals of the driver through the assembly language program. To rotate the stepper motor in anti-clockwise direction the same code is applied in the reverse order.

Stepper Motor interface- Schematic Diagram (for 8051)



The assembly language program for 8051 is given below.

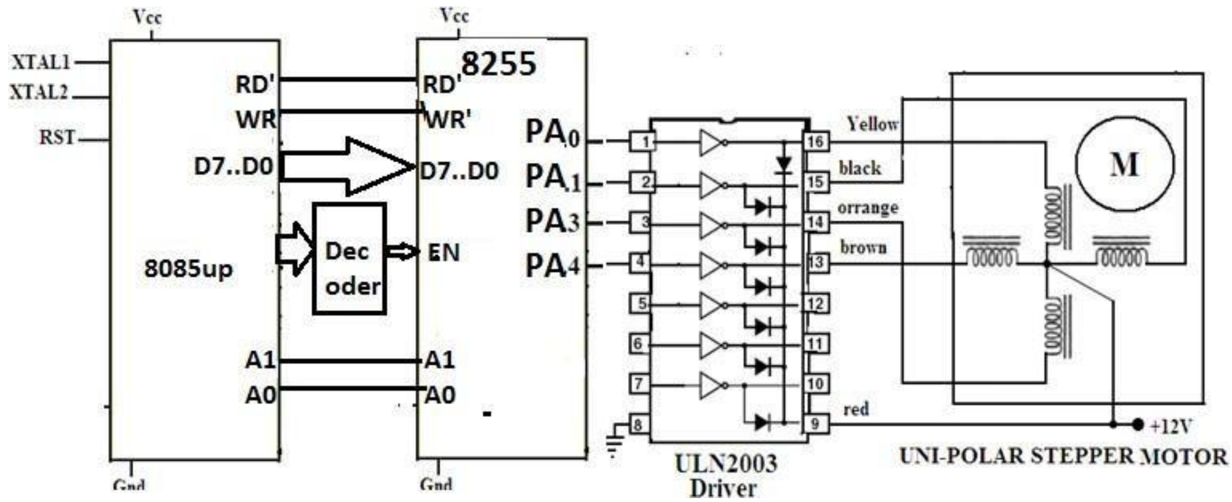
ASSEMBLY LANGUAGE PROGRAM (8051)

```
Main : MOV A, # 0FF H        ;  Initialization of Port 1
       MOV P1, A             ;
       MOV A, #77 H          ; Code for the Phase 1
       MOV P1, A             ;
       ACALL DELAY           ; Delay subroutine
       MOV A, # BB H         ; Code for the Phase II
       MOV P1, A             ;
       ACALL DELAY           ; Delay subroutine.
       MOV A, # DD H         ; Code for the Phase III
       MOV P1, A             ;
       ACALL DELAY           ; Delay subroutine
       MOV A, # EE H         ; Code for the Phase 1
       MOV P1, A             ;
       ACALL DELAY           ; Delay subroutine SJMP
       MAIN; Keep the motor rotating continuously.
```

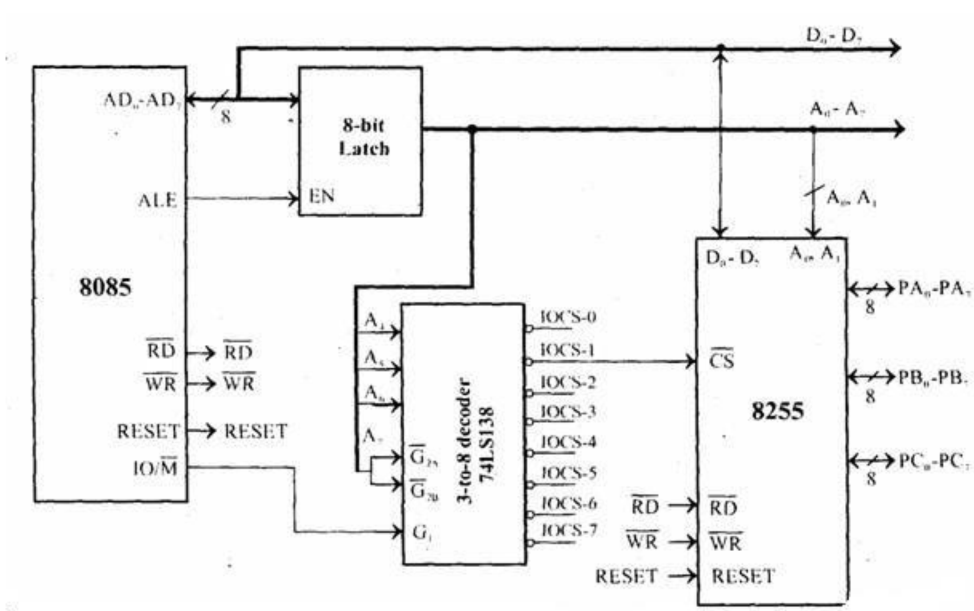
DELAY Subroutine

```
        MOV R4, #0FF H       ;  Load R4 with FF
        MOV R5, # 0FF        ; Load R5 with FF
LOOP1:  DJNZ R4, LOOP1       ; Decrement R4 until zero,wait
LOOP2:  DJNZ R5, LOOP2       ; Decrement R5 until zero,wait
        RET                  ; Return to main program .
```

Stepper Motor interface - Schematic Diagram for (8085)



Detailed Connection diagram between 8085 and 8255



ASSEMBLY LANGUAGE PROGRAM (8085)

```
Main    : MVI A, 80             ;  80H → Control word to configure PA,PB,PC in O/P
          OUT CWR_Address       ; Write control word in CWR of 8255
          MVI A, 77             ; Code for the Phase 1
          OUT PortA_Address     ; sent to motor via port A of 8255          ;
          CALL DELAY            ; Delay subroutine
          MVI A, BB             ; Code for the Phase II
          OUT PortA_Address     ; sent to motor via port A of 8255
          CALL DELAY            ; Delay subroutine.
          MVI A, DD             ; Code for the Phase III
          OUT PortA_Address     ; sent to motor via port A of 8255;
          CALL DELAY            ; Delay subroutine
          MVI A, EE H           ; Code for the Phase 1
          OUT PortA_Address     ; sent to motor via port A of 8255                    ;
          CALL DELAY            ; Delay subroutine
          JMP MAIN              ; Keep the motor rotating continuously.
```

DELAY Subroutine

```
          MVI C, FF             ; Load C with FF -- Change it for the speed variation
LOOP1:  MVI D,FF                ; Load D with FF
LOOP2:  DCR D
          JNZ LOOP2
          DCR C
          JNZ LOOP1
          RET                   ; Return to main program .
```

UNIT V
DESIGN OF MECHATRONICS SYSTEM

Stepper Motors

The stepper motor is a device that produces rotation through equal angles, the so called steps, for each digital pulse supplied to its input. Thus, for example, if with such a motor 1 pulse produces a rotation of 60 then 60 pulses will produce a rotation through 360º.

1. Variable reluctance stepper motor

In this type of motor the rotor is made of soft steel and is cylindrical with four poles, i.e., fewer poles than on the stator. When an opposite pair of windings has current switched to them, a magnetic field is produced with lines of force which pass from the stator poles through the nearest set of poles on the rotor.

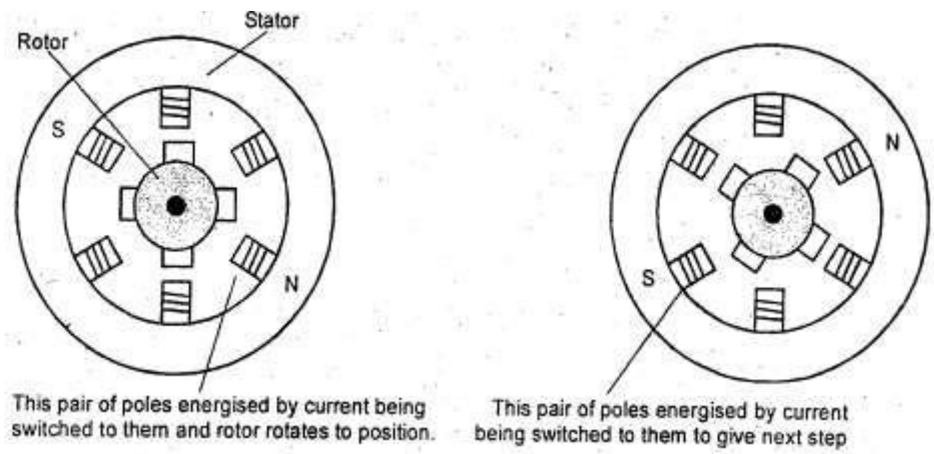


Figure 5.1: Variable reluctance stepper motor

Since lines of force can be considered to be rather like elastic thread and always trying to shorten them, the rotor will move until the rotor and stator poles line up. This is termed the position of minimum reluctance. This form of stepper generally gives step

2. Permanent magnet stepper motor

The permanent magnet stepper motor has a stator with four poles. Each pole is wound with a field winding, the coils on opposite pairs of poles being in series. Current is supplied from a D.C source to the windings through switches.

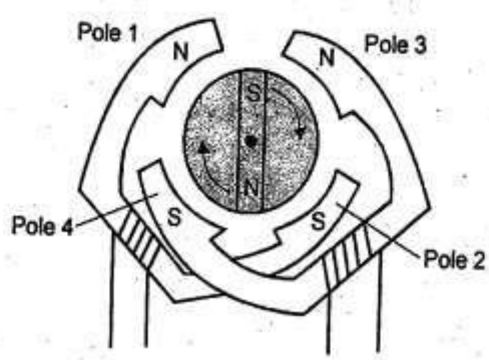


Figure 5.2: Permanent magnet stepper motor

The rotor is a permanent magnet and thus when a pair of stator poles has a current switched to it, the rotor will move to line up with it. Thus for the currents giving the situation shown in the figure the rotor moves to the 45° position.

If the current is then switched so that the polarities are reversed, the rotor will move a further 45° in order to line up again. Thus by switching the current through the coils the rotor rotates in 45° steps. With this type of motor, step angles are commonly 1.8°, 7.5°, 15°, 30° or 90°.

3. Hybrid stepper motor

Hybrid stepper motors combine the features of both the variable reluctance and permanent magnet motors, having a permanent magnet encased in iron caps which are cut to have teeth

The rotor sets itself in the minimum reluctance position in response to a pair of stator coils being energized. Typical step angles are 0.90º and 1.80º such stepper motors are extensively used in high-accuracy positioning applications, e.g. in computer hard disc drives.

Stepper Motor Control

Solid-state electronics is used to switch the d.c. supply between the pairs of stator windings. Two-phase motors, e.g. Figure, are termed bipolar motors when they have four connecting wires for signals to generate the switching sequence Such a motor can be driven by H circuits.

Phase A Phase B

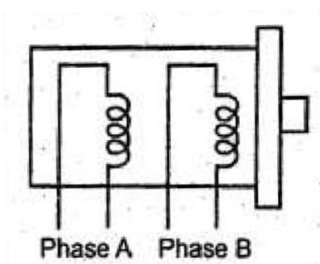


Figure 5.3: Bipolarmotor

Step	Transistors			
	1 and 4	2 and 3	5 and 8	6 and 7
1.	On	Off	On	Off
2.	On	Off	Off	On
3.	Off	On	Off	On
4.	Off	On	On	Off

Table: Switching sequence for full-stepping bipolar stepper

The sequence gives a clockwise rotation; for an anti-clockwise rotation the sequence is reversed. Half-steps, and hence finer resolution, are obtainable if instead of the full-stepping sequence needed to implement a pole reversal to get from one step to the next, the coils are switched so that the rotor stops at a position halfway to the next full step.

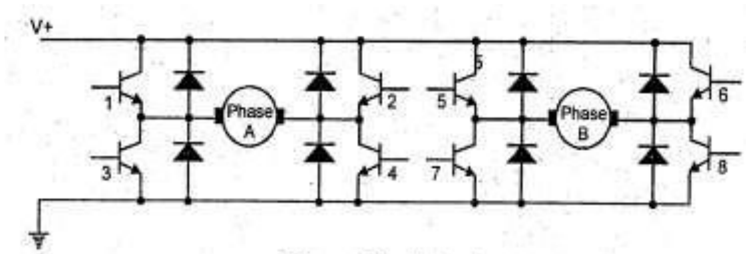


Figure 5.4: H circuit

Two-phase motors are termed uni polar when they have six connecting wires for the generation of the switching sequence. Each of the coils has a centre-tap, with the centre-taps of the phase coils connected together; such a form of stepper motor can be switched with just four transistors.

gives the switching sequence for the transistors in order to produce the steps for clockwise rotation, the sequence then being repeated for further steps. For anticlockwise rotation the sequence is reversed. Table shows the sequence when the unipolar is half-stepping. .

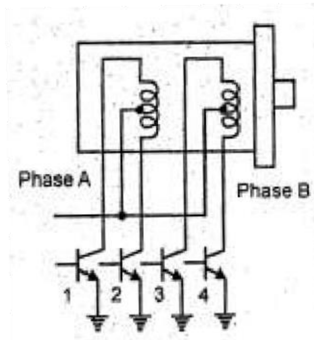


Figure 5.5: Unipolar motor

Some applications require very small step angles. While the step angle can be made small by increasing the number of rotor teeth and/or the number of phases, generally more than four phases and 50 to 100 teeth are not used. Instead a technique known as mini stepping is used.

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 involves an integration of the electronics and computing technologies with the mechanical system throughout the design process.

This mechatronic approach may be used to provide an 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. 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.

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. Shortly, 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 third 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 in early 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 are to be checked.

7. Production of working Drawings:

The selected design or solution is then translated into working drawings, circuit diagrams, etc. Drawings are also included the manufacturing tolerances for each component.

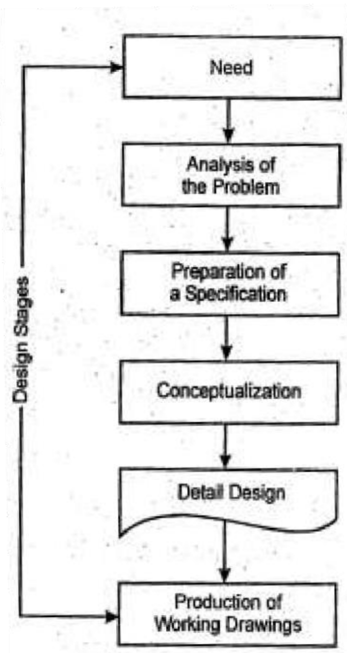


Figure 5.6: Stages in designing mechatronics system

Traditional and Mechatronics Designs

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.

For example

Timed Switch

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

a) Mechanical Solution

Timed switch uses a mechanical carn for this purpose. The rotating member (carn) of a system is rotating at a constant rate. Depend on the shape of the earn, the cam follower is used to actuate a switch for a period of time. The rotaly motion of the cam is conversed into reciprocating motion of the follower. Here, the pivoted flexible arm acts as a follower.

The main disadvantage in the mechanical system is that different earns are needed for different time periods.

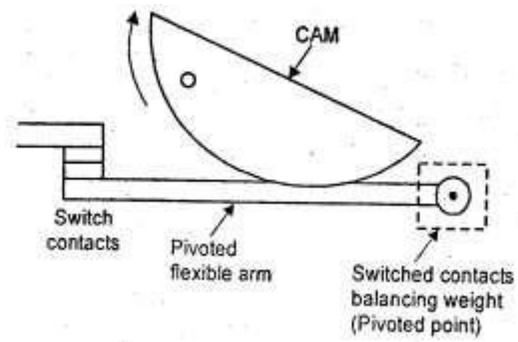


Figure 5.7: Timed switch

b) PLC Solution

The disadvantage of mechanical system may be avoided by PLC system which uses a timer preset values to ON/OFF the switch through program. The software solution is much easier to implement that the .hardware one. 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.

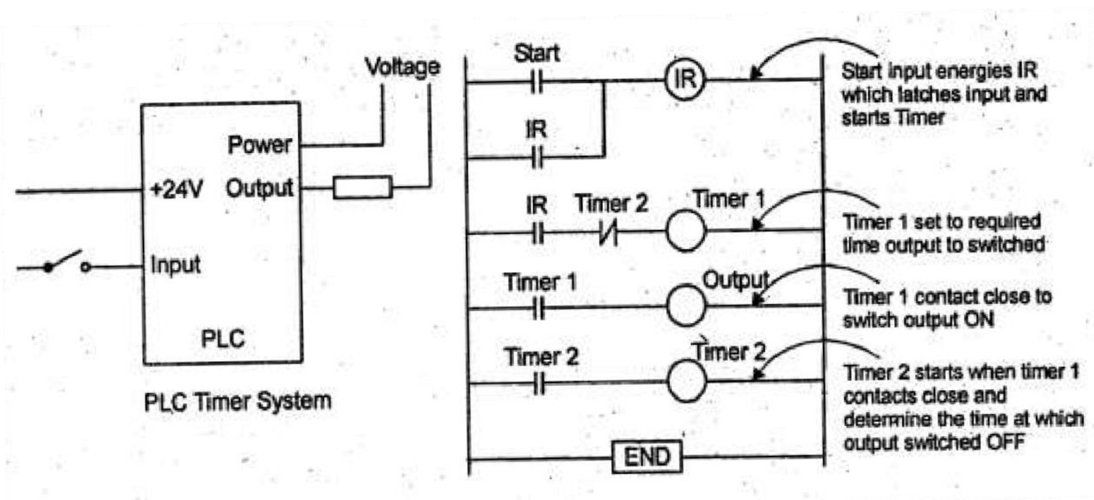


Figure 5.8: PLC ladder lodge

c) Microprocessor Solution

A microprocessor based solution consists of a microprocessor, I/O interfaces and a memory chip containing program. The program has a set of instructions for a microprocessor to switch an output for some time delay and then turn to off. The time delay is produced by a block of program which contains the timing loop. This cycle is repeated by changing the value in timing loop to have a required time delay.

d) Solution through 555 Timer IC Module

This system used a microprocessor with a 555 Timer IC module. The external resistors and capacitors are used to set the timing intervals in 555 timers. When the circuit is triggered with input, the output is turned 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 IKΩ to IMΩ and correspondingly C varies from 0.1 μF to 10μF. 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 10 S. If more time delay is required about from 16ms to days, 555 timer is replaced with ZNI034E timer.

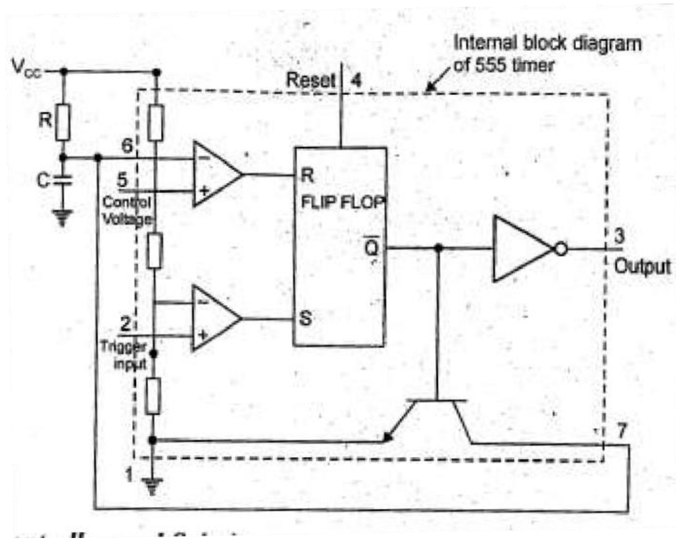


Figure 5.9: 555 timer with IC module

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.

a) Mechanical solution

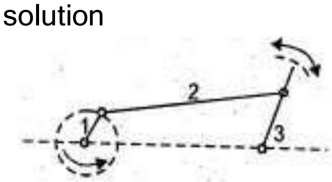


Figure 5.10: Wind Screen- Wiper Motion

It works like a four bar mechanism, when the crank rotates, the arm 1 rotates. This makes the arm 2 to oscillate the arm 3.

b) Mechatronics Approach

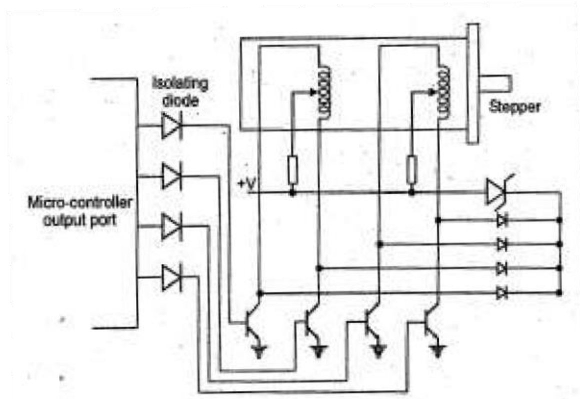
The mechatronics approach uses a stepper motor with microprocessor for controlling it. The input to the stepper is required to cause it to rotate a number of steps in one direction and then reverse to rotate the same number of steps in other direction.

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

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 sequence is 6, 5, 9, A and then back to 6.



STEP	BIT 3	BIT 2	BIT 1	BIT 0	CODE
1	1	0	1	0	OA
2	1	0	0	1	09
3	0	1	0	1	05
4	0	1	1	0	06
1	1	0	1	0	0A

Figure 5.11: Full step Configuration

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 sequence is 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	OA
2	1	0	0	0	08
3	1	0	0	1	09
4	0	0	0	1	01
5	0	1	0	1	05
6	0	1	0	0	04
7	0	1	1	0	06
8	0	0	1	0	02
9	1	0	1	0	OA

Figure 5.12: Half step Configuration

For this, the program steps are

For many time to oscillate the arm, a counter to increment with each step and loop until the counter value reaches the required number.

1. Advance a step
2. Jump to time delay routine to give time for the step to be completed
3. Increment the counter

4. Loop or Repeat the above with Successive steps until the counter indicates the requested number of steps completed in forward direction.

5. Reverse the direction

6. Repeat the above for the same number of steps in reverse direction

Bathroom Scales

Consider the design of a simple weighing machine i.e., Bathroom scales. It is a device which is used to indicate the weight of a person standing on it. The main 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.

Mechanical Solution

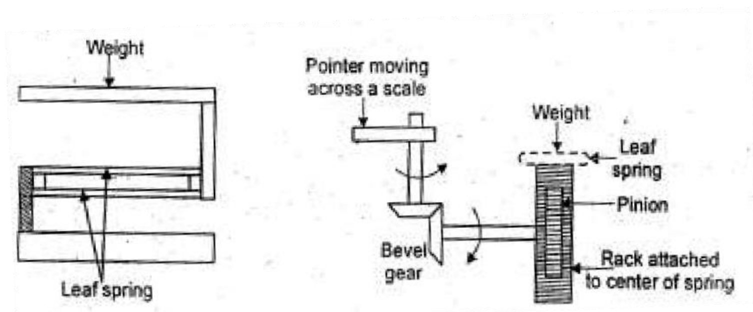


Figure 5.13 Mechanical solution for bathroom scales

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.

a) Mechatronics Solution

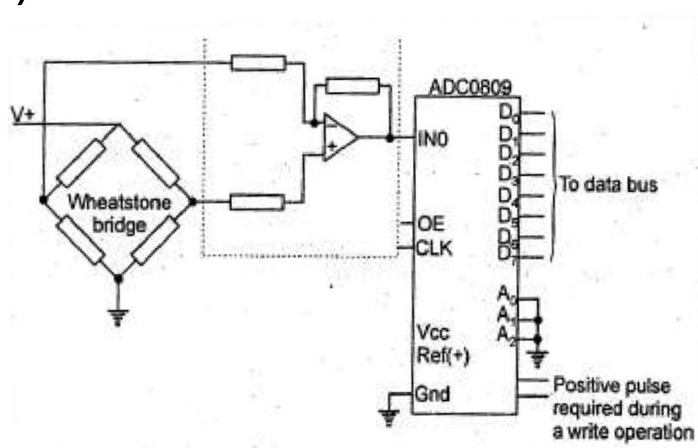


Figure 5.14 Mechatronics Solution for bathroom scales

The mechatronics solution uses a microprocessor for this problem. The platform can be mounted on load cells 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 analog 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 display. 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. The program structure may be

1. Clear LED and memory and initialize them.
2. Check whether the person standing on the scale or not. If not display 000
3. If yes, i) Get the data i.e., weight
    ii) Convert weight data into suitable form
    iii) Send data to decoder through output ports and LED Display
    iv) Introduce time delay to retain the display
4. Repeat the same steps again and again.

Case Studies of Mechatronics Systems

Mechatronics systems are widely used now-a-days in many industries. Some of the example outlines are given below.

A Pick and Place robot

Figure 10.6 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.

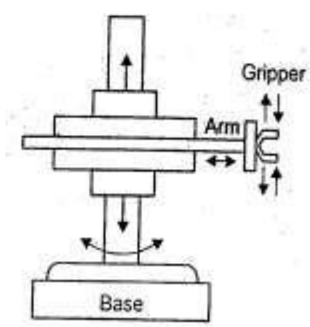


Figure 5.15: Pick and Place Robot

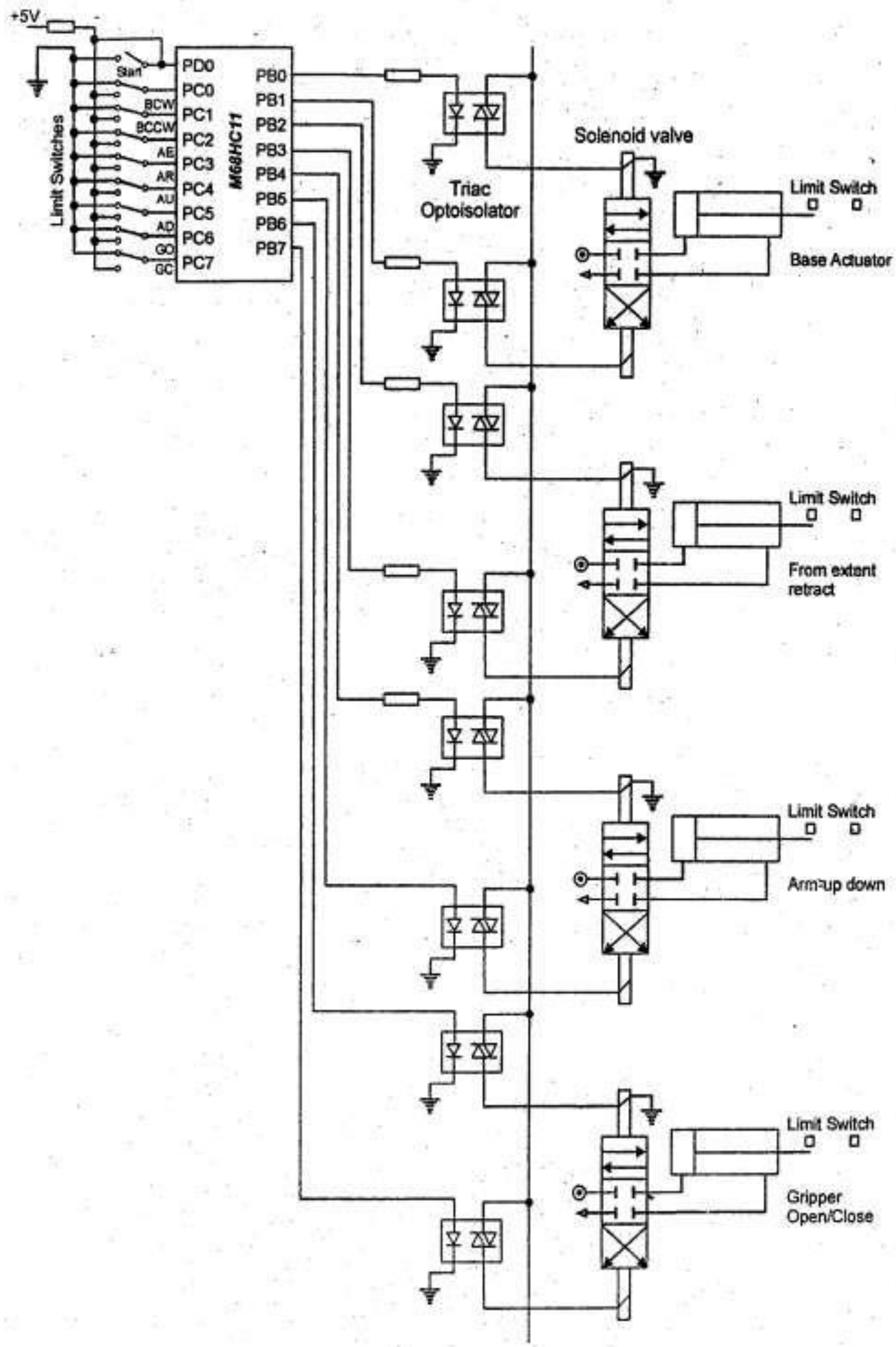


Figure 5.16: Pick and Place Robot

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 valves 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. Figure 5.11 shows the micro controller used to control the solenoid values and hence the movements of the robot unit.

The type of microcontroller used in M68CII. A software program is used to control the robot.

TRIAC opto isolator consists of LED and TRIAC. For example, when the base has to rotate in clockwise direction, a high signal is sent through line.

The diode is forward biased and the TRIAC opto isolation operates, regulating the supply to the solenoid value which in turn operated the piston rod of the pneumatic cylinder.

The base clockwise continues the rotation till it reader the position of second limit switch.

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.

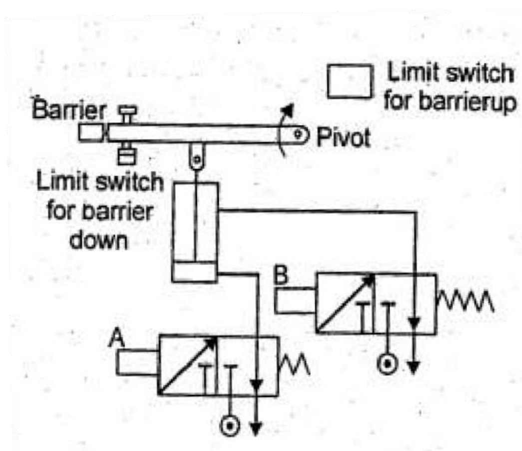


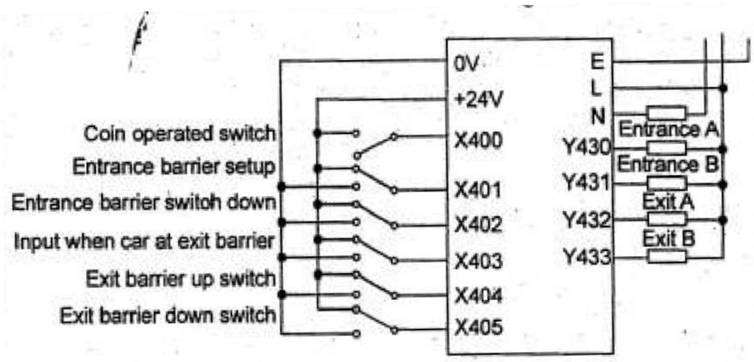
Figure 5.17: Automatic Car Park System

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 and causes the barrier to get down. Limit switches are used to detect when the barrier is down and also when fully up.



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

Figure 5.18: Automatic Car Park System

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 a switch 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.

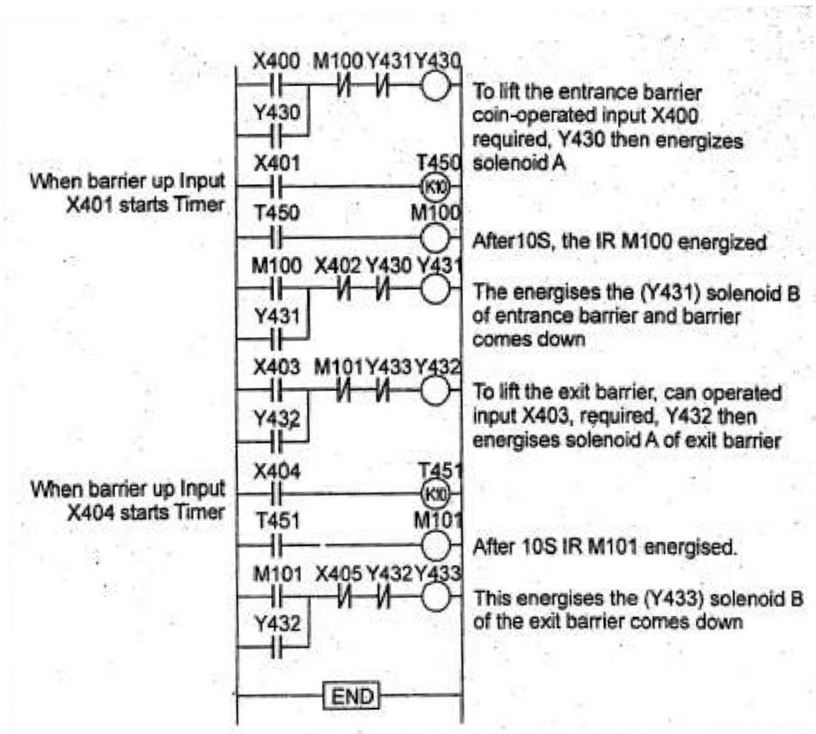


Figure 5.14: Automatic Car Park System

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 Generalised block diagram of an Engine management system is shown in figure below.

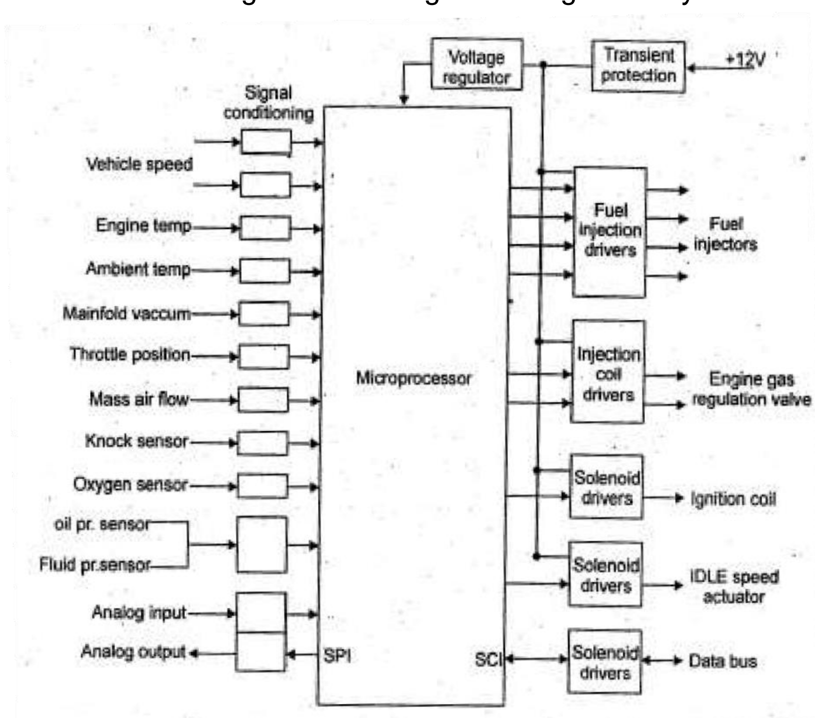


Figure 5.15: Engine Management System

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 fuelling requirements of the engine.

The power and speed of the engine are controlled by varying the ignition timing and the Air-fuel mixture. In modern 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-fuel 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 supply input signals to the microprocessor after suitable signal conditioning and provides output signals via drivers to actuate corresponding actuators.

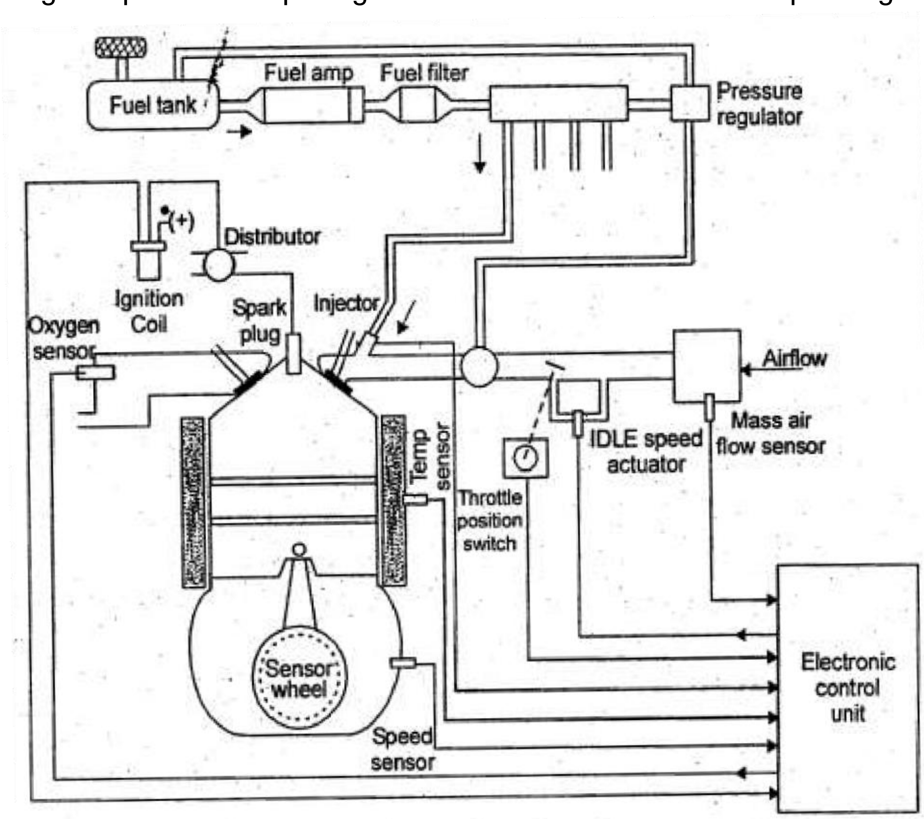


Figure 5.20: Engine Management System

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 Anenometer:

Hotwire Anenometer 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 become permeable to oxygen ions so that a voltage will be produced between the electrodes.

The various drivers such as fuel injection drivers, ignition coil drivers 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.