INTRODUCTION TO MECHATRONICS

Definition and Evolution Level of mechatronic:-

The synergistic combination of precision mechanical engineering, electronic control and systems thinking in the design of products and manufacturing processes.

or

Integration of electronics, control engineering and mechanical engineering.

→ mechatronics involves a number of technologies such as:-

1. mechanical engineering;
2. Electronic engineering;
3. Electrical engineering;
4. computer technology;
5. control engineering

This can be considered to be the application of computer based digital control techniques through electronic and electric interfaces to mechanical engineering problem.

ADVANTAGES AND DISADVANTAGES OF MECHATRONICS :-

ADVANTAGES :-

1. The products produced are cost effective and of very good quality.
2. The performance characteristics of mechatronics products such which are otherwise very difficult to achieve without the synergistic combination.
3. High degree of flexibility.
4. A mechatronic product can be better than just sum of its parts.

5. Greater extent of machine utilisation.
6. Due to the integration sensors and control systems in a complex system, capital expenses are reduced.
7. Owing to the incorporation of intelligent, self correcting sensory and feedback system, the mechatronic approach results in:
   → greater productivity;
   → higher quantity and producing reliability;

DISADVANTAGES:-

1. High initial cost of the system.
2. Imperative to have knowledge of different engineering fields of design and implementation.
3. Specific problems for various system will have to be addressed separately and properly.
4. It is expansive to incorporate mechatronics approach to existing/old system.

Applications of mechatronics:-

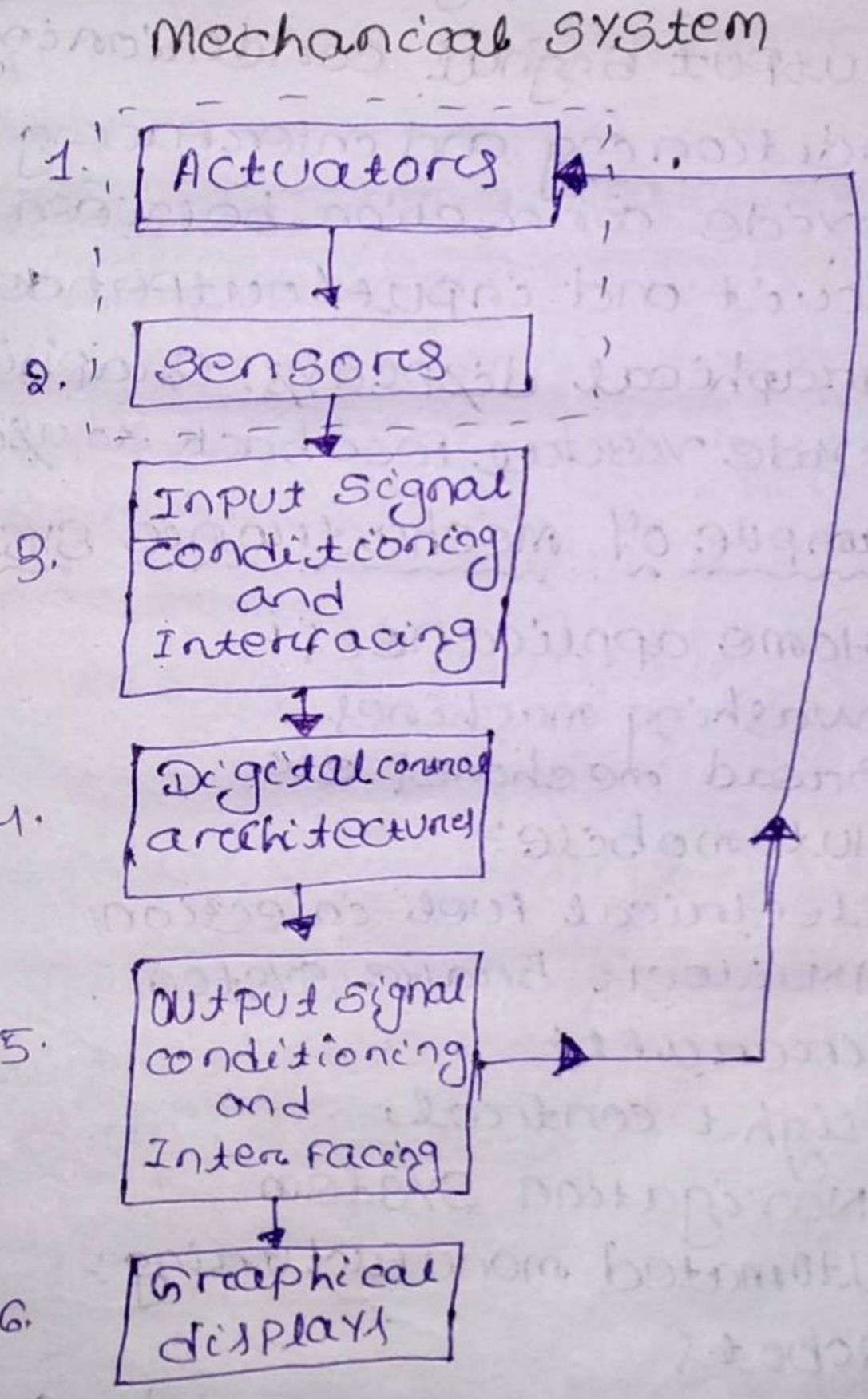
1. Automotive mechanics.
2. Fax and photocopier mechanics.
3. Dish washers.
4. Air conditioners, elevator controls.
5. Automatics washing machines.
6. Flexible manufacturing systems.
7. Document scanners.
8. Integrated circuits manufacturing systems.
9. VCRs and CD players
10. Robotics employed in welding, nuclear inspection etc.

Scope of mechatronics in industrial Sector:

1. Better design of products.
2. Better process planning.
3. Reliable and quantity-oriented manufacturing.
4. Intelligent process control.

Components of a mechatronic system:-

The term mechatronic system encompasses a myriad of devices and systems.



1. Actuators:- The actuators produce motion or cause some action.

Ex:- Solenoids, voice coils, dc motors, stepper motors, servo motor, hydraulic

2. Sensors:- The sensors detect the state of the system parameters, input and output.

EX:- Switches, Potentiometers, Digital encoders, Strain gauge, Thermocouple

3. Input signal conditioning and interfacing:-
EX:- Discrete circuits, Amplifiers, Filters, A/D, D/D

4. Digital control Architectures:- Digital devices control the system.
EX:- Logic circuits, microcontroller, SBC, PLC, control algorithms, communication.

5. output signal conditioning and interfacing:-
conditioning and interfacing circuits provide connection between the control circuit and input/output devices.

6. Graphical displays:- Graphical displays provide visual feedback to users.

Example of mechatronic system:-

1. Home appliances:-
- washing machines
- Bread machines etc

2. Automobile:-
- Electrical fuel injection
- ANtilock brake system

3. Aircraft:-
- Flight controls,
- Navigation System.

4. Automated manufacturing:-
- Robots
- Numerically controlled (NC) machine tool.

copy machine :- Example of mechatronic system.

Major components :-

(i) Analog circuits :
- controlling lamps.
- Heaters.

(ii) Digetial circuits.
- control digit dilplays.
- Indicator lights
- Buttons
- Switches.

(iii) Microprocessor - co-ordinates all of the functions in the machine.

(iv) Servo and stepper motors - Loading and transporting the paper, turning the drum and indexing the sorter.

copying process:

An original in a loading bin
↓
scanning
↓
metal drum with charge distribution
↓
The paper from a loading cartidge with an electrostatic deposition of link tone powder
↓
Heated the paper
↓
delivered the copy to an appropriate bin by a sorting mechanism.

{ ELEMENTS OF CNC MACHINES }

Introduction to numerical control of machine and CAD/CAM :-

NC machines :- NC Machines assimilate a method of automation, where automation of medium and small volume production is done by some controls under the instructions of a program the definition of NC (Numerical control) as given by EIA (Electronic industries Association) is as under.

"A system in which actions are controlled by the direct insertion of numerical data at some point. The system must automatically interpret at least some portion of this data."

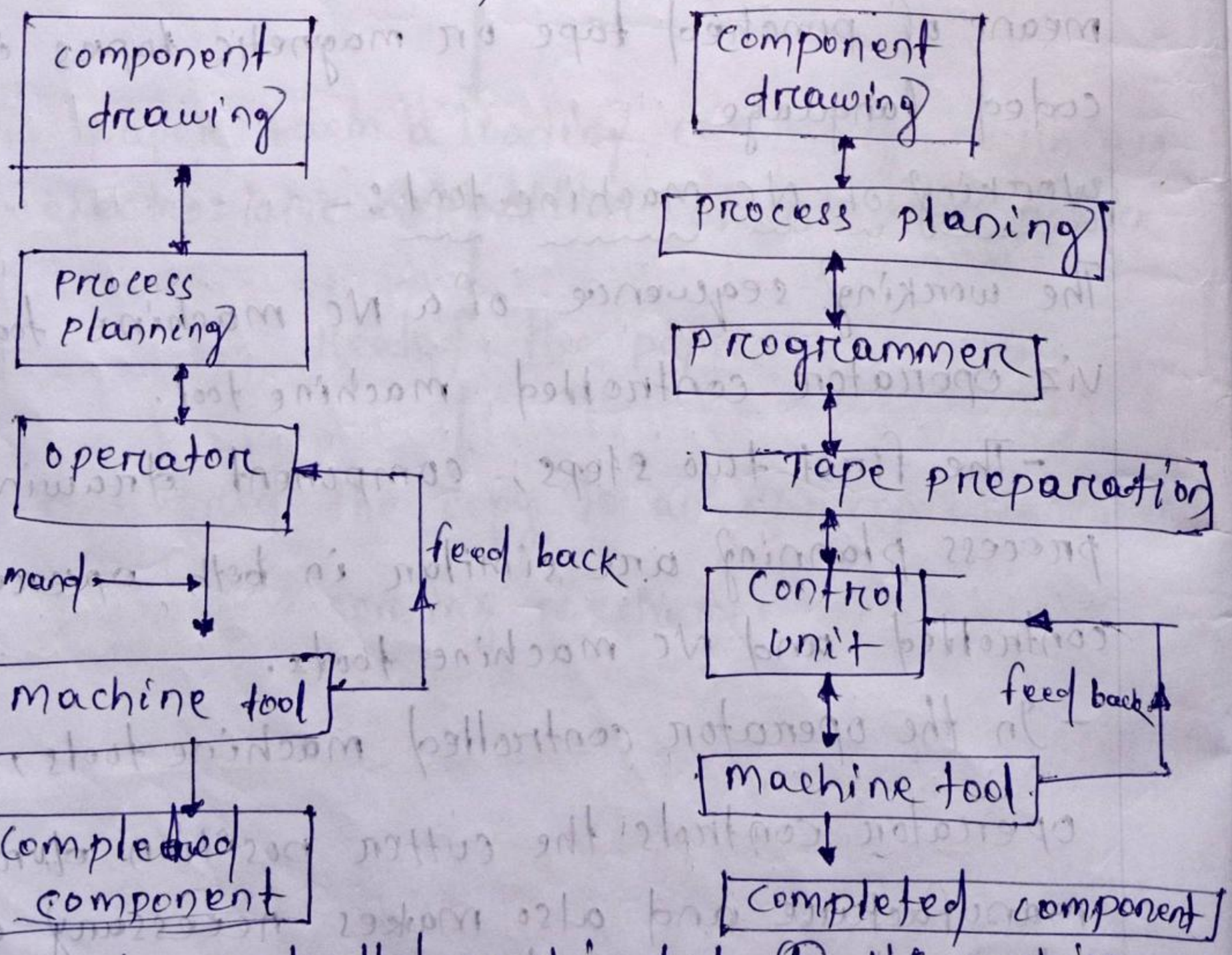
In NC machines, the input information for controlling the machine tool motion is provided by means of punched tape or magnetic tapes in a coded language.

Working of NC machine tool :-

The working sequence of a NC machine tool viz-a-viz operator controlled machine tool.

- The first two steps, component drawing and process planning are similar in both operator controlled and NC machine tools.
- In the operator controlled machine tools, the operator controls the cutter position during manufacture and also makes necessary adjustments and corrections to produce the desired compont

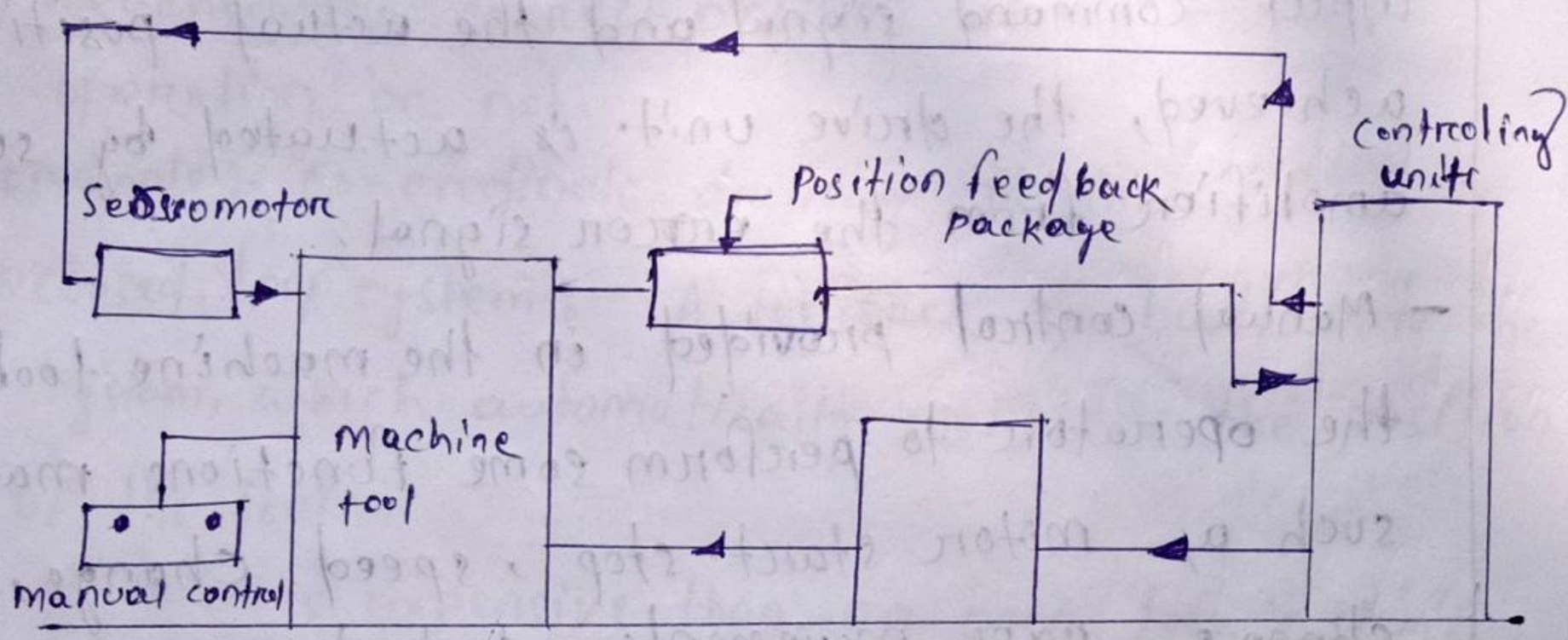
- However, in NC machine tool the operator is replaced by the data processing part of the system and the control unit.
- In the data processing unit, the co-ordinate information regarding the component is recorded on a tape by means of a teleprinter.
- Tape is fed to the control unit which sends the position command signals to sideway transmission elements of the machine. At the same time, the command signal is constantly compared with the actual position achieved, with the help of position feedback signal derived from automatic monitoring of the machine tool slide position. The difference in two signals, if any, is corrected until the desired component is produced.



(a) operator controlled machine tool (b) NC machine tool.

Main elements of a NC machine tool :-

① The control unit (also known as NC ~~machine tool or~~ console or director).
② The drive units.
③ The position feedback package.
④ Magnetic box.
⑤ manual control.



Main elements of a NC machine.

- In the control unit, a tape recorder reads the instructions (written in a coded language) for manufacturing the component.
- The instructions under electronic processing and the control unit sends command signals to the drive units of the machine tool and also to the magnetic box (Electrical control cabinet). command singnals sent to the drive units of the machine tool, control the length of travel and feed rate, while the command signals sent to the magnetic box control other functions such as spindle motor starting and stopping selecting

spindle speeds, actuation of tool change, coolant supply etc.

- A feed back transducer provided in the machine tool checks whether the required lengths of travel have been obtained. It sends the information of the actual posisition achieved to the control unit. In case there is any difference between the input command signal and the actual position achieved, the drive unit is actuated by suitable amplifier from the error signal.
- Manual control provided in the machine tool assist the operator to perform some functions manually such as motor start-stop, speed change, feed change, axes movements, coolant supply etc.

classification of NC machines :-

A). According to control system.

① . Point-to-point system :- The machining is done at specific positions.

Example :- ~~stepped turning on lathe, pocket milling ect~~. Drilling machine operation

② Straight line system :- It is an extension of point to point system.
Ex:- stepped turning on lathe, pocket milling etc.

③ Contour system :- There are continuous, simultaneous and co-ordinated motions

of the tool and workpices along different coordinate axes.

Ex:- machining of profiles, contours and curved surfaces.

(B) According to feed back :-

① open loop system :- There on 'feedback' and on return signal to indicate whether the tool has reached the correct position at the end of operation on not.

Example :- co-ordinate drilling machine.

② closed loop system :- A feedback is built in to the system, which automatically monitors the position of the tool.

It is more expensive than an open loop system.

Applications of NC Machines :-

The major applications of NC Machines are :-

① complex parts.

② parts which are frequently subjected to design changes.

③ Repetitive and precision quality parts which are to be produced in low to medium batch quantity.

④ To cut down lead time in manufacture.

⑤ In situations where the investment on tooling and fixture inventory will be high if parts were made on conventional machines tools.

Advantages of NC machines :-

① Accuracy achived is of high order.
② Reduced production cost per piece.
③ Less scap.
④ High production rate.
⑤ Less operator skill required.
⑥ Excellent reliability.
⑦ Tooling cost low.
⑧ Less cycle time and increased tool life.
⑨ Increased flexibility.
⑩ Production of complem parts.
⑪ Reduced set-up time.
⑫ Elimination of special jigs and finturues.
⑬ ~~Elimination of special jigs and fintures~~
⑬ Reduced inspection.
⑭ Lower labour cost.
⑮ Reduced floor space.
⑯ Easy and effective production planning.

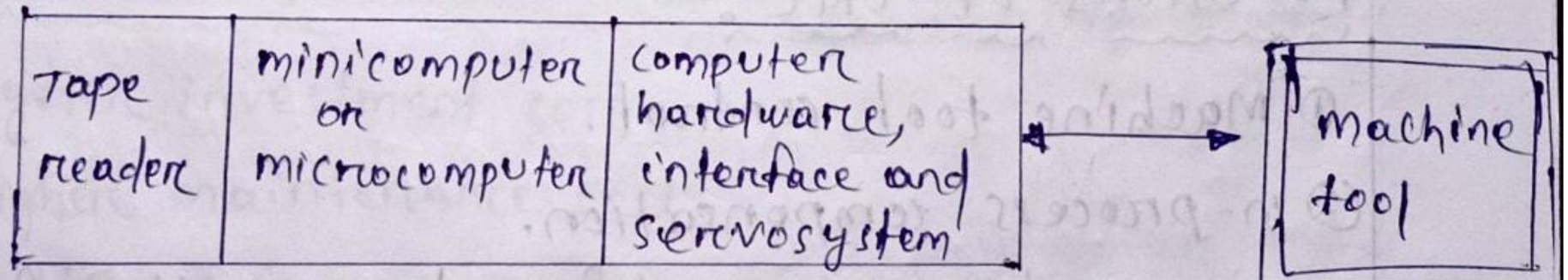
CNC Machines :-

In a CNC machine, a mini computer is used to control machine tool functions from stored in information on punched tape input or computer terminal input.

The definition CNC (computer Numerical control) as given by EIA is as under: "The numerical control system where a dedicated, stored program computer is used to perform some or all of the basic numerical control functions in accordance with control programmes stored in read/write memory (RAM) of the computer".

CNC may also be defined as: "An NC system with a microcomputer or microprocesson using software to implement control algorithms.".

The control unit and panel of a CNC. The following points about CNC machines are worth nothing.



computer Numerical system (CNC).

- The control unit and a panel of CNC differs from that of NC controls in that, it works in ON-line mode whereas NC works in batch processing mode.
- A typical CNC may need only the drawing specifications of a part to be manufactured and the computer automatically generates the part program for the loaded part.
- The part program once entered into the

computer memory can be used again and again.
- The input information can be reduced to a great extent with the use of special sub-programs developed for repetitive machining sequences.
- The CNC machines have the facility for proving the part program without actually running it on the machine tool.
- CNC control unit allows compensation for any changes in the dimensions of the cutting tool.
- With CNC control systems, it is possible to obtain information on machine utilisation which is useful to the managements.

Functions of CNC :-

① Machine tool control.
② In-process compensation.
③ Improved programming and operating features.
④ Diagnostics.

Advantages of CNC machine :-

① Greater flexibility
② Increased productivity
③ Reduced data reading error.
④ Consistent quality.
⑤ Automatic material handling.
⑥ Elimination of operator errors.
⑦ Reduced operator activity.
⑧ Lower labour cost and smaller batches.

⑨ Longer tool life.
⑩ just-in-time (JIT) manufacture.
⑪ Reliable operation.
⑫ Elimination of special jigs and fixtures.
⑬ Reduced inspection.
⑭ less scrap.
⑮ Accurate costing and scheduling.
⑯ CNC machine can diagnose program and can detect the machining malfunctioning even before the part is produced.
⑰ conversion of units - possible within computer memory.

Disadvantages of CNC Machines :—

① Higher investment cost.
② Higher maintenance cost.
③ costlier CNC personnel.
④ Airconditioned places are required for the installation of the machines.
⑤ unsuitable for long run applications.
⑥ Planned support facilities.

Applications of CNC :-

- Drilling machines.
- Turning machines.
- Boring machines.
- milling machines.
- Grinding machines.

- pipe bending machines.
- coil winding machines.
- flame cutting machines.
- welding, wire cut EDM and several other areas.

CAD / CAM :-

CAD/CAM (computer - Aided design / computer - Aided manufacture) technology was comitiated in the ~~apet~~ aprospace industry but presently it is spreading at a rapid pace in all industries.

It can be defined most simply as the use of computers to translate a product's specific ~~equi~~ requirements in to the final physical product.

Following points are worth nothing about CAD/CAM technology :-

- with this system, a product is designed, produced and inspected in one automatic process.
- It plays a key role in areas such as design analysis, production planning, detailing, ~~doca~~ documentation, N/C part programing, tooling fabrication, assembly, j'ig and fixture design, quality control, and testing.
- whenever any deviation is noted, a programmable controller takes automatic corrective action to compensate for the deviation. Thus a

closed loop system is formed which produces consistent quality products, reduces wastes and improves productivity.

- CAD/CAM system is ideally suited for designing and manufacturing mechanical components of free form complex with threee dimensional shapes.

CAD

Definition:- In the modern sense, CAD (Computer Aided Design) is defined as:-

"A design process using sophisticated computer graphics techiques, backed up with computers software packages to aid in the analytical, development, costing and ergonomic problems associated with design work".

Advantages:-

① Drawings can be produced at a faster rate.
② Drawings produced by CAD systems are more accurate and neat.
③ In this system there is no repetition of the drawings.
④ CAD systems assimilate several special draughting techniques which are not available with conventional means.
⑤ Design calculations and analysis can be carried out quickly.
⑥ With CAD systems superior design forms can be produced.
⑦ CAD simulation and analysis techniques can

drastically cut the time and money spent on prototype testing and development - often. the costliest stage in the design process.

⑥ Using CAD systems design can be integrated with other disciplines.

CAM

General aspects :-

CAM (computer-Aided manufacture) concerns any automatic manufacturing process which is controlled by computers.

The most important elements of CAM are:-

① CNC manufacturing and programming techniq
② computer controlled robotics manufacture and assembly.
③ flexible manufacturing systems (FMS).
④ Computer Aided Inspection (CAI) techiniques.
⑤ Computer Aided testing (CAT) techniques.

Advantages :-

① Product obtained is superior in quality.
② The manufactured form has a greater versatility.
③ Higher production rates with lower workforces.
④ There is less likelihood of human error.
⑤ As a result of increased manufacturing efficiency cost savings are materialised.

Software and hardware for CAD/CAM:-

The functions of CAD/CAM systems are mainly determined by the software. Software usually consists of a number of separate application packages to perform the desired function. The size of computer depends on the number and sizes of packages and number of work stations.

Hardware:-

Hardware is responsible for the reliability and speed of response of the system. A wide range of standard software is available and generally it is not worth developing users own software. Though a system can be built up from standard software packages from different sources and standard hardware, it is often costly because of the considerable programming effort required to interface the packages to a common data base to provide user frindly software to adapt the system to the user's requirements. It is thus advisable to adopt turn key system for turn key suppliers.

Functioning of CAD/CAM system:-

- CAD/CAM is an interactive computer graphic tool that enhances design and manufacturing functions to creat a highly profitable product. This technique is being applied by big industries for

improving overall manufacturing performance.

- It is not a standard tool which can be fitted into any company but has to be tailored to suit the needs of the company. It is rather complex technolo and has wide potential for immediate benefits.
- Usually this tool consists of a dedicated compute which is connected to a number of work-stations. The system is used to assist in the design and manufacturing, through the use of an expandable set of linked software modules. A designer can define dimensions and display views of 2 dimensions, $2\frac{1}{2}$ dimensions and 3 dimensions parts or modules. It is possible to generate the families of part directly by a parametric processor either by direct scaling or using a catalogue of subprograms. From the geometric definition a solid model can be constructed, to assist in visualisation. It is possible to store ~~model can be constructed, to assist in~~ v. complete details of designs on numerical control types for subsequent use on demand. Bench making tests are carried out to ensure system's capability.

Features and characteristics of CAD/CAM systems :-

① A major portion of the output of the engineering sector involves batch production and CAD/CAM offers immense cost and quality benefits for such requirements.

② The work-in-progress, in batch production, is reduced considerably.

③ It is possible to produce at random all the variants and series of a product planned to be manufactured by a firm.

④ Such a system has inherent flexibility to cater to new models of the product in pipeline without major modification.

⑤ In such a system, several machining centres are arranged one after the other with robots and proper automatic materials handling equipment. Software is developed ~~robots and proper automatic materials h~~ to integrate the machine CNC control and the handling system. Each machining centre is equipped with several tool magazines. All the tools required to complete each operation on each model of the product can be stored in the magazine.

⑥ All the part programs for the different models are stored in the memory. System has only to identify the model of the product presented to a machine in order to complete the

machining operations. Thus it is possible to have totally random mixes of models of a product proceeding down the line at any one time.

⑦ The system can be conceived in multiples of 15-20 minutes operations. if certain operations take longer, then multiples of similar machines can be installed in the line. Sometimes identical machines are introduced for each operation so that production can continue even if one machine goes down.

⑧ - The components are loaded on to a pallet. Means are provided to identify the exact model.

- Loaded pallets enter the line and wait at the start of the line until a signal that one of the first operation machines is vacant is obtained.
- The handling system automatically directs the pallet to the first vacant machine for first operation.
- The pallets are loaded on a finture. The finture is designed so that it permits access to all four sides and end faces and wherever machining operation is required. The pallets are designed to have windows where access for machining is required.

- As the pallet enters the machining area, air blast clears both the finture and pallet locations. The finture is then properly clamped and supported. Touch trigger probes are used to check its location in the pallet.
- Tenders and estimates can be quickly produced to high quality.

Application areas for CAD/CAM :-

① Design and design analysis :-

- CAD system would be best suited for drawing offices where frequent modifications are required on drawing and several parts repeat.
- It must be remembered that it is very easy with computer to make modifications and very fast to draw part profile once its details are fed into computer.
- once a drawing is entered in the CAD system, later modifications can be done quickly, and detail drawings can be prepared quickly from a general arrangement drawing.
- NC tapes can be produced.
- storing of the drawing is very convenient, easy, occoupies very less space and symbols ~~for of the~~ for electrical, hydraulic, control and instrumentation circuits can be called up quickly and positioned

on the schematic drawing.

- Standard components can be stored permenently in the data base and called up and positioned on the drawing, resulting in saving of time and enforcement of standards. It is possible to associate nongraphical information like part number, supplier, material etc, for any component assembly.
- It is very convenient to calculate properties like weight, centre of gravity, moment of inertia, etc, because 3-D models can be easily produced.
- It is also possible to carry out finite element analysis by producing meshing for analysis.

② Manufacture:-

- With CAD/CAM system the complete NC part programming process can be carried out interactively, including post processing and production of NC tape. Source programs in languages such as APT can be produced. Systems can verify tapes by producing tool centre path plots.

ELEMENTS OF CNC MACHINES :-

Introduction :- A computer numerically controlled (CNC) machine is a mechatronic system since the machine tool which is a mechanical system is

incorporated or integrated with the electronic controls for its different drives and computer system for interfacing the software with the mechanical and electronic system.

Hardware or electronic circuits control the motions of various drives. The design and construction of CNC machines differs greatly from that of conventional machine tools. This difference arises from the requirement of higher performance levels. The CNC machines often employ the various mechatronic elements that have been developed over the years. However, the quality and reliability of these machines depends on the various elements and subsystems of the machines.

The following are some of the important constituent parts, and aspects of CNC machines to be considered in their designing.

① Machine structure.
② Guideways / slideways.
③ Drives.
④ spindle and spindle bearings.
⑤ measuring systems.
⑥ Controls.
⑦ Gauging
⑧ Tool monitoring
⑨ swarf removel.
⑩ safety.

Machine structure :-

The "machine structure" is the load carrying and supporting members of the machine tool. The design and construction of CNC machine should be such that it meets the main "objectives" (i) High precision and repeatability, (ii) reliability (iii) Efficiency. In order to meet these requirements, the numerically controlled machine tools should have a structure with the following characteristics:

(1) It does not deform or vibrate beyond the permissible limits under the action of static and dynamic forces, to which it is subjected.

- static load of a machine tool results from the weights of slides and the workpiece, and the forces due to cutting.

(2) Its design should be such that the thermal distortion is minimum. The machine tool should be protected from external and internal heat sources; some of these heat sources are: Electric motor; friction in mechanical drives, gear boxes, bearings and guideways; machining process; temperature of surrounding objects.

- Thermal deformation due to thermal load may be reduced by :-

(i) Designing the structure thermo-symmetrically.

(ii) External mounting of drives.

(iii) Using a proper lubrication system for removing frictional heat from bearings and guideways.

(iv) Removing the coolant and swarf efficiently for the dissipation of heat generated from the machining process.

(3) The machine structure design should be such that the removal of swarf is easy and the chips etc, do not fall on the slideways.

Guideways / slideways :-

Introduction :- In machine tools the guideways are used to serve the following purpose :

(i) To control the direction or line of action of the carriage or the table on which a tool or a workpiece is held.

(ii) To absorb all static and dynamic loads.

The guideways may be an integral part of the machine structure or may be mounted separately on the structure. These guideways may be horizontal, vertical or inclined. However vertical and inclined guideways are preferred so that chips produced during the cutting operation do not get collected

on the quickways.

The shape and size of the work produced depends on the accuracy of the movement and kinematic accuracy of the guidway, kinematic accuracy depends on the straightness, flatness and parallelism errors in the guideway.

- In a CNC machine the design of guideway / slideway should :-

(i) Reduce friction,

(ii) Reduce wear,

(iii) satisfy the requirements of movement of the slides;

(iv) Improve smoothness of the drive.

Factors influencing the design of guideways :-

① Geometric and kinematic accuracy.

② Position in relation to work area.

③ Provision for adjustment of play.

④ Rigidity.

⑤ Damping capability.

⑥ velocity slide.

⑦ friction characteristics.

⑧ wear resistance.

⑨ Protection against swarf and damage.

⑩ protective guards to safeguard the guideways against accidental damages.

⑪ freedom for unnecessary restraints.

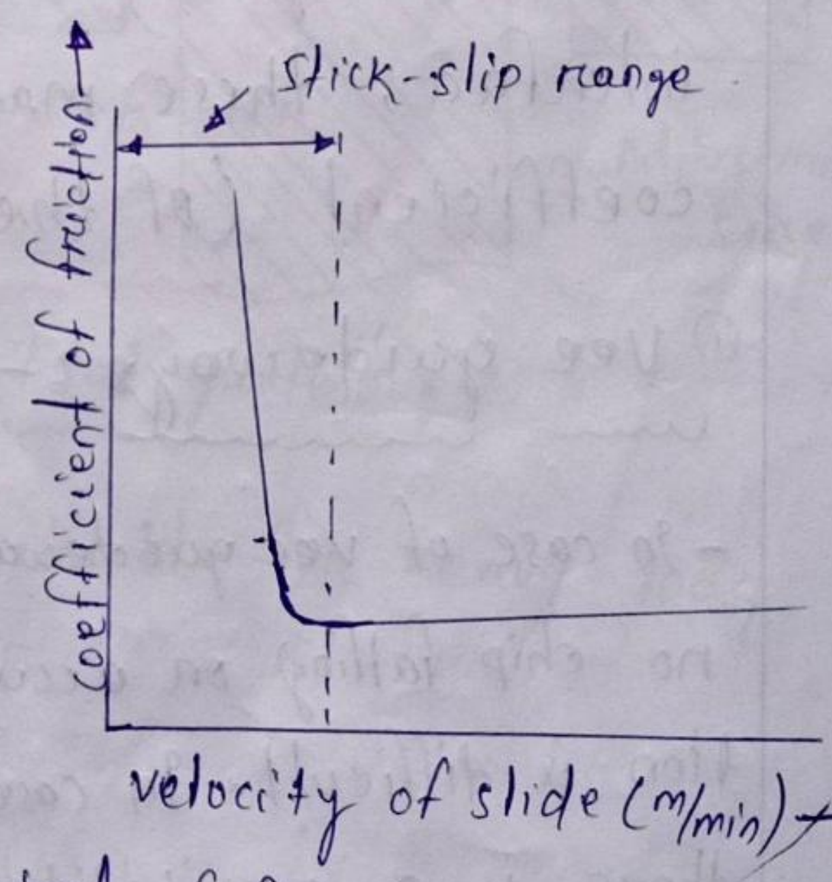
⑫ Effective lubrication and efficient lubrication systems.

Types of guideways :-

① friction guideways.
  ⊕ vee guideways.
  - flat guideways.
  - Dovetail guideways.
  - cylindrical guideways.
② Antifriction linear motion (LM) guideways.
③ frictionless guideways:
  (i) Hydrostatic guideways.
  (ii) Aerostatic guideways.

Friction guideways.

- These guideways find wide application in conventional machine tools due to their low manufacturing cost and good damping properties.
- They operate under conditions of sliding friction and do not have a constant coefficient of friction. The frictional coefficient varies with the sliding velocity as shown in fig.



coefficient of friction v/s velocity of slide graph for friction guideways

- At the commencement of the movement, the coefficient of friction is very high, but as the velocity increases it falls rapidly and beyond a certain

critical velocity it remains almost constant. Thus, to start motion / movement, the force to overcome friction has to be correspondingly high. This force results in the drive machanism such as a screw, being elastically deformed.
- with the increase in speed, the friction decreases and a greater amount of movement than that intended for the slide takes place, this may lead ultimately to a jerky motion. This phenomenon is known as "stick-slip phenomenon".

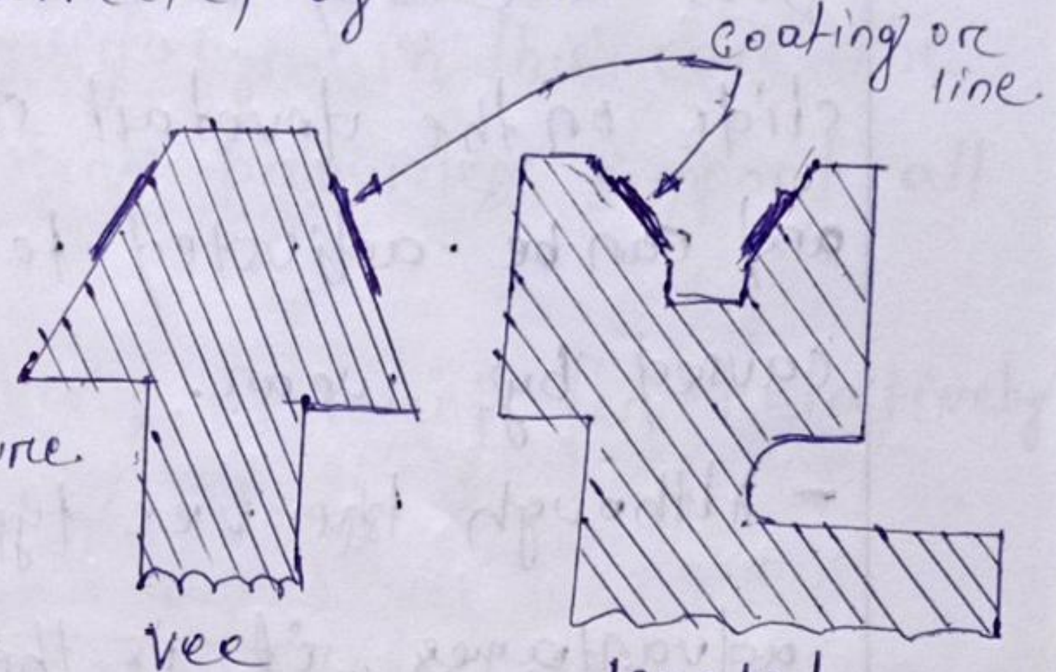
The possibility of this phenomenon can be reduced by using materials such as PTFE (Poly tetra fluoro ethylene) and turcite at the guideways interface, these materials have a low and constant coefficient (of the order of 0.1).

① Vee guideways :-

- In case of vee guideways with apex upwards, there is no chip falling or accumulation. In this case lubrication is difficult. In case of inverted vee guideways there is a possibility of falling and accumulation of chips; however lubrication is easier.
- The vee guideways are widely used on machine tools, especially on lathe beds.
- One of the advantages of vee guideways is

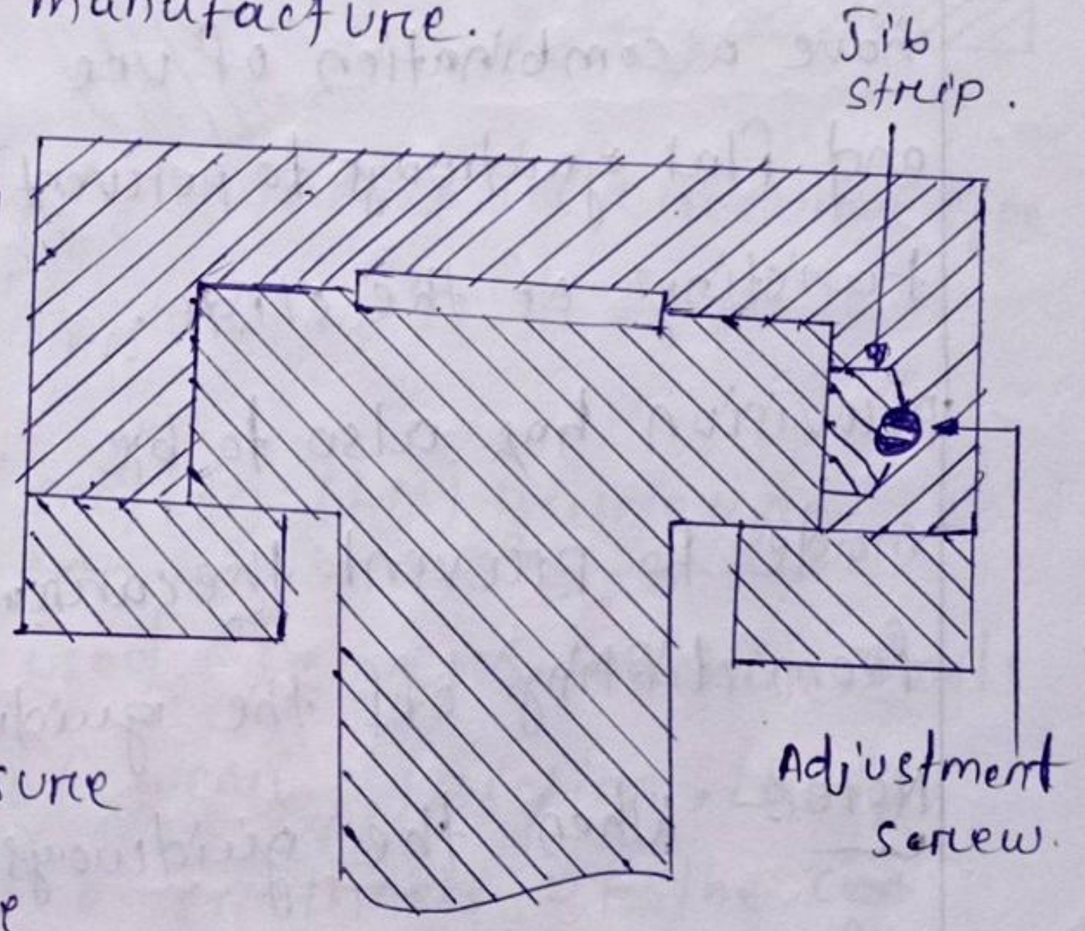
that the parallel alignment of the guideway with the spindle axis is not affected by wear.

- These guideways wear away rapidly due to lack of bearing surface. These are difficult to manufacture.



(II) Flat guideways :-

- These guideways have better load bearing capabilities than other guideway.
- These are easier to manufacture.
- In such guidways the chip accumulation and lubrication problems are serious.
- These do not wear uniformly.
- Jigs are used to ensure accurate fitting of the slide on the flat surface.



flat guideways.

- These guideways are suitable for heavy load transmission.

(III) Dovetail guideways :-

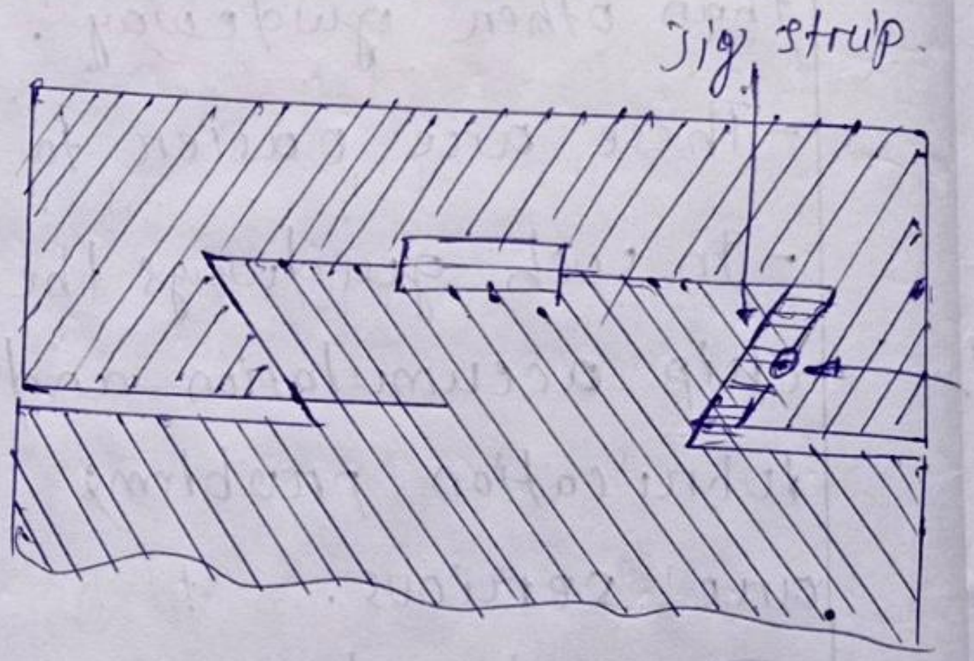
- These guidways have large load carrying capacity and tend to check the overturning tendency under eccentric loading.
- They are preferred when both horizontal and vertical locations of moving parts are considered

essential.

- Jibs are used to ensure accurate fitting of the slide on the dovetail surface. The jibs are tapered and can be adjusted to reduce excessive clearance caused by wear.

- Although the vee type guideways have certain advantages, if is the flat or dovetail forms which are used on CNC machine tools.

- The majority of lathes have a combination of vee and flat guideways to prevent twisting of the slide. Provision has also to be made to prevent the carriage from lifting off the guideways.



Dovetail guideways.

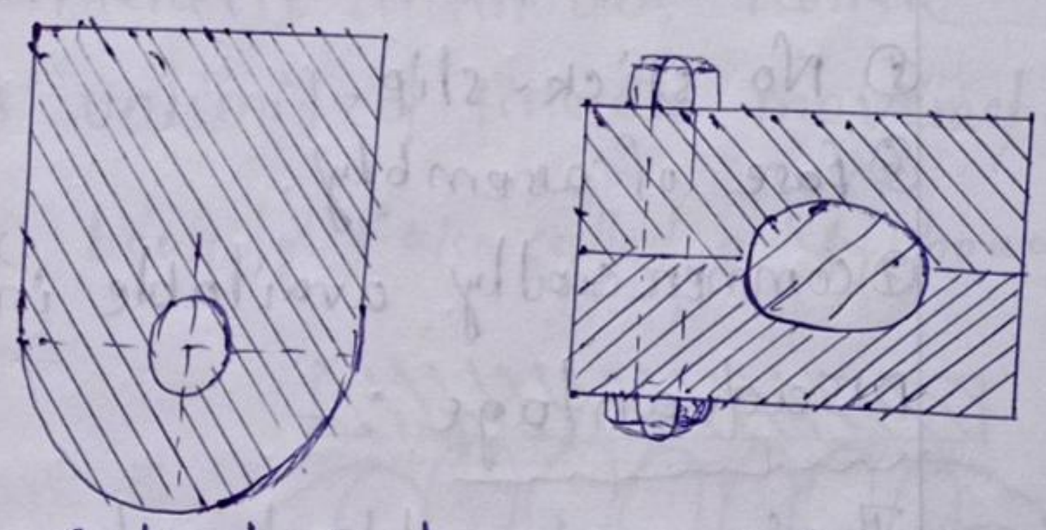
Note:- When the guideways are an integral part of the castings and get worn out after a period of time, it is necessary to dismantle the machine to remachine the guideways so that their accuracy is restored. To overcome this difficulty. pre-machined hardened steel guideways are fastened to the main casting which can be replaced if they are worn out or damaged.

(iv) Cylindrical guideways :-

a cylindrical form of guideways, in this case the bore in the carriage housing provides support all around the guideways.

- These guideways are very efficient for relatively short traverses and light loads.

- Their use for long traverses and heavy loads is not suitable because the guideways may sag or bend in the centren of the span under a load.



cylindrical or circular type guideways.

Antifriction linear motion (LM) guideways :-

These guideways are used on CNC machine tools to reduce amount of wear, friction, heat generation and improve smoothness of the momemet.

- The antifriction guideways are employed to overcome the relatively high coefficient of friction in metal-to-metal contacts and the resulting limitations addressed above.

- They use rolling elements in between the moving and stationary elements of the machine

Advantages :- The antifriction guideways claim the following advantages over the friction guides:

① High load carrying capacity.
② Heavier preloading possibility.
③ High traverse speeds.
④ ~~Hio~~ Low frictional resistance.
⑤ No stick-slip.
⑥ Ease of assembly
⑦ Commercially available in ready-to-fit condition.

Disadvantage :-

Their main disadvantage is lower damping capacity - Although the rolling element bearing have less damping characteristics than friction guideways, LM guideways have become common in mechine tools on account of their rapid traverse rates.

Types of antifriction guideways :-

Although several types of antifriction guideway are put to use, yet the most commonly used in CNC machines are :-

① Linear bearing with balls.
② Linear bearing with rollers.

① **Linear bearing with balls :-**

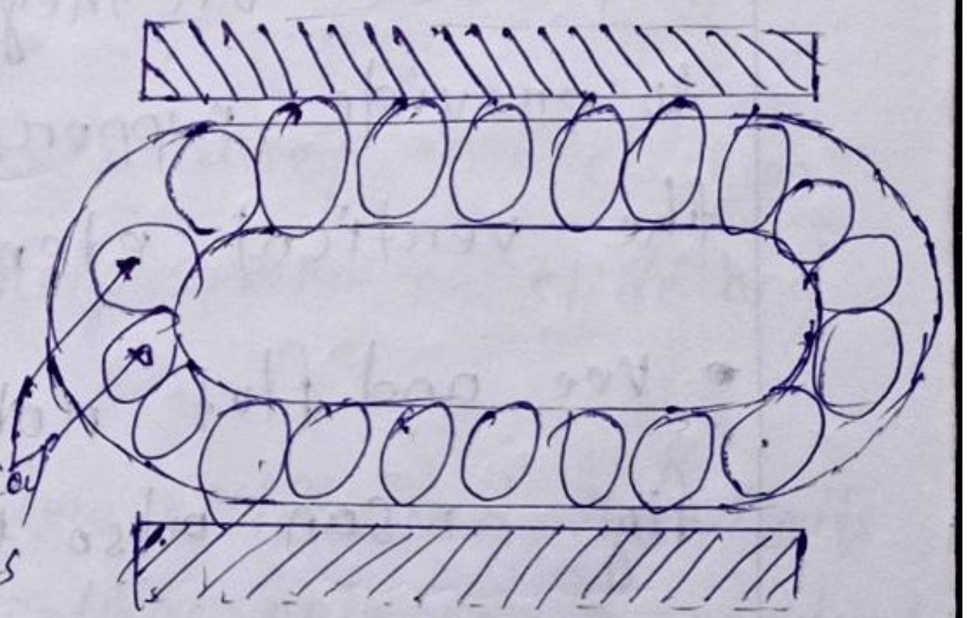
A linear ball bush, uses recirculating balls within a bush type of bearing. These are designed to run

along precision ground shafts and offer frictionless movement over varying strokes of length with high linear precision.

② Linear bearing with rollers :-

The recirculating linear roller bearings are used for movement along a flat plane. Their main characteristic feature is that there is continuous roller circulation which allows unlimited linear movemet.

fig. shows a linear roller bearing (also called a "tychoway").



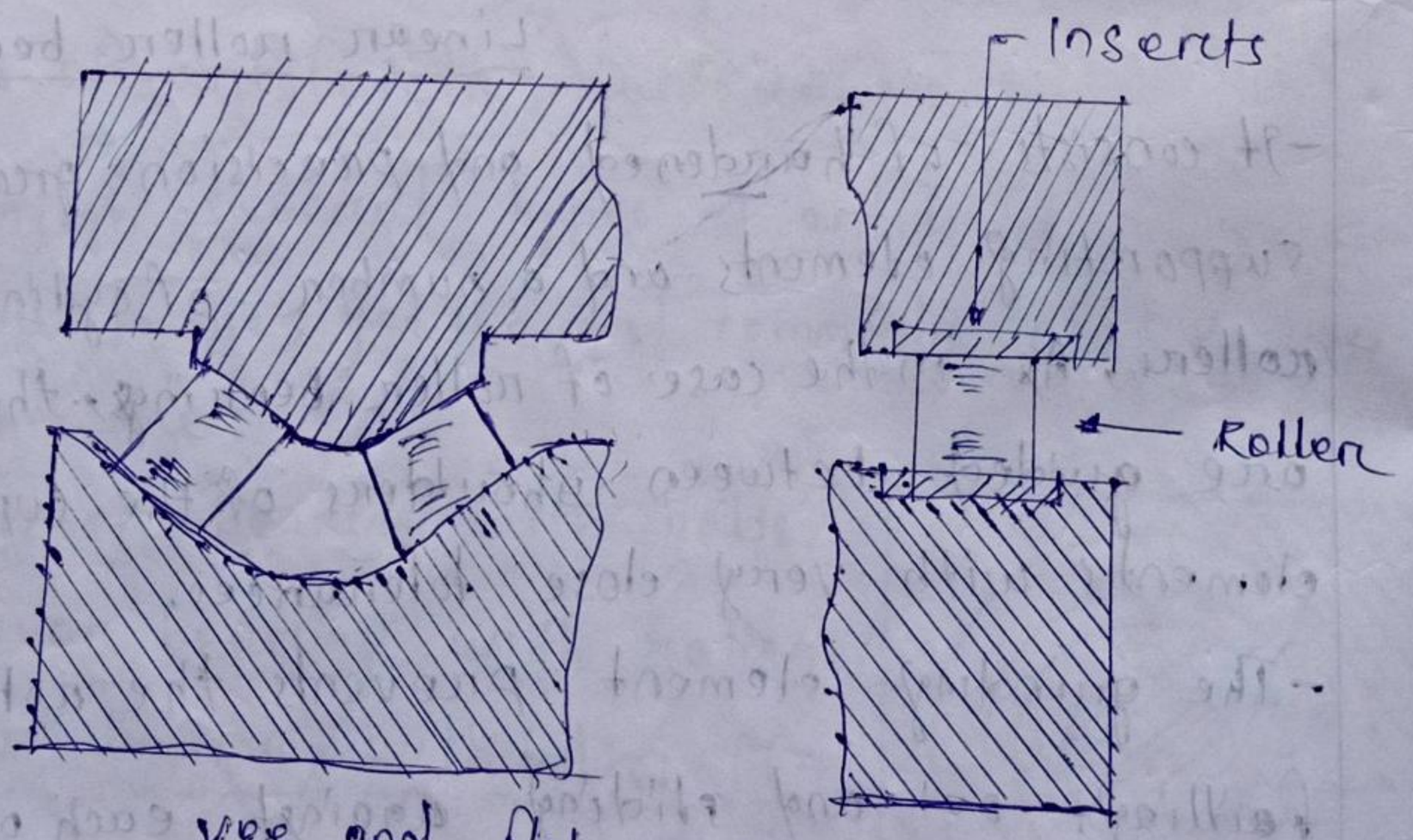
Linear roller bearing.

- It consists of hardened and precision ground supporting elements and a number of cylindrical rollers. As in the case of roller bearings, the rollers are guided between shoulders of the supporting elements with very close tolerances.
- The grinding element prevents the rollers from falling out and sliding against each other. Also the guiding element assists in smooth returns of the rollers to the loading zone.

- The rollers are in constact with guideway machined on the bed of the machine. This arrangement provides smooth and easy movement but the machine bed has to be machined to an accurate form. Also the machine bed surfaces coming in contact with the rollers have to be hardened.

- These bearings can be mounted horizontally for load carrying applications such as machine tool table or they can be mounted vertically to provide supports guidance and motion for the vertical elements of the machine tool.

- Vee and flat roller arrangement shown in fig, can also be used to provide friction-less linear movement.



Vee and flat rollers.

Frictionless guideways:-

① Hydrostatic guideways :- In these guideways the

surface of the slide is separated from the guide-way by a very thin film of fluid supplied at pressures as high as 300 bars.
- In hydrostatic guideways frictional wear and stick slip are entirely eliminated.
- In such guideways a high degree of dynamic stiffness and damping is obtained, both the characteristics contributing to good machining capabilities.
- Owing to high cost and difficulty in assembly, their application is limited.

(ii) Aerostatic guideways:-
In these guideways, the slide is raised in a cushion of compressed air which entirely separates slide and guidway surfaces.
- Their major limitation is low stiffness and this limits their use to positioning applications only eg. a coordinate measuring machine (cmm).

Advantages of frictionless guideways:-
① Longer life.
② Large damping capability.
③ frictionless
④ High stiffness.
⑤ No stick-slip.
⑥ Less thermal distortion due to better heat dissipation.

Disadvantages:-
①. Difficulty in assembling the guideways.
② High cost.
③ Leakage problems.

Selection of guideways :-

The selection of guides for a particular application basically depends upon the requirements of :-

(i) The load carrying capacity;
(ii) Denaturing;
(iii) The traverse speed.

for getting the maximum benefit, most of the machine tool manufacturers make use of a combination of antifriction and friction guideways with PTFE/ turcite lining. In such a combination antifriction guideways improve the load carrying capacity while friction guideways improve damping property.

Drives :-

Drives are devices which impart motion to mechanical elements.

- In a CNC machine tool there are three major group of elements.

(i) control and electronics.
(ii) Electric drives (electromechanical drives)
(iii) Mechanical elemets (table, slide, tool holder etc.)

In addition, there can be hydraulic and pneumatic systems which are integrated with CNC machine tool.

The primary function of the drive is to cause motion of the controlled machine tool member to conform as closely as possible to the motion commands issued by the CNC system.

- In order to ensure a high degree of consistency in production, variable speed drives are essential.
- Most of the drives used in machine tools are electrical.

Depending on their characteristics, machine tool drives can be classified as follows:-

① spindle drives :- (constant power)

(i) D.C. spindle drives :-
- separately excited D.C. shunt moter.
- controller.
  - Thyristor (SCR) amplifier, or
  - microprocessor based self-tuned thyristor amplifier.
- speed control :-
  - Armature and field control.

(ii) A.C. spindle drives :-
- squirrel cage induction motor.
- controller:
  - microprocessor based pulse width modulated (PWM) inverter.
- speed control:
  - frequency, vector control.

② feed drives :- (constant torque)

(i) D.C. servo-drive:
- motor - permanent magnet.
- controller
  - Thyristor D.C. amplifier
  - Transistor PWM D.C. chopper
- speed control:
  - Armature voltage.

⑪ A.C servo - drive:

- Motor - synchronous three phase A.C. motor with permanent magnet motor.
- controller.
  - Transistor for pwm frequency inverter; ~~angu eg~~ analog drive amplifier.
  - Transistor pwm frequency inveter, digital drive amplifier.
- speed control:
  - frequency control.

- Spindle drives :—

The following motors are used in spindle drives :-

(i) D.C. shunt motor (seperately excited).

(ii) Three-phase A.C. induction motor.

The requirements of a spindle drive motor are:

① compactness

② High overload capacity.

③ Large speed range of at least 1:1000.

④ Maximum speed upto 9000 - 20000 R.P.M.

⑤ High rotational accuracy.

⑥ Range of rated output from 3.7 - 50 KW.

⑦ wide constant power band.

⑧ fast dynamic response.

⑨ Excellent running smoothness.

In CNC machines the D.C. Spindle drives are commonly used (say for stepless speed variation

However, with the advent of microprocessor based A.C. frequency inverter, of late, the A.C. drives are being referred to D.C. drives as they offer several advantages:

- The main advantage of microprocessor - based frequency converter is the possibility of using the spindle motor for c-axis applications for speed control in the range of $1:10^8$ with positioning.

Feed drives:-

The main components of a feed drive are: (i) A feed servomotor; (ii) Mechanical transmission system.

A "feed motor", unlike a spindle motor, has special characteristics like constant torque and positioning.

In continuing operations where a prescribed path has to be followed continuously, several feed drives have to operate simultaneously, this requires a sufficiently damped servo system with high band width, i.e. fast response and matched dynamic characteristics for different axes.

following are the requirements of CNC feed drive.

① High torque - to - weight ratio.
② Integral mounting feedback devices.
③ During machining, the required constant torque for overcoming frictional and working forces must be provided.
④ Low electrical and mechanical constants.

⑤ Low armature or motor inertia.
⑥ Permanent magnet construction.
⑦ Total enclosed non-ventilated design.
⑧ Maximum speed upto 3000 r.p.m.
⑨ The drive should be infinitely variable with a speed range of at least 1: 20,000.
⑩ Positioning of smallest position increments like 1-2 μm should be possible.
⑪ four quadrant operation - quick response characteristics.
⑫ High peak torque for quick respones.

For CNC machines the commonly used feed drives are D.C. and A.C. servomotors. Although earlier D.C. servomoteors, because of thire excellent speed regulation, high torque and efficiency, ~~who~~ were used most commonly on CNC machine, but now A.C. servomotors have become more popular for machine tool applications because of the following 'characteristics':-

① Higher reliability as composed to D.C. servomotors.
⑪ Provide a constant torque over their entire speed range.
⑫ Require less maintenance due to brushless operation.

(iv) Provide a better response and dynamic stiffness.
(v) Excellent temperature resistance.
(vi) fast response.
(vii) Increased power density.
(viii) Low motor inertia.

- All the axes in a CNC machine are controlled by servomotors. The movement along the different axes is required either to move the cutting tool or the work material to the designed positions.
- In order to accomplish accurate control of position and velocity, stepper motors are used for axis drive. The use of stepper motor considerably simplifies the system as feedback devices are not used. The cost of machine tool is also less. The steppers motors are suitable only for light-duty machines due to low power output.

Mechanical transmission system :-

The mechanical transmission system of a feed drive consists of the following elements :-

① Elements to convert the rotary motion to a linear motion (Recirculating ball screwnut or rack-and-pinion system)

② Elements to transmit torque (gear box or timing belt and couplings).

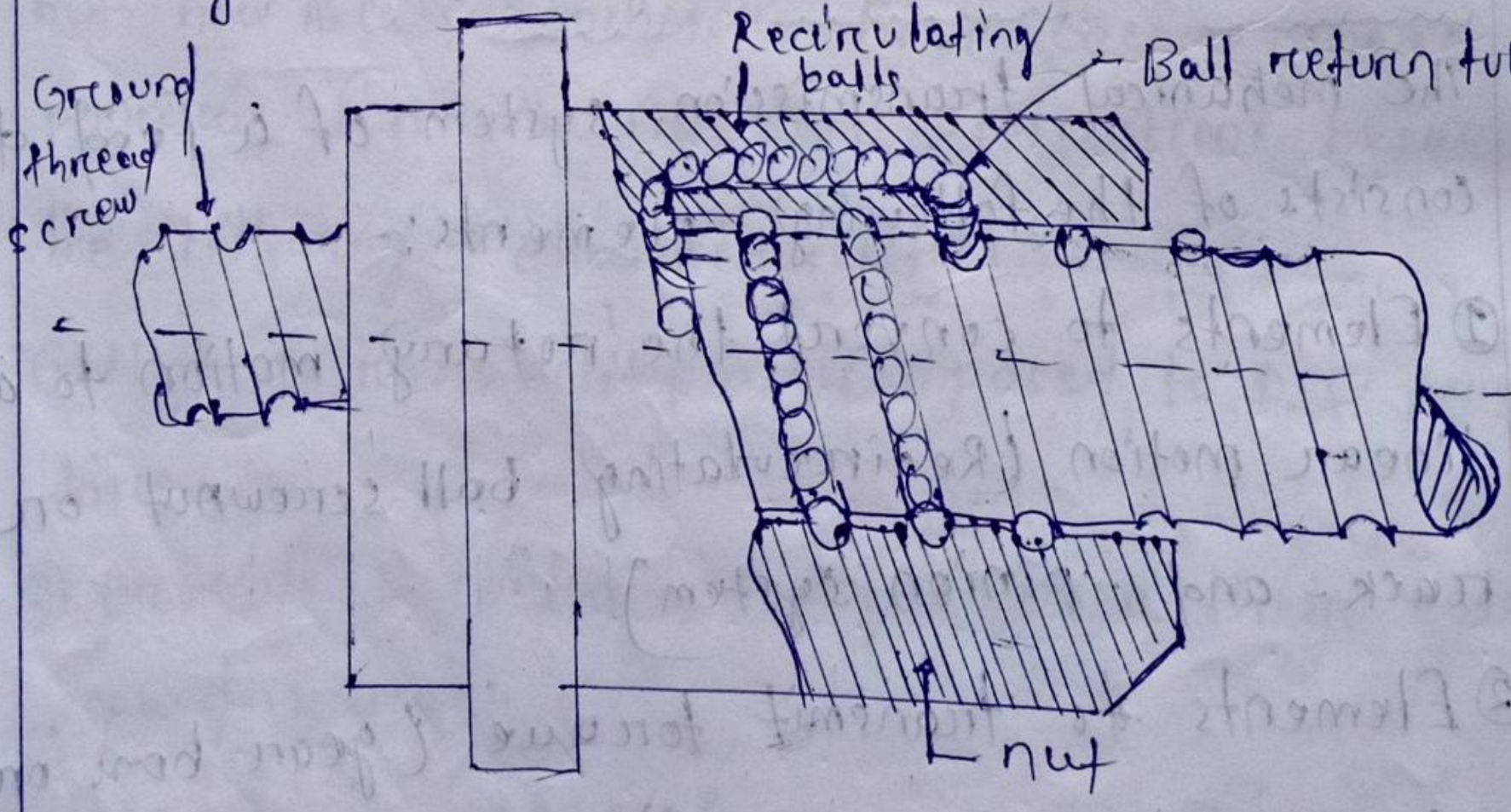
To keep the transmisson error to a minimum is the primary requirement in the design of a mechanical transmission system. To achive this, the following requirements are essential :-

(i) Low friction (ii) High stiffness.
(iii) Sufficient damping (iv) Backlash free operation.
(v) High natural frequency.

1. Recirculating ballscrew and nut :-

In ballscrews, the sliding friction encountered in conventional screws and nuts is replaced by rolling friction in a manner analogous to the replacement of simple journal bearing by ball bearing.

Shows the recirculating ballscrew and nut arrangement.



Recirculating ballscrew and nut arrangement.

- The mounting arrangement of a ball screw depends on its required speed, length and size, the position of the ballscrew should be near the line of the resultant force arising from cutting, frictional and inertial forces.
- The efficiency of a recirculating ballscrew is of the order of 90 percent and is obtained by the balls providing a rolling motion between the screw and the nut.
- In a ballscrew system, attention should be paid to the selection of end bearings to minimise the positioning inaccuracies.
- The ballscrews used on CNC machines are usually of precision grade.

Advantages :-

The recirculating ballscrews are widly used on CNC machines because of the following advantages :-

(i) High efficiency.
(ii) No stick-slip effect.
(iii) Low frictional resistance.
(iv) Low drive power requirement
(v) High traverse speed.
(vi) Less wear and hence longer life.
(vii) Little temperature rise.

Preloading of nuts :-

one of the primary requirements of screw

and nut mechanism in CNC machines employed for motion transmission is that there should not be any backlash and if any should be minimum between the screw and nut. Backlash free motion results in the slide traveling without any positioning error.

Spindle and spindle Bearings :-

Spindle :- The spindle carrying the workpiece or tool when subjected to high cutting speeds and high material removal rates, experience deflection and thrust forces. To ensure increased stability and minimise torsional strain, the machine spindle is designed to be short and stiff and the final drive to the spindle is located as near to the front bearing as possible.

The rotational accuracy of the spindle is dependent on the quality and design of bearings used. The ball or roller bearings are suitable for high speeds and high loads because of low friction, lower wear rate and lesser liability to incorrect adjustment the ease of replacement when necessary.

Spindle bearings :- In modern machine tools, which employ high performance cutting tool materials the designed characteristics of spindles used are :-

(i) Minimum deflection under varying loads.
(ii) Long service life.
(iii) stiffness.
(iv) Thermal stability.
(v) Good running accuracy both in radial and axial directions.
(vi) Axial load carrying capacity.
(vii) High speed of operation, without chatter, vibration.

On these characteristics do the accuracy and quality of the jobs produced depend. This can be achieved by using proper spindle bearing.

The various types of spindle bearings used in the design of a spindle for machine tools are :-

1. Antifriction bearing.
2. Hydrostatic bearing.
3. Hydrodynamic bearing. } --- fluid bearings.

① Antifriction bearing :-

The antifricton bearings are suitable for high speeds and high loads.
These are often preferred to hydrodynamic bearings because the following reasons.

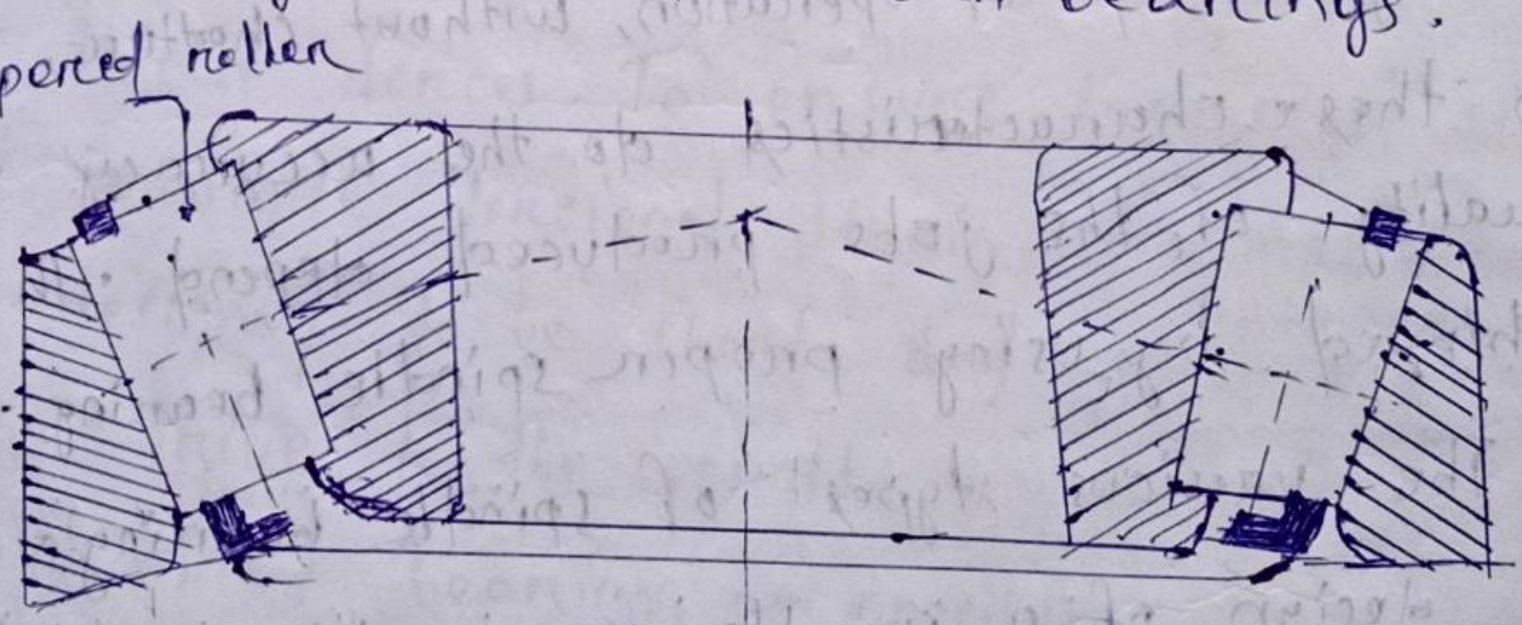
- High reliability.
- Ease of replacement
- Low friction.
- Moderate dimensions.
- lesser liability to suffer from wear or incorrect adjustment.

on CNC machines, the following types of ball and roller bearings are used:

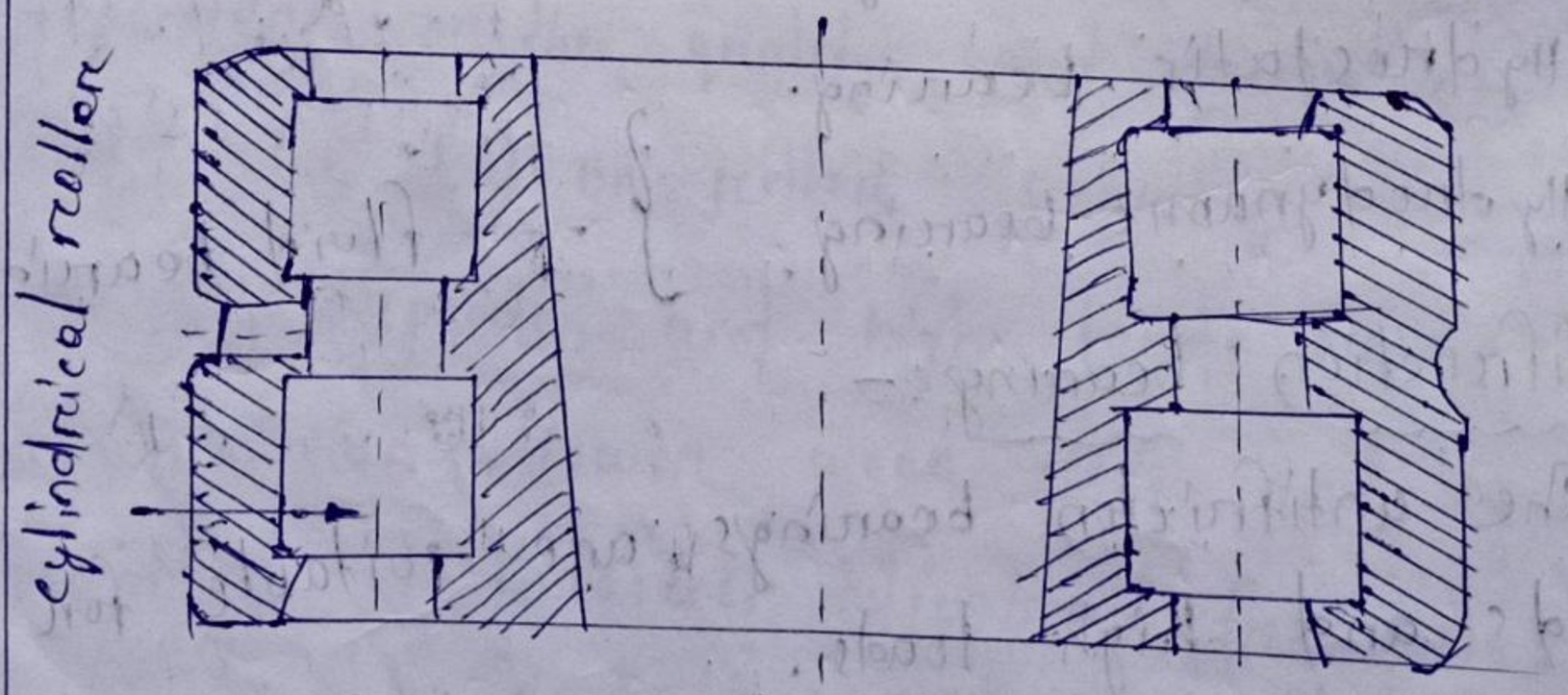
① Ball bearings.

ⓐ Deep groove ball bearings.

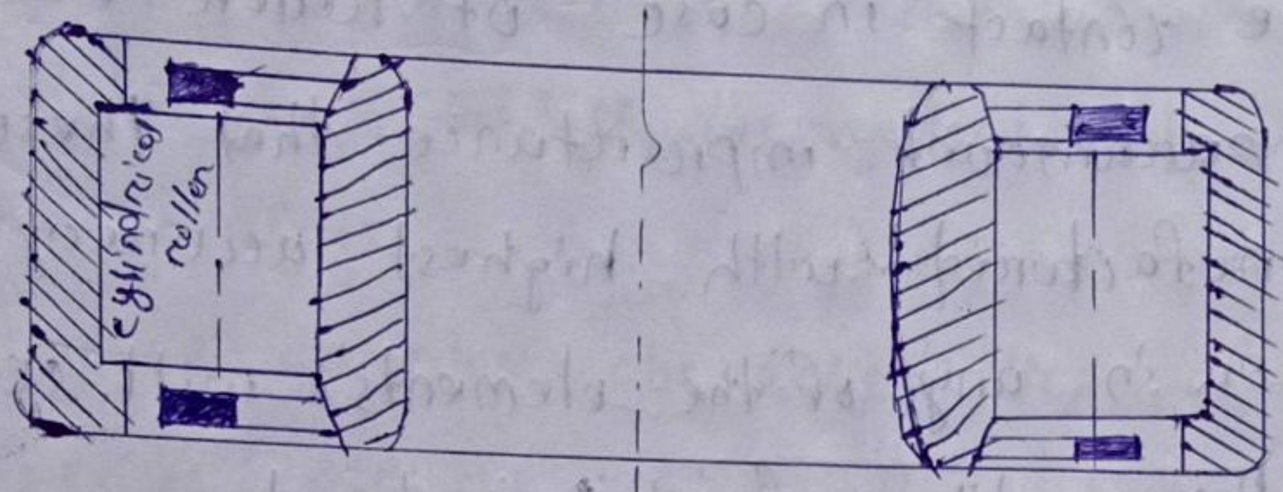
ⓑ Angular contact ball bearings.



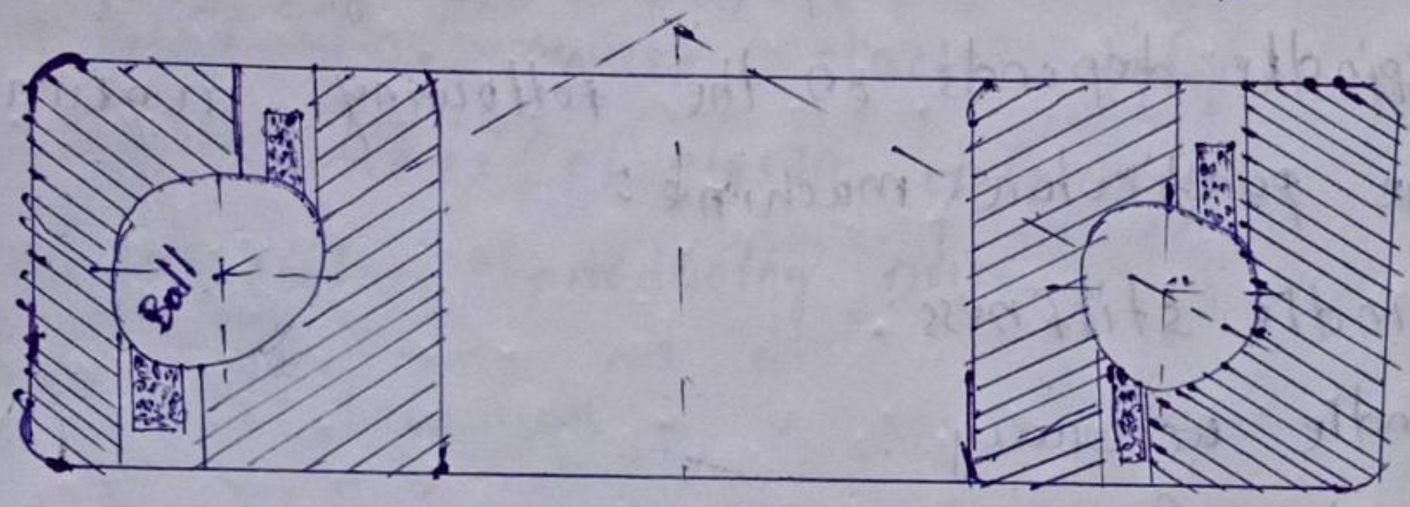
Tapered roller bearing:



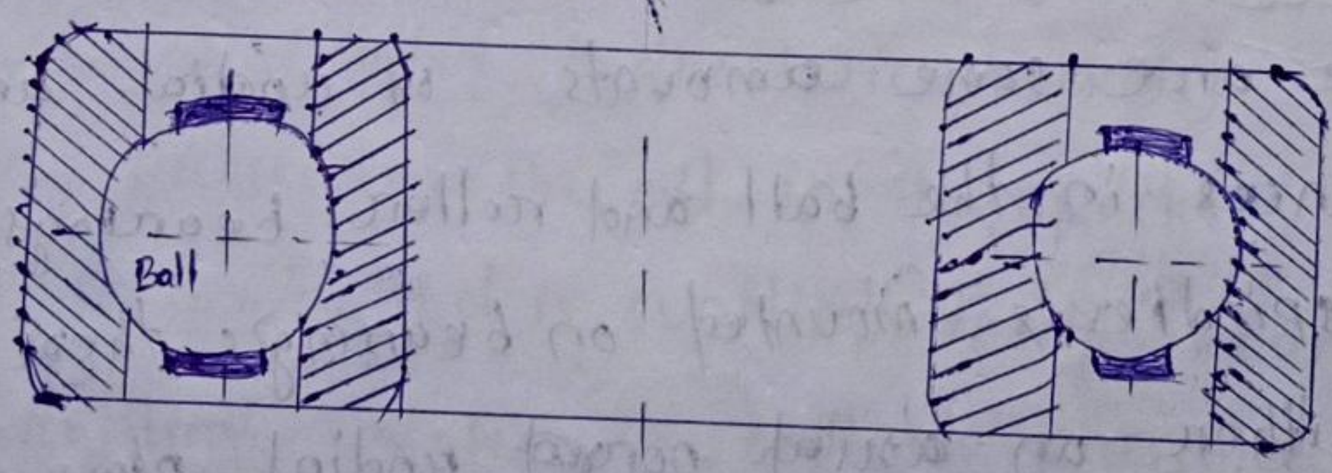
cylindrical roller bearing with tapered bore.



Cylindrical roller bearing:



Angular contact ball bearing:



Deep groove ball bearing

(ii) Roller bearings :-

(a) cylindrical roller bearings.

(b) cylindrical roller bearing (double row) with tapered bore.

(c) Tapered roller bearings.

- The ball and roller bearings are called antifriction bearings because the contact of support of rolling element is point contact in case of ball bearing

and line contact in case of roller bearing. It is of paramount importance that these bearing are manufactured with highest accuracy otherwise any error in any of the elements will severely affect the quality of job produced.

- The selection of a particular type of bearing for the spindle depends on the following requirements of the particular machine:
  (i) spindle stiffness.
  (ii) spindle accuracy.
  (iii) speeds of operation.

Preloading of bearings :-

There are some amounts of radial and axial clearances in the ball and roller bearings. When a main spindle is mounted on bearings there should be neither an axial nor radial play in the main spindle assembly. This is achieved by preloding.

- In case of tapered roller bearing and angular contact ball bearings, the axial and radial clearances can be taken up simultaneously by preloading.
- cylindrical roller bearings (double row) with tappered bores are radially preloded by pushing the inner race against the taper on the spindle.

Advantages :-

(i) Preloading increases the radial and axial rigidity of the bearings.

(ii) Improves damping characteristics of bearings.

(iii) Prevents rolling elements from disengaging themselves from the race ways.

- Preloading causes elactic deformation of the bearings. Excess of elastic deformation causes metal to-metal contact producing noise.

(2) Hydrostatic bearings :-

Shows the principle of hydrostatic bearings :-

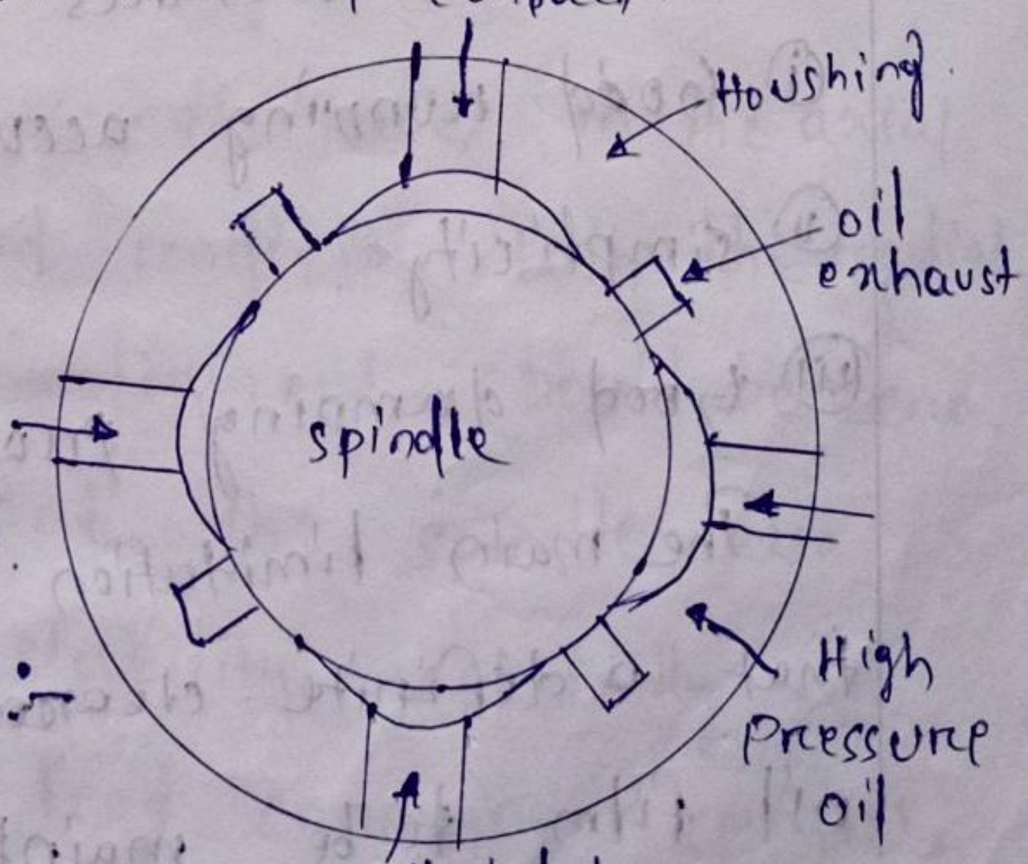
- Here the spindle is supported by a relatively thick film of oil (called hydrostatic pockets) supplied under pressure; the oil in the pockets being stationary. The oil is supplied to the bearing through a throttling system to control pressure and volume. Lubricating seals are used to prevent the leakage of oil. There is no mechanical contact.

- The load carrying capacity of this type of bearing is independent of the speed of rotation. They have the following :-

(i) High wear resistance.

(ii) High damping properties

(iii) High running accuracy.



Principle of hydrostatic bearings.

• These bearings are used in grinding and boring machines etc. (where temperature causes problems in the part accuracy).

(2) Hydrodynamic bearings :-

shows the principle of hydrodynamic bearings :-

- The pressure of oil within the bearing is created by the rotation of the spindle. As the rotation of the spindle. As the spindle rotates, the oil in contact with the spindle is carried into wedge-shape cavities between the spindle and the bearing due to centrifugal action. As the oil is forced through the small clearances between the bearing and spindle, the oil pressure is increased.

- In this type of bearing there is a constant flow of oil round the spindle, maintaining a thick oil film.

The essential features of these bearings are:-

(i) Good running accuracy

(ii) simplicity

(iii) Good damping properties.

The main limitation of this type of baring is that a definite clearance must be provided for the oil film to be maintained between the baaring and the spindle; the clearances normally

provided vary from 50 μm to 200 μm depending upon the journal diameter.

- These bearings are used where the load carrying capacities are low and frequent starting and stopping of the spindle is not required as in the case of grinding machines.

Selection of spindle bearing :-

The selection of spindle bearing depends on the following factors :-

(i) Type of load - axial, radial, or combination.
(ii) Load intensity.
(iii) Rotational speed.
(iv) Spindle stiffness.
(v) Thermal stability

The accuracy of a spindle depends on : (i) Radial runout i (ii) Axial runout.

- In radial runout the spindle shifts radially in any of 360° directions.
- In axial run out the spindle moves in the axial direction. for an ideal condition both the radial runout and axial runout should be zero.
- Since the accuracy of the spindle also depends on thermal stability especially for high speed and high load carrying spindles, a proper provision should also be provided for lubricating the spindles, bearings.

• In recent development the metal balls and rollers are replaced by ceramic balls and rollers because the latter offer the following advantages:

(i) Low coefficient of friction.

(ii) Greater thermal stability.

(iii) High ~~wear resistance~~ hardness.

(iv) High wear resistance.

The ceramic bearings can be employed for spindle speed in range of 10,000 to 20,000 R.P.M.

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{ ROBOTICS }

Definition and Advantages of Robotics :-

Definition :-

Robotics may be defined as follows :-

"Robotics is the science of designing and building robots suitable for real-life applications in automated manufacturing and other non-manufacturing environments."

or,

"Robotics is the art, knowledge base and knowhow of designing, applying and using robots in the human endeavors"

- Robotics is an interdisciplinary subject that benefits from mechanical engineering, electrical and electronic engineering, computer science, and several other disciplines.

Advantages :-

The main advantages of robotics are :-

1. Reliability.
2. Increased flexibility.
3. Low cost in the long run.

Laws of Robotics :-

following are the law (philosophical in nature) of robotics (Sir Issac Asimov proposed three basic laws; "zeroth law" was added later on) :

zeroth law :- A robot must not harm a human being or, through inaction, allow one to come to harm.

first law :- A robot must not harm a human being or, through inaction, allow one to come to harm.

second law :- A robot must always obey human beings unless it is in conflict with a higher order law.

Third law :- A robot must ~~not harm a~~ protect itself from harm unless that is in confict with a higher order law.

ROBOT :-

- The origin of word 'robot' is in the czech word 'robota' meaning either a slave or a mechanical item that would help its master. A robot therefore carries out the task done by a human being.
- The word 'robot' always refers to an automated multifunctional manipulator that works by energy, to perform a variety of tasks.
- A robot is any mechanical device operated automatically to perform in a seemingly human way. By this definition, a garage door opener, which automatically opens the door by remote control is also a robot; obviously this is not an industrial robot.
- Robot, once a creature of science friction, is today a reality, it is the off-shoot of the second industrial revolution.
- A robot by virtue of its reprogrammability and versatility is productive, dynamic and flexible to an extent.

• Robots range from toys to automated assembly lines.

Functions of a Robot :-

The functions of a robot can be classified into three areas :-

① "sensing" the environment by external sensors.
Example : vision, voice, touch, proximity and so on.

② "Decision making" based on the information received from the sensors.

③ "performing" the task decided.

Advantages and Disadvantages of Robots :-

Advantages :-

① Lifting and moving heavy objects.
② Working in hostile environments.
③ Providing repeatability and consistency.
④ Working during unfavourable hours.
⑤ Performing dull or monotonous jobs.
⑥ Increasing productivity, safety, efficiency and quality of products.
⑦ Achieving more accuracy than human beings.

Disadvantages :-

① The robots lack capability to respond in emergencies;
② The initial and installation costs of equipments of robots are quite high.
③ They replace human workers, thus causing

resentement among workeres.

Types of Industrial Robots :-

Industrial robots can be broadly divided into two main groups as follows:

① General purpose robots.
② Special purpose robots.

① General purpose robots :-

- These robots carry standard designs and parts and readily available.
- They can be easily adapted to the users' requirements by attaching suitable end-effectors or fingers to them according to the requirement of the work, such as a part picking operation, welding operation, spray painting etc.
- Since such robots are mass produced, they are cheaper.

② special purpose robots :-

- These robots are tailor made to specific job requirements. The ultimate user has to feed his requirements and, based on them, these robots are specially designed and built to cater to such specific needs. Obviously, their designing and manufacturing consumes a lot of time. As such, they can not be readily available in market.

-since they can not be manufactured on mass scale, their prices are bound to be higher.

Robotic systems :-

A system is an integral whole of parts or subsytems. It has a specific goal or output for a given set of inputs; a system may have many goals as well.

- A "robot" is a system as it combines several subsystems that interact themselves as well as with the environment in which the robot works.

- A robot has some specific objective. It may be designed for the following jobs/ assignments:

(i) To simply pic up and place the workpieces.

(ii) To interact with and work load a lathe, a milling machine or any equipment;

(iii) To perform some assembly work.

To accomplish these assignments a robot should have the following "components".

- A suitable manipulator arm with specified coordinated systems to attain a designed reach in the working space.

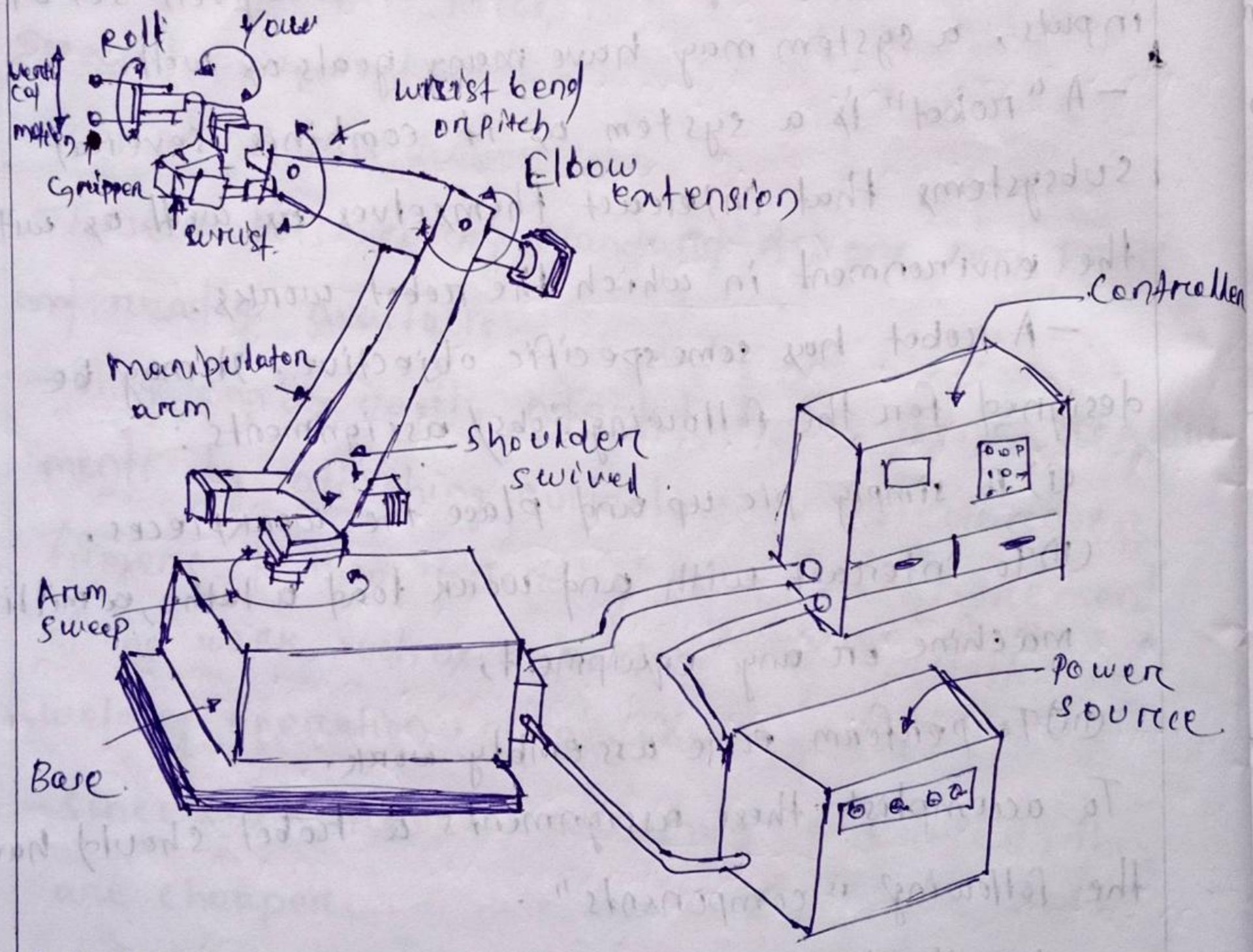
- A suitable control system with or without servo-mechanisms for sending signals to the drives, or permitting storage of programmes and data for desired path planning with adequate speed and good accuracy.

- Some sensors to feed back information for modifying the motion or path.

- A controller is provided with interfacing units connected to external equipment in the outside world.

- fig shows a scheme of robotic system.

Robot components : Refer to :



Robotic system - main components of a robot and the basic motions. The various components of a robot are enumerated and discussed below :-

① Base.
② Manipulator arm.
③ End-effector.
④ Actuators and transmissions.
⑤ Controller.
⑥ Sensors.

① Base :- The base may be fixed or mobile.

② manipulator arm:-

- The most obvious mechanical configuration of the robot is the manipulator arm.
- There are several designs of the arm ~~of~~ to facilitate movemet within the work envelope with maximum possible load and speed with high precision and repeatability.
- The simplest robot may be a two or three-axes arm. The axis is meant to understand independent movement or degree of freedom (DOf).
- A robotic manipulator arm consists of several separate links making a chain. The arm is located relative to the ground on either a fixed base or a movable base. It has a free-end where an end-deflector or gripper or sometimes a specialised tool holder (for holding, say, a welding gun) or any powered device (say, a drill) is attached.
- In a fixed base, six degrees of freedom robot, the first three links of the manipulator constitute the body and they help to place the end-effector at a desired location inside its work environment or working volume. The remaining three links make up the wrist of the manipulator and are used to define the orientation of the manipulator end points.

• A robot is essentially a movable open chain of successively coupled bodies with one end fixed to the ground and the free end containing ~~and~~ an end-effector. The bodies of the open chain are usally links which are joined together by some lower pair connectors. The most common types of lower pair connectors are:-

(1) Revolute pair (R) - - (1 DOF):

- It permits relative rotation about a unique pair axis and has a single degree of freedom.

(11) Prismatic pair (P) - - (1 DOF):-

- It allows relative sliding parallel with a unique pair axis and has one degree of freedom

(111) Cylindrical pair (C) - - (2 DOF):-

- It permits independent relative rotation about and relative sliding parallel to a pair axis and it has two degrees of freedom.

(1v) Spherical pair (S) - - (3 DOF):-

- It is a ball and shoket joint that permits relative rotation about three non-coplanar interacting axes and has three degrees of freedom

(v) Hook's joint (T) - - (2 DOF):- It permits independent rotation about two intersecting axes offeset by an angle α and has two degrees of freedom.

• The number of independent movemets that an object can perform in a 3-D space is called the number of degrees of freedom (DOF).

However, the most basic joints are the one-Dof revolute pair (R) and one-DOF prismatic pair (P) and these two pairs are excessively used in combination in the robotic manipulators.

③ End-effector:-

- Robot end-effector is the gripper or end of arm tooling mounted on the wrist of the robot manipulator arm.
- A robot performs a variety of tasks for which various tooling and special grippers are required to be designed.
- A robot manipulator is flexible and adaptable, but its end effector is task-specific.
- A gripper designed for picking up a tool to be fitted to a CNC machine tool is not suitable for welding a railway vagon.

The wide range of gripping methods include:-

(i) Mechanical clamping.
(ii) Magnetic gripping
(iii) Vacuum (suction) gripping.

④ Actuators and Transmissions:-

Actuators:- The robot arm can be put to a desired motion with its payload if actuator modules are fitted in to provide power drives to the systems.

There are three different types of power drives in common use. They are:-

① Pneumatic drives :-

- These systems use compressed air to move the robot arm.
- The pneumatic systems may employ a linear actuators, i.e. double acting cushioned cylinders. or it may employ rotary actuators like vane motors. However, linear actuators are more popular.
- The "advantages" of ~~per~~ pneumatic actuators are: simple construction, relatively inexpensive, fast and reliable. The "disadvantages" of ~~pea~~ pneumatic system are smaller payloads, the mass inertia and delayed response of the robot arm due to the sponginess and reduced repeatability.
- Non-servo robots can be built up with pneumatically powered actuators.

② Hydraulic drives :-

- In a hydraulic system, the electric motor pumps fluid (oil) from a reserve tank to the hydraulic actuators which are, in general, double acting piston-cylinder assemblies - fluid at a higher pressure passes through control valves before its entry into the linear actuators. on the other hand, rotary actuator comprising some motors or hydraulic motors which

rotate continuously may also be employed.

- The hydraulic drives have high payload capacities and are relatively easy to maintain. They are, however, rather expensive and not as accurate as either the pneumatic or electric drives.

(iii) Electrical drives :-

- These drives are clean and quiet with a high degree of accuracy and reliability. They also often a wide range of payload capacity, accompanied by an equally wide range of costs.

- D.C. servo motors, Brushless D.C. motors, Reversible A.C. servo motors and stepper motors are important electrical drives.

Transmission :-

"Transmission" are elements between the actuators and the joints of the mechanical linkage. They are generally used for the following three reasons :-

(i) often the actuator output is not directly suitable for driving the robot linkage.

Example: The high speed D.C. motor running at 3000 r.p.m (say) may not be suitable for running a robot at slower speeds. However, with appropriate gearing on transmission, the speed may be reduced to 30 rpm (i.e. $\frac{1}{2}$ rotation per second) which is reasonably fast. In addition, the rated torque at 3000 r.p.m is amplified by 100.

(ii) The out put of the actuator may be kinematically different from the joint motion.

(iii) The actuators are usually big and heavy and often it is not practical to locate the actuator at the joint.

- Firstly, big actuators have large inertias and they are harder to move around in space then the links that comprise the mechanical linkage. So it is desirably to locate them at a fixed base.
- Secondly, because of their size, they can impede the motions of one or more links of the robot.

Thus, it is not uncommon to find linkages or gear train that transmits the power from the actuator over a large distance to the joint.

(5) Controller :-

The "controller" provides the intelligence that is necessary to control the manipulator system. It looks at the sensory information and computes the control commands that must be sent to the actuators to carry out the specified tasks. It generally includes :-

(i) Memory to store the control program and the state of the robot system obtained from the sensors.

(ii) A computational unit that computes the control commands.

(iii) The appropriate hardware to interface with the external world.

(iv) The hardware for a user interface.

- The "user interface" allows the use of a human operator to monitor or control the operation of the robot.
  - It must have a display that shows the status of the system.
  - It must also have an input device that allows the human to enter commands to the robot.

The users interface may be a 'personal computer' with the 'appropriate software' or a "teach pendant".

(B) Sensors :-

The sensors perform the following functions::

(i) To act as feedback devices to direct futhther actions of the manipulator arm and the end effector (gripper),

(ii) To interact with the robot's working environment.

usually there are two basic types of sensors. These are.

(i) Tactile sensors :-

These are 'contact sensors" that must be brought in contact with the object to obtain signals to measure the necessary qualities.

- When the tactile sensors mark physical contact with the object, an electrical analog or digital signal is generated and sent to the robot controller. Electrical signals may be obtained through the contacts of microswitches. Signals may also be obtained through mechanical pressures on

which change resistances of electrical strain gauge or general electrical potentials in piezoelectric ~~system~~. crystals.

- Typical contact type robotic sensors include:

ⓐ force sensors. ⓑ Touch sensors

ⓒ Torque sensors. ⓓ Position sensors.

ⓑ Non-tatile sensors :-

These are "contactless sensors" which sense the signals remotely, but only within the specified range of distance from the object.

- They detect and measure magnetic fields, infrared and ultraviolet light, x-rays, electrical fields, ultrasonic sound waves or electromagnetic waves.

- Typical non-contact robotic sensors include:

ⓐ Proximity sensors.

ⓑ Electro-optical sensors.

ⓒ Range imaging sensors.

Basic motions :-

The six basic motions or degrees of freedom (DOFs) are as follows :

① Vertical motion :- The entire manipulator arm can be moved up and down vertically either by means of the shoulder swivel, i.e., turning it about a horizontal axis, or by sliding it in a vertical slide.

② Radial motion :- Radial movement, i.e. in and out movements, to the manipulator arm is provided by Elbow extension by extending it and drawing back.

③ Rotational motion :-
clockwise or anticlockwise rotation about the vertical axis to the manipulator arm is provided through Arm sweep.

④ Pitch motion :- It enables up and down movement of the wrist and involves rotational movement as well. It is also known as wrist bend.

⑤ Roll motion :- Also known as wrist swivel, it enables rotation of wrist.

⑥ Yaw :- Also called wrist yaw, it facilitates rightward or leftward swivelling movement of the wrist.

The most versatile robots can have following degrees of freedom (DOFs) :

(i) Horizontal travel.
(ii) Rotary movement.
(iii) Radial arm movement
(iv) Vertical arm movement.
(v) Rotary wrist movement.
(vi) Wrist bend.
(vii) Wrist sweep.

These axes of movement enable movements to be programmed that duplicate those of a human operator in performing a job.

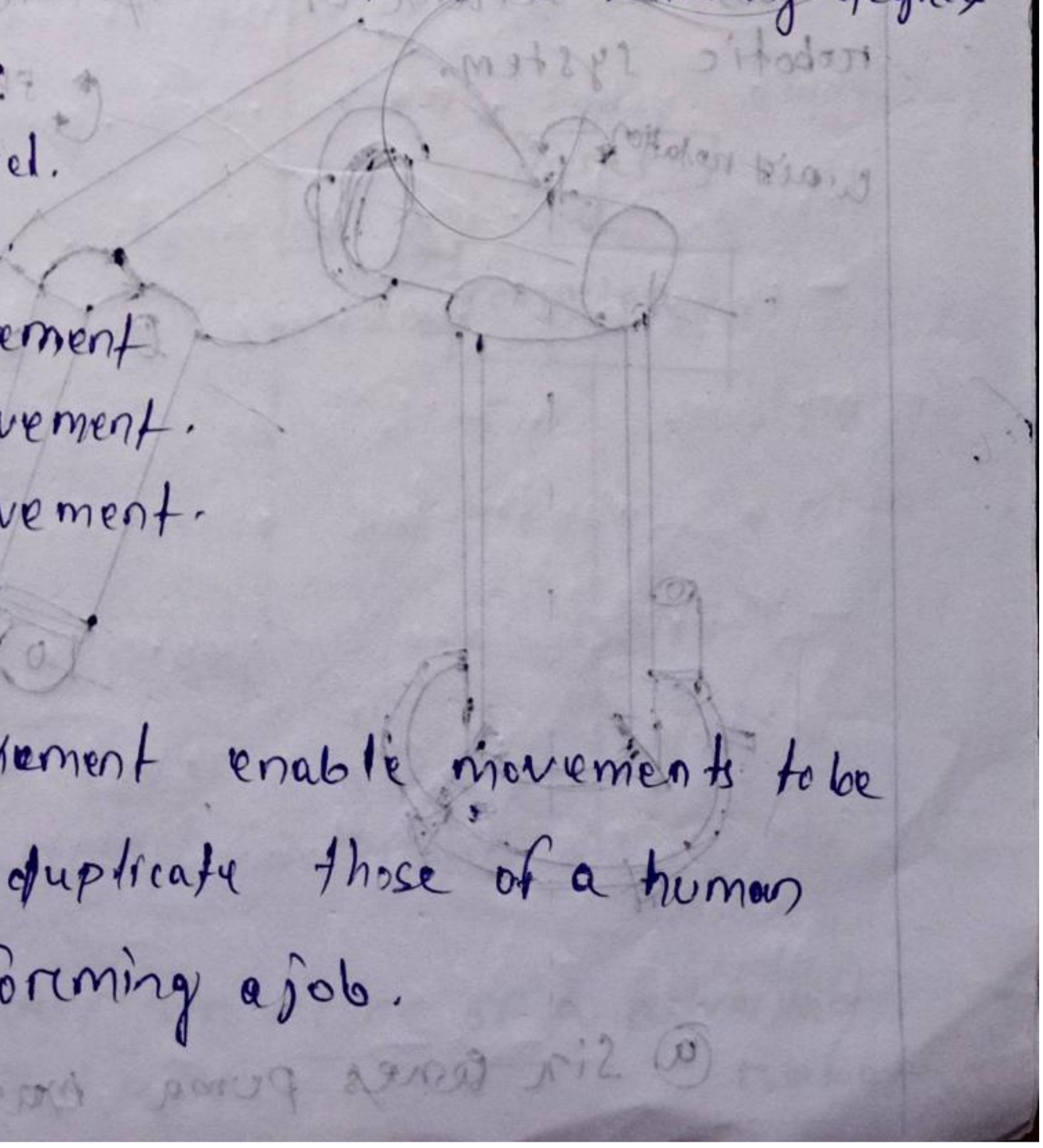
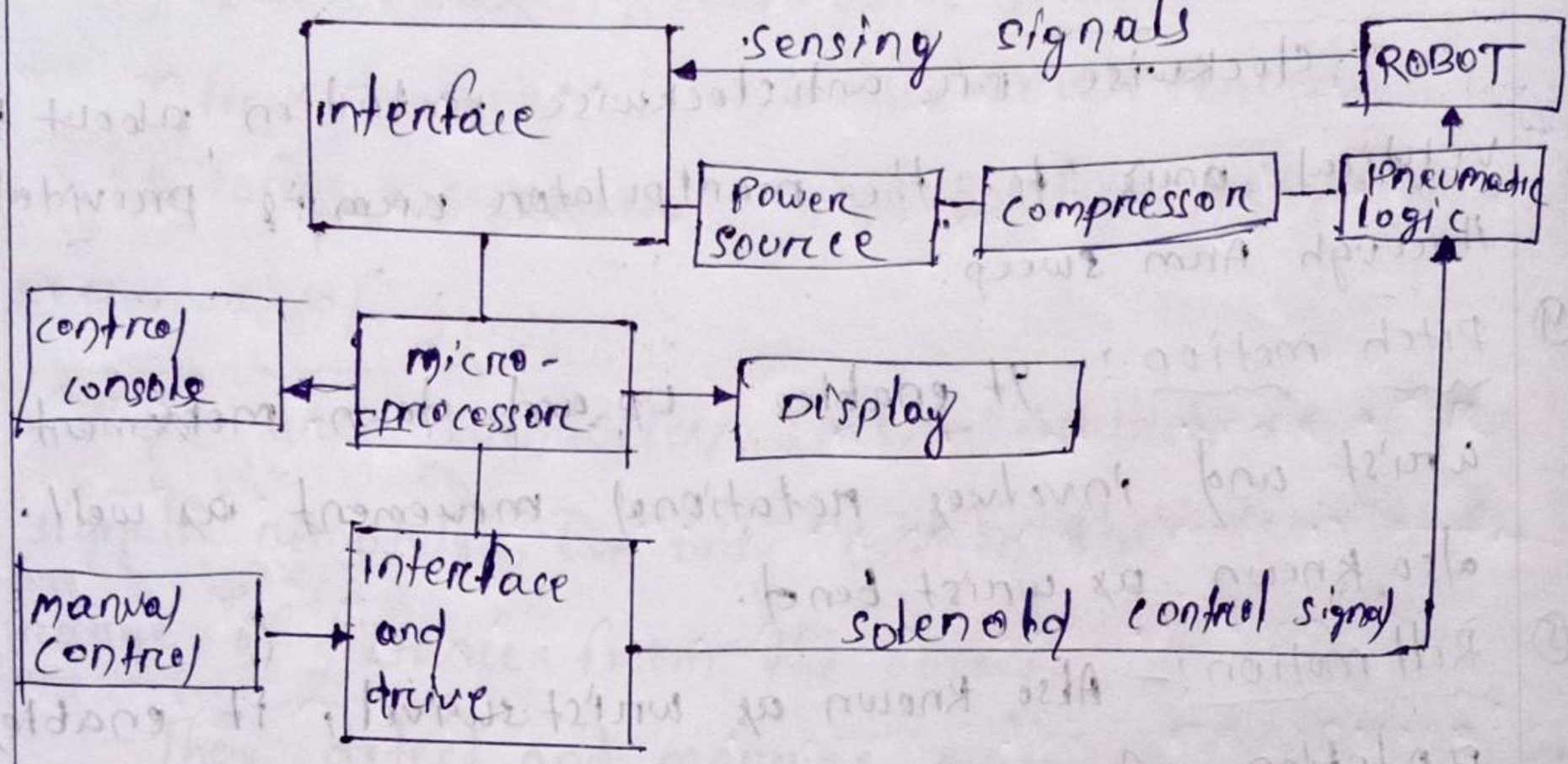
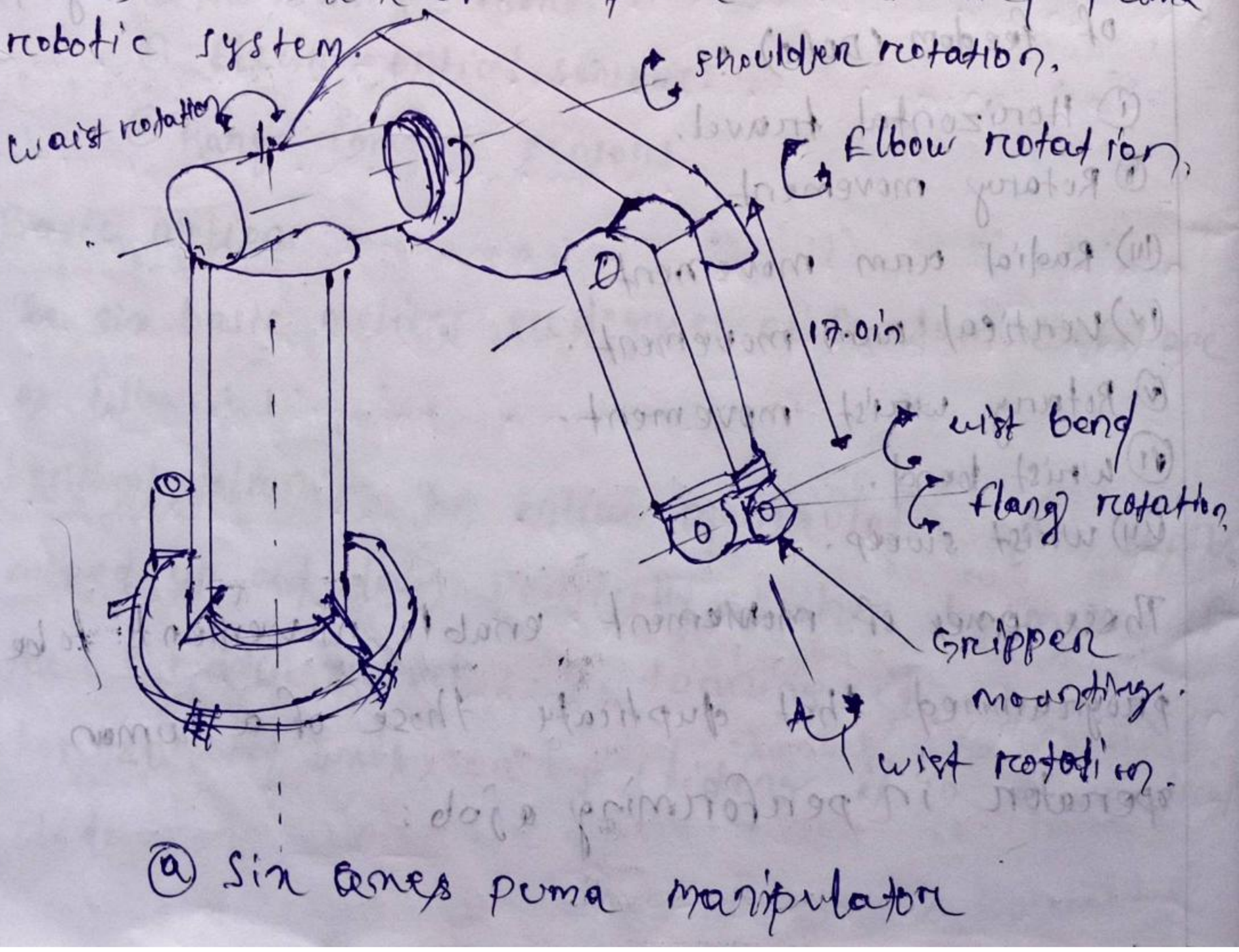


fig shows the basic components of microprocessor - based pneumatic robotic system.

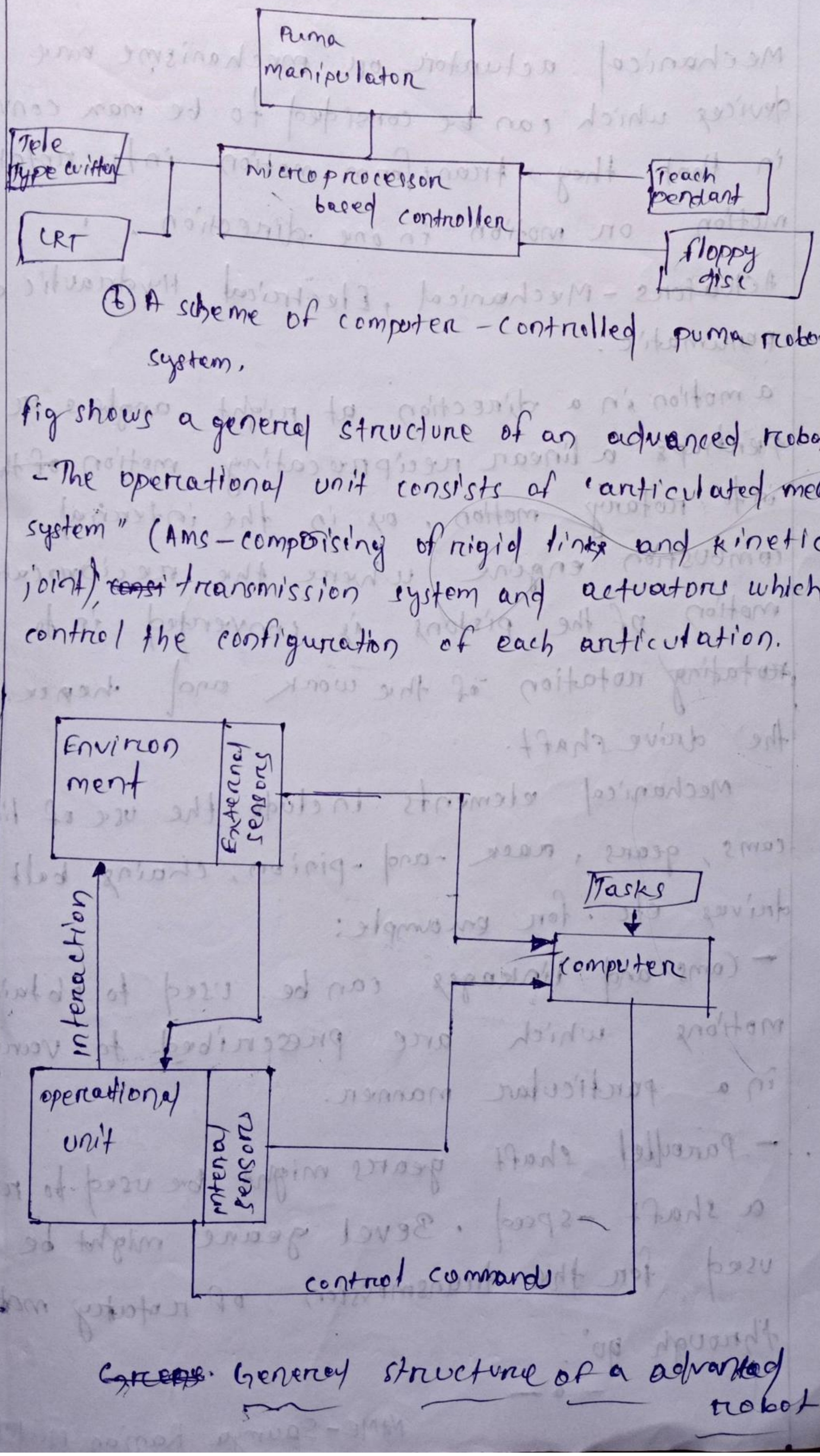


Basic components of a microprocessor - based robotic system.

Shows a six axes puma manipulator and fig shows a scheme of computer - controlled puma robotic system.



(a) Six axes puma manipulator



(b) A scheme of computer-controlled puma robotic system.

fig shows a general structure of an advanced robot. - The operational unit consists of 'articulated mechanical system" (AMS - comprising of rigid links and kinetic joint), ~~consi~~ transmission system and actuators which control the configuration of each articulation.

Generay structure of a advanced robot.

Mechanical actuator or mechanisme ware devices which can be consided to be man convert in that they transform motion into rotational motion, or motion in one direction.

Actuators - Mechanical, Electrical, Hydraulic and pneumatic.

a motion in a direction at right angles, or perhaps a linear reciprocating motion ~~of the~~ into rotary motion, as in the internal combustion engine where the reciprocating motion of the pistons is converted into ~~rotating~~ rotation of the work and thence the drive shaft.

Mechanical elements include the use of linkages cams, gears, rack-and-pinion, chains belt drives etc. for example:

- Cams and linkages can be used to obtain motions which are prescribed to vary in a particular manner
- Parallel shaft gears might be used to reduce a shaft-speed. Bevel geare might be used for the transmission of rotary motion through 90°.

—o—

Sensors and Transducer

* Definition of Sensor-

The Sensor is the device which sense the condition, state or value of process variable and produce an output which reflects this condition, state or value.

eg → Thermometer sense temperature. The mercury expand or contract depending on temperature which is easily measured with help of calibrated glass tube.

* Definition of Transducer-

A transducer is a device that converts one form of energy to another.

Most of transducers either electrical energy into mechanical displacement and/or convert some non-electrical physical quantity to an electrical signal.

eg → potentiometer

* Classification of Transducer

A. Based on whether an external power source is required or not

→ 1. Active transducer - They dont require any power source for their operation. They produce electrical signal proportional to input. They work on energy conversion principle.

eg → Thermocouple Transducer

→ 2. Passive transducer - They require an external power source for their operation.

eg → Thermistor

B. Based on type of o/p -

→ 1. Analogue Transducer - These transducer convert i/p physical quantity to analogue o/p which is continuous function of time.

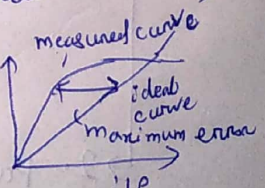
→ 2. Digital Transducer - These transducer convert i/p physical quantity into electrical o/p which may be in form of pulse.

C. Classification based on electrical principle involved

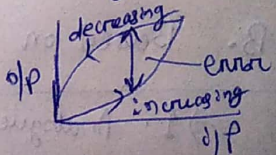
1) Variable resistance type → eg. Strain & Pressure gauge, Thermistor
2) Variable - inductance type → eg. Linear Variable differential Transformer (LVDT), Eddy current gauge
3) Variable - capacitance type → eg. Capacitor microphone, Dielectric gauge
4) Voltage generating type → eg. Thermocouple, Photovoltaic, Pizeoelectric
5) Voltage - divider type → eg. Potentiometer position sensor, Pressure - actuate voltage divider

* Various Specification of transducer

1) Range - It indicate the limit between which i/p can vary.
2) Span - It is difference between maximum & minimum value of i/p.
3) Error - It is difference between result of measurement and true value.
4) Accuracy - It is closeness to true value.
5) Sensitivity - It is defined as ratio of change in o/p to per unit change in i/p.
6) Nonlinearity - deviation of actual measured curve from ideal curve.



7) Hysteresis error - It is maximum difference in o/p within specified range of sensor when approaching point first with increasing and then with decreasing i/p parameter.



8) Resolution - It is smallest detectable incremental change of i/p that can be detected in o/p s/g.

9) Dead band/time — It is range of i/p values for which there is no o/p.

* Electromechanical Transducer –

It is a device which convert mechanical motion (Vibration) into variation of electric current or voltage and vice versa. These transducer are used primarily as ~~actuating~~ actuating mechanism in automatic control system.

Advantage –
1) Less power consumption
2) Good frequency & transient response
3) Friction effects minimum
4) more compact

eg – piezoelectric transducer, loudspeaker, microphone

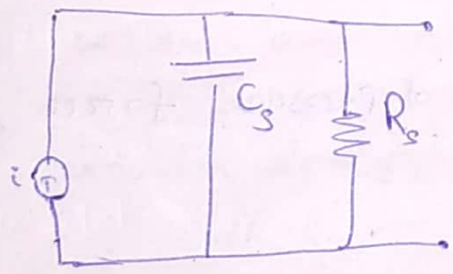
*Piezoelectric Transducer -

Piezoelectric material is one in which an electric potential appears across certain surface of crystal if the dimension of crystals are changed by application of mechanical force. When it is stressed or compressed generate electric charges with one face of material becoming positively charged and opposite face negatively charged. As a result voltage is produced.

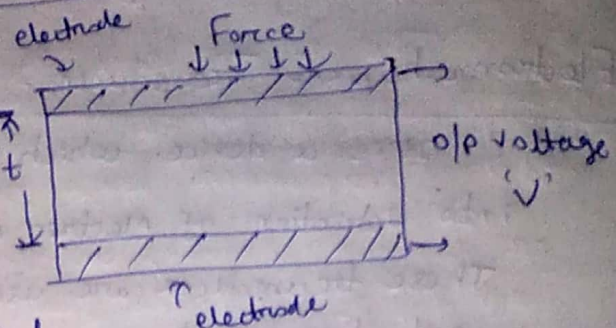
The effect is reversible, if a varying potential is applied to proper axis of crystal, it will change the dimension of crystal. This effect is

eg of piezoelectric crystal - quartz, tourmaline, rochelle salt, lithium sulphate.

Equivalent circuit of piezoelectric sensor -



Working of piezoelectric Device



There is net displacement of charge with one face becoming positively charged and other negatively charged with application of force.

- The net charge $q = SF$

where $S \rightarrow$ charge sensitivity

$f \rightarrow$ force applied

The capacitance C of piezoelectric material between metal electrode is

$$C = \frac{\epsilon_0 \epsilon_r A}{t}$$

$\epsilon_r \rightarrow$ relative permitivity of material

$A \rightarrow$ Area

$t \rightarrow$ thickness

Since $q = CV$

$$V = \frac{q}{C} = \frac{SF}{\frac{\epsilon_0 \epsilon_r A}{t}}$$

$$\Rightarrow V = \frac{St F}{\epsilon_0 \epsilon_r A}$$

$$\Rightarrow V = S_v t (F/A) = S_v t P$$

where $S_v \rightarrow$ voltage sensitivity factor $= S/\epsilon_0 \epsilon_r$

$P \rightarrow$ Pressure applied $= F/A$

Application

Measurement of pressure, force, acceleration

Q) A 2.5 mm thick quartz piezo electric crystal having a voltage sensitivity factor of 0.055 Vm/N is subjected to a pressure of 1.4 MN/m². If permittivity of quartz is 40.6×10^{-12} F/m, calculate i) voltage o/p

ii) charge sensitivity of crystal

Soln-

Given $S_v = 0.055$ Vm/N

$G = 40.6 \times 10^{-12}$ F/m

$P = 1.4$ MN/m²

i) Voltage o/p $V = S_v \cdot t \cdot P$

$= 1.4 \times 10^6 \times 2.5 \times 10^{-3} \times 0.055$

$= 192.5$ V

ii) charge sensitivity $S = \epsilon \cdot S_v$

$= 40.6 \times 10^{-12} \times 0.055$

$= 2.233$ pc/N

* Light Sensor -

1) Photodiode - Photodiodes are one type of light detector, used to convert the light into electrical energy. Photo diode operates in reverse bias condition so giving a high resistance. When light falls on junction the resistance drops and current in circuit rises appreciably.

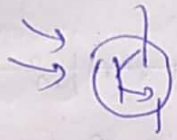
Symbol -

eg → PIN, avalanche photodiode, schottky photo diode

2) Photo transistor - Photo transistor have a light sensitive collector-base pn junction. When there is no incident light there is a very small collector to emitter current.

When light is incident, a base current increases which is directly proportional to light intensity. Darlington arrangement can be used because it has higher current gain so device gives greater current gain for given light

Symbol -



3. Photoresistor / light dependent resistor (LDR) -

Photo-resistor is generally made of semiconductor material. Cadmium - sulphide is mostly used. ~~Who~~ Photoresistor has resistance which depends on intensity of light falling on it. Resistance decreases as intensity of light increases. This happened because valence electron jump to conduction band absorbing light energy.

Symbol -

Application - used in street light - automatic switching on of street lights due to presence of LDR.

Temperature Sensor

1) Resistance Temperature Detector (RTD) -

→ It is used to determine temperature by measuring resistance. The RTD wire is a pure material typically Platinum, nickel or copper.

→ These detector are characterised by positive temperature characteristic (Resistance increases when there is increase in temp.).

→ Relation between resistance and temperature is

$$R_T = R_0 (1 + \alpha \Delta T)$$

where, $\Delta T = T - T_0$

T_0 → Reference temperature

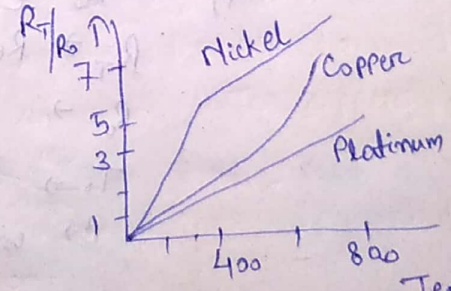
R_0 → Resistance at reference temperature

T → Temp. under measurement

R_T → Resistance at temp. T

α → constant (Temp. coefficient of resistance)

Typical I/O relation of RTD look like →



eg) A Platinum thermometer has resistance of 100Ω at 25°C. find its resistance at 65°C, if it has $\alpha = 0.00392 /°C$.

Soln →

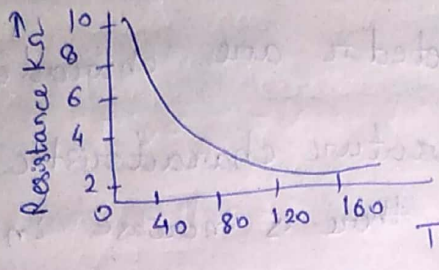
$$R_T = R_0 (1 + \alpha \Delta T)$$
$$= 100 (1 + 0.00392 \times (65 - 25))$$
$$R_T = 115.68\ \Omega \quad \text{(Ans)}$$

(2)

Thermistor -

→ Thermistor are small pieces of material made from mixture of metal oxides such as iron, magnese, nickel. These oxides are semiconductor.

→ The relationship between temp. & resistance is non-linear. A typical graph is shown below.



Thermistors are two type :

i) Negative Temp. coefficient (NTC) Thermistor -

→ When temp. increases, resistance decreases
& When " decreases, " increases

ii) Positive Temp. coefficient (PTC) Thermistor -

→ When temp. increases, resistance increases
& When " decreases, " decreases

NTC Thermistor -

→ Relationship between resistance and temp is

$$R_T = R_0 \, e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)}$$

R_T → Resistance at temp. T
R_0 → " at temp T_0
T_0 → Reference temp.
β → constant

Advantages

→ Thermistor are small and cheaper.
→ They have fast response times

Disadvantage - nonlinearity

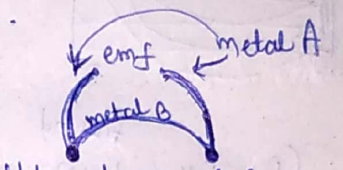
③ Thermocouple-

→ used to measure temp. in the form of electric current of emf.

→ Thermocouple consist of two different metals joined together.

→ These are active transducer which based on Seeback effect. Emf is developed when two junction are maintained at different temperature.

The value of emf depend upon two metal concerned and temp. of both side.



	Materials used	Temp. range °C
①	chromel/constantan	-200 to 1000
②	Iron/constantan	-200 to 900
③	copper/constantan	-200 to 400
④	chromel/alumel	-200 to 1300

→ If both junction are at same temp. then no emf is generated.

→ Usually one junction is ~~hot~~ held at 0°c.

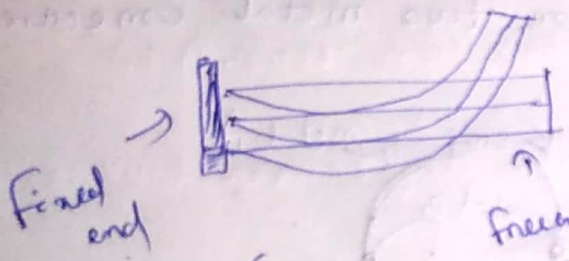
④ Bimetallic strip -

→ It is used to convert a temp. change into mechanical displacement.

→ It consist of two different metal strips bonded together.

→ The metals have different coefficient of expansion

⇒ When temp. increases, strip bends towards the metal which has low-temp. coefficient. and when temp. decreases, the strip bends towards the metal which has high-temp. coefficient.



(Bimetallic strip)

* Displacement and position sensor -

Displacement sensors are deal with measurement of amount by which some object has been moved. position sensor are concerned with determination of position of some object with reference to some reference point.

Various types sensor are given below -

(1) Linear Variable differential Transformer (LVDT)

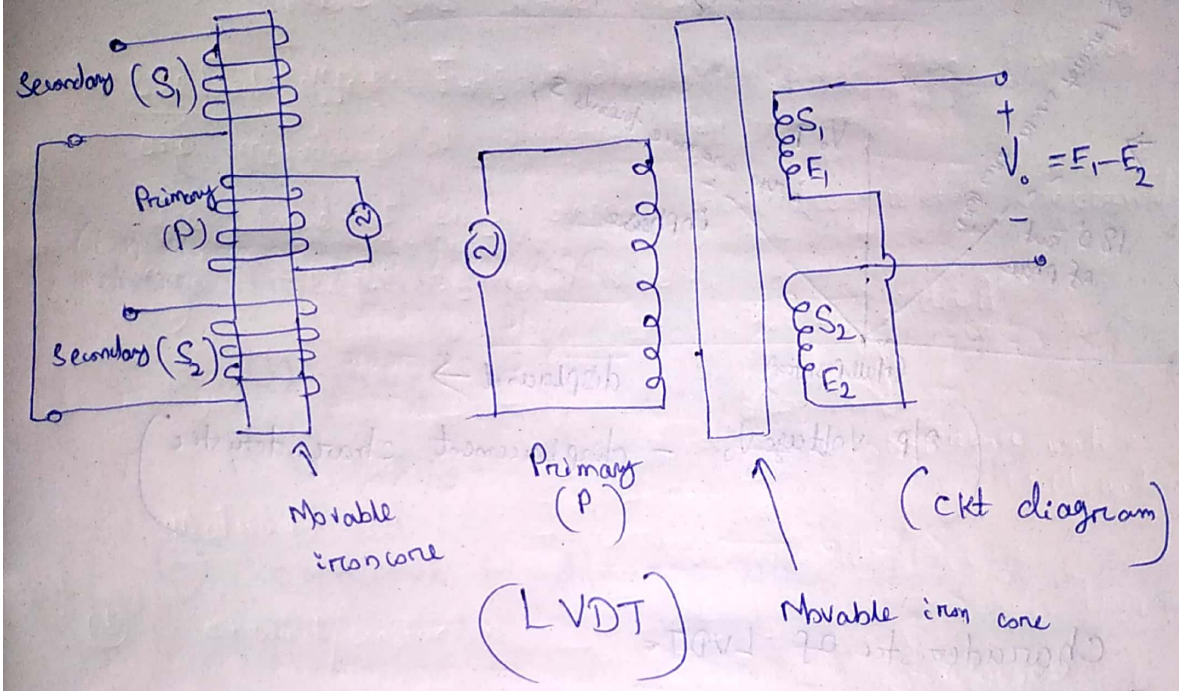
→ It is variable inductance based transducer that sense the displacement under measurement.

Construction → It basically consist of single primary (P) & two secondary winding (S_1 & S_2) with soft iron core placed symetrically between primary and secondary winding.

→ The iron core is free to move axially inside the coil assembly.

→ The two secondary winding (S_1 & S_2) have equal no. of turn but are connected in series opposition

→ AC supply is given to Primary winding.



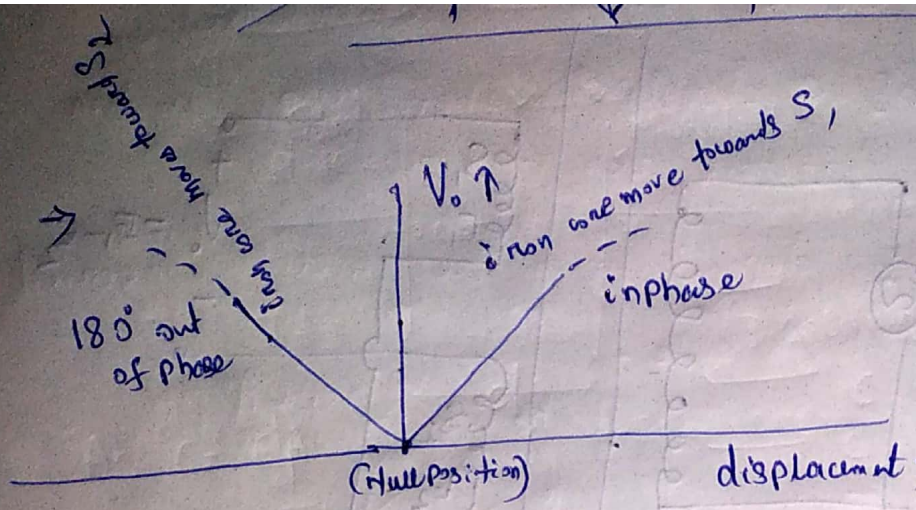
Working

→ Emf is induced in a secondary coil by changing current in primary coil, this effect is called mutual inductance.

→ When iron core is in centre, the induced emf E_1 & E_2 are equal and opposite hence $V_o = E_1 - E_2 = 0$

→ When iron core is moved towards S_2, then $E_2 > E_1$ and o/p voltage V_o is -ve.

→ When iron core is moved towards S_1, then $E_1 > E_2$ and o/p voltage V_o is +ve.



(o/p Voltage V_o – displacement characteristic)

Characteristic of LVDT-

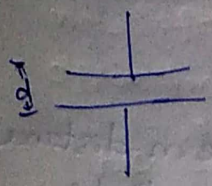
→ less frictional losses
→ Highly linear i/p - o/p characteristic
→ highly sensitivity
→ It show low hysteresis

Disadvantages

→ sensitive to stray magnetic field
→ affected by vibration

② Capacitive transducer

Capacitance of parallel plate capacitor is



$$C = \frac{\epsilon A}{d}$$

where $\epsilon \rightarrow$ Permittivity

$A \rightarrow$ Overlapping area of plate

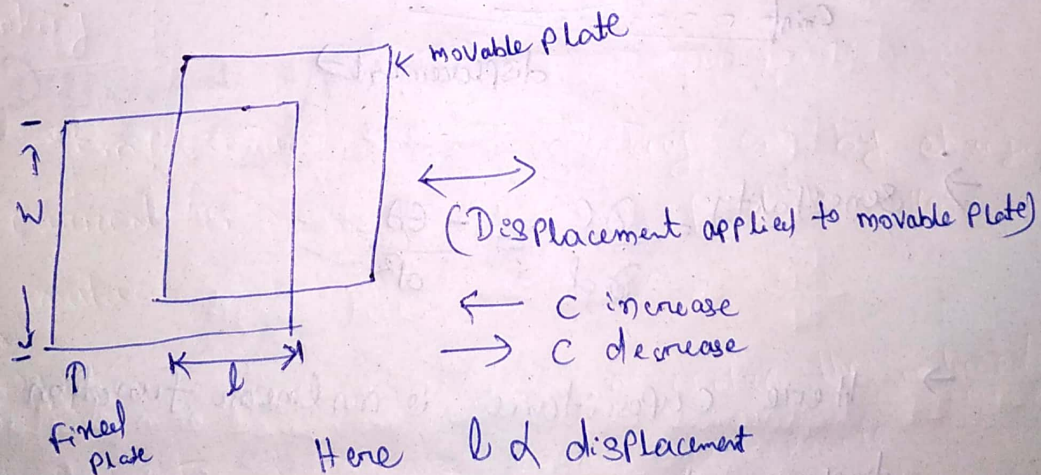
$d \rightarrow$ distance between two plate

→ Displacement can be measured by measuring change in capacitance. Capacitance can by changed by

(i) change in area, or

(ii) change in distance between two plate

(i) capacitive transducer – using change in area of plate



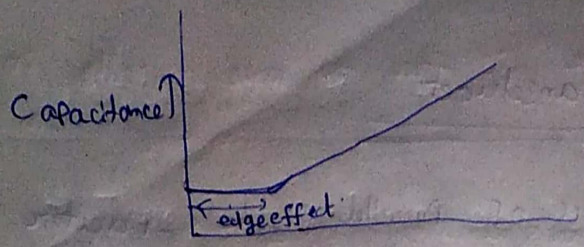
Here $l \propto$ displacement

overlapping area $= l \times w$

$$C = \frac{\epsilon A}{d} = \frac{\epsilon l w}{d}$$

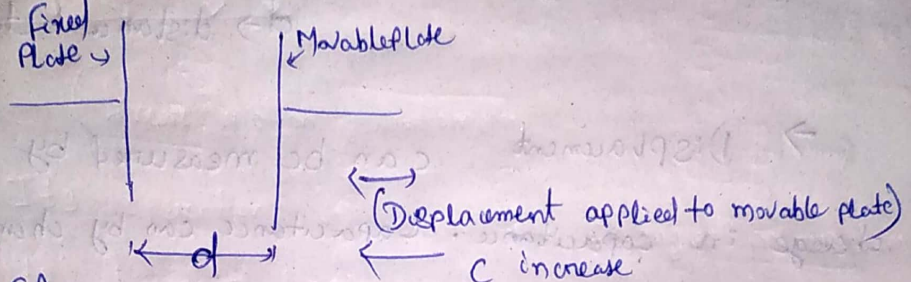
$$C \propto l$$

$\Rightarrow$ C ∝ displacement



→ Sensitivity $= \frac{\partial C}{\partial l} = \frac{\epsilon W}{d} =$ (constant)

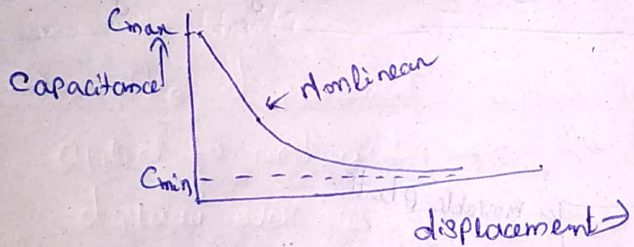
(ii) Capacitive transducer - using change in distance between plate



As $C = \frac{\epsilon A}{d}$

So, $C \propto \frac{1}{d}$

$\Rightarrow C \propto \frac{1}{\text{displacement}}$

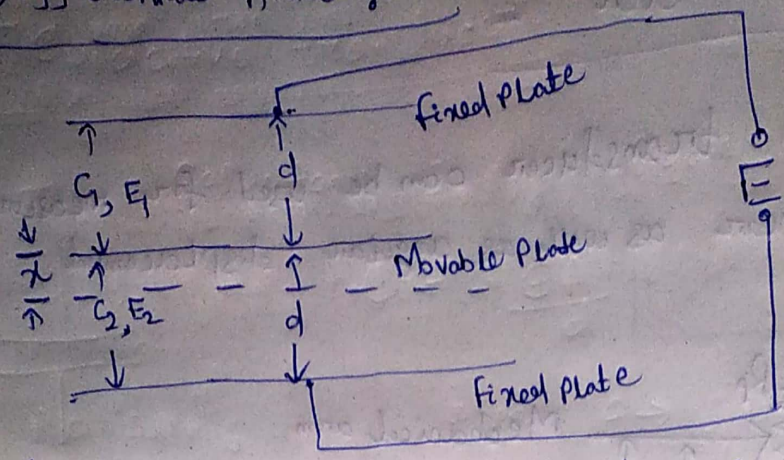


→ Sensitivity $= \frac{\partial C}{\partial d} = \frac{-\epsilon A}{d^2}$

→ Here capacitance is non linear function of displacement.

So, we go for differential arrangement to obtain linear characteristic.

Differential Arrangement



$E_1 \rightarrow$ Voltage across C_1

$E_2 \rightarrow$ Voltage across C_2

→ Let normal position of central plate represented by solid line.

Here $C_1 = \frac{\epsilon A}{d} = C_2$

→ When central plate is displaced by x, the capacitance are

$$C_1 = \frac{\epsilon A}{d+x}$$

$$C_2 = \frac{\epsilon A}{d-x}$$

Then Voltage across C_1 is $E_1 = \frac{EC_2}{C_1+C_2} = E\frac{d+x}{2d}$

" " C_2 is $E_2 = \frac{EC_1}{C_1+C_2} = E\frac{d-x}{2d}$

Differential o/p voltage

$$\Delta E = E_1 - E_2$$

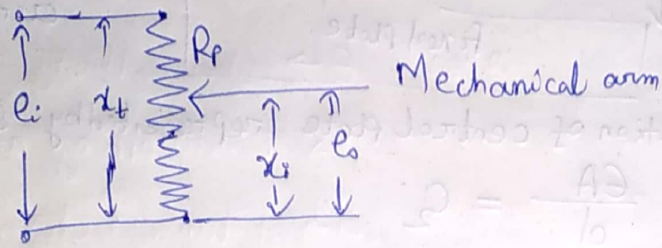
$$= \frac{Ex}{d}$$

$$\Rightarrow \Delta E \propto x$$

So, different o/p voltage is a linear function of displacement.

(3) Potentiometer –

→ These transducer can be used for measurement of both linear as well as angular displacement



(Linear motion potentiometer)

→ Its operation is based on changed in resistance due to ~~change in~~ displacement

→ It basically consist of resistive element R_p of length x_p on which a mechanical arm is placed.

→ The displacement under measurement (x_i) is applied to mechanical arm due to which arm gets displaced over resistive element

R_p → Total resistance of resistive element

x_t → length of resistive element

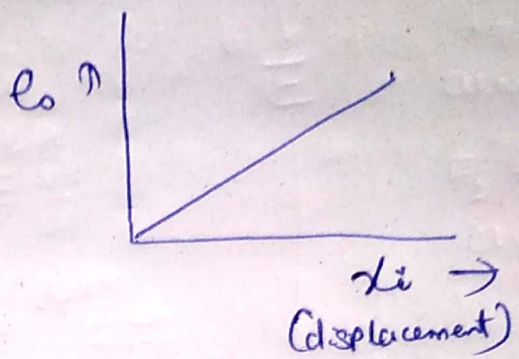
$\frac{R_p}{x_t}$ → resistance / unit length

→ If displacement applied to mechanical arm, displaces it over R_p by x_i then resistance of element under mechanical arm will be $\frac{R_p}{x_t} \times x_i$

→ Voltage under mechanical arm $e_o = \frac{\left(\frac{R_p}{x_t} \times x_i\right)}{R_p} \times e_i$

$\Rightarrow \boxed{e_o = \frac{e_i}{x_t} \times x_i}$ (By voltage division rule)

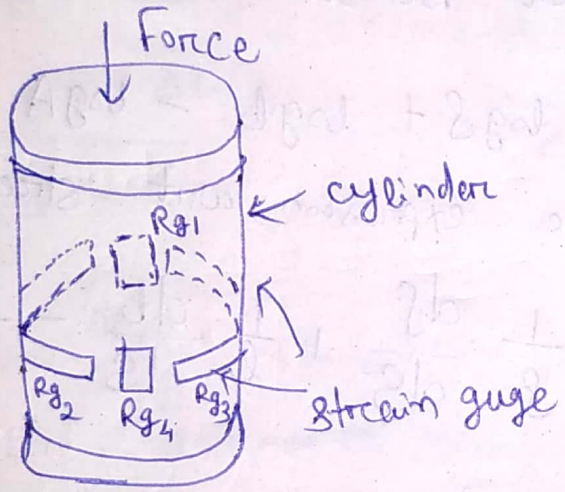
→ Sensitivity $= \frac{\partial e_o}{\partial x_i} = \frac{e_i}{x_i}$ = constant



* Force Transducer

Strain gauge loadcell -

This is a cylindrical tube to which strain gauge have been attached. When force are applied to cylinder to compress it, then strain gauge gives a resistance change which is a measure of strain and hence applied force.



(Load cell)

→ In load cell all four gauges are connected electrically to four arm of wheatsone bridge circuit

Strain gauge

→ When strain gauge is subjected to force (stretched/compress) its resistance changes. By measuring change in resistance, strain can be measured.

→ When strain gauge is subjected to positive strain its length increases while its cross-sectional area decreases. hence resistance changes.

We know that $R = \frac{\rho l}{A}$

$\rho \rightarrow$ Resistivity

$l \rightarrow$ length of conductor

$A \rightarrow$ crosssectional area

Taking log on bothside

$$\log R = \log \rho + \log l - \log A$$

Differentiate above expression wrt stress (S)

$$\frac{1}{R}\frac{dR}{dS} = \frac{1}{\rho}\frac{d\rho}{dS} + \frac{1}{l}\frac{dl}{dS} - \frac{1}{A}\frac{dA}{dS}$$

Putting $A = \pi r^2 = \frac{\pi D^2}{4}$ ($D \rightarrow$ diameter)

$$\frac{1}{R}\frac{dR}{dS} = \frac{1}{\rho}\frac{d\rho}{dS} + \frac{1}{l}\frac{dl}{dS} - \frac{4}{\pi D^2} \times \frac{2\pi D}{4}\frac{dD}{dS}$$

$$\Rightarrow \frac{1}{R}\frac{dR}{dS} = \frac{1}{\rho}\frac{d\rho}{dS} + \frac{1}{l}\frac{dl}{dS} - \frac{2}{D}\frac{dD}{dS}$$

For small variation, the above expression can be expressed,

$$\frac{\Delta R}{R} = \frac{\Delta \rho}{\rho} + \frac{\Delta l}{l} - \frac{2\Delta D}{D}$$

From poission ratio we have

$$\mu = \frac{\text{Lateral strain}}{\text{Longitudinal strain}}$$

$$= \frac{-\Delta A/A}{\Delta l/l}$$

$$= \frac{-\Delta D/D}{\Delta l/l}$$

$$\frac{\Delta R}{R} = \frac{\Delta l}{l}\left(\frac{\Delta \rho/\rho}{\Delta l/l} + 1 - \frac{2\Delta D/D}{\Delta l/l}\right)$$

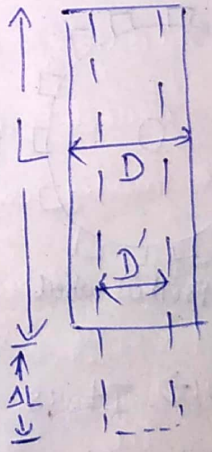
$$\Rightarrow \frac{\Delta R/R}{\Delta l/l} = \frac{\Delta \rho/\rho}{\Delta l/l} + 1 + 2\mu$$

$$\Rightarrow \boxed{G = \frac{\Delta \rho/\rho}{\Delta l/l} + 1 + 2\mu}$$

gauge factor

→ Here $G = \frac{\Delta R/R}{\Delta L/L}$ → gauge factor.

Gauge factor is defined as ratio of per unit change in resistance to per unit change in length.



→ For metal wire strain gauge which exhibit a change in resistance due to change in mechanical dimension. The term $\Delta\rho/\rho = 0$.

Hence gauge factor $G = 1 + 2\mu$

Q) The gauge factor of resistance wire strain gauge using a soft iron wire of small diameter is 4.2. Neglecting the piezo-resistivity effect, calculate poisson's ratio.

Solution-

According to question piezo-resistivity effect is neglected. i.e $\Delta\rho/\rho = 0$

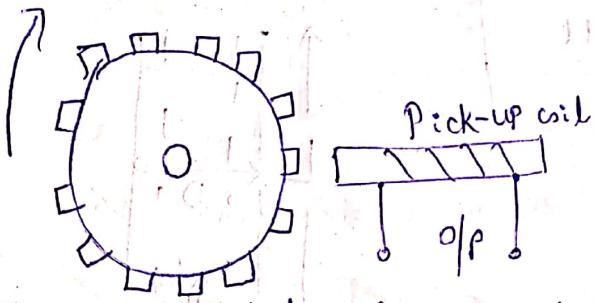
So, $G = 1+2\mu$

$\Rightarrow 4.2 = 1+2\mu$

$\Rightarrow \mu = \frac{4.2-1}{2} = 1.6$ (Ans)

* Velocity Sensor -

① Variable reluctance tachogenerator -



(Variable reluctance Tachogenerator)

⇒ It is used to measure angular velocity.

Construction → It consists of toothed wheel of ferromagnetic material which is attached to rotating shaft.

→ Pickup coil is wound on a permanent magnet.

Working principle -

As wheel rotates, teeth move past the coil and air gap between coil & ferromagnetic material changes

Thus flux linked by a pick-up coil changes and produces alternating emf in coil.

→ The reluctance of circuit depends on the width of air gap between toothed wheel and coil. When tooth is close to ~~pole~~ pi coil, the reluctance is minimum and it increases when tooth moves away from coil. So it is called variable reluctance tachogenerator.

→ Flux change with time for coil can be written as

$$\phi = \phi_0 + \phi_a \cos n\omega t$$

where ϕ_a → amplitude of flux variation

n → no. of teeth

ω → angular velocity

ϕ_0 → Mean value of flux

From faraday's law

$$e = -N \frac{d\phi}{dt}$$

(e → induce emf, N → no. of turn in pick-up coil)

$$= -N \frac{d}{dt} (\phi_0 + \phi_a \cos n\omega t)$$

$$= N \phi_a n\omega \sin(n\omega t)$$

$$\Rightarrow e = E_{max} \sin n\omega t$$

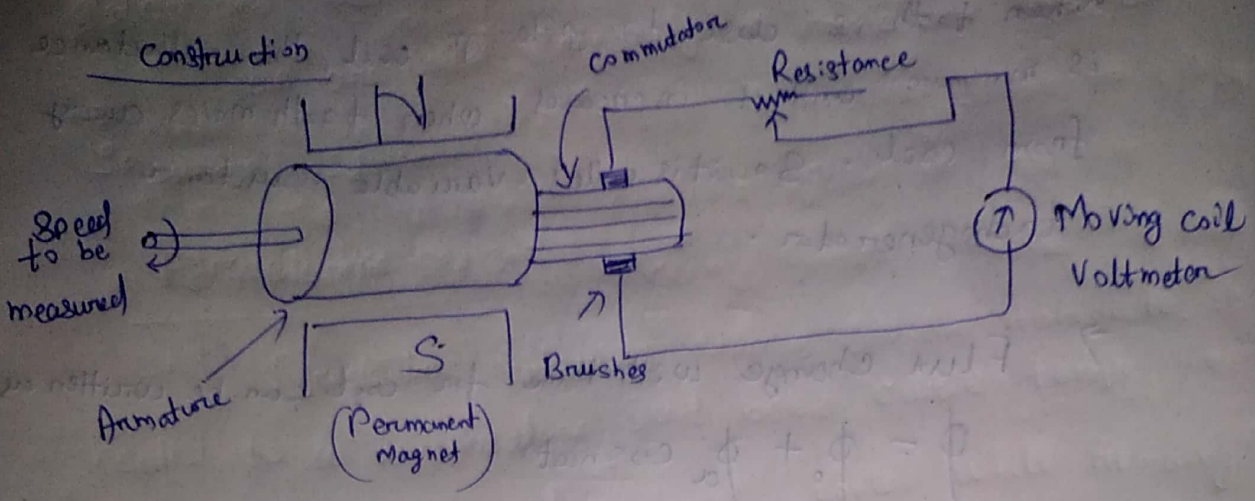
where $E_{max} = N \phi_a n\omega$

→ Tachogenerator is used to measure angular velocity in terms of emf.

② DC Tachogenerator

→ This is used to measure angular velocity.

Construction



→ It consist of small armature. This armature revolves in magnetic field of a permanent magnet.

Working -

When armature revolves between constant field of permanent magnet, the emf is induced. The commutator converts the alternating current of armature to direct current with the help of brushes. The moving coil voltmeter measures the induced emf.

→ The resistance is connected in series with voltmeter to limit current.

Advantage -

→ The polarity of induced emf determines the direction of motion of shaft.

Disadvantage -

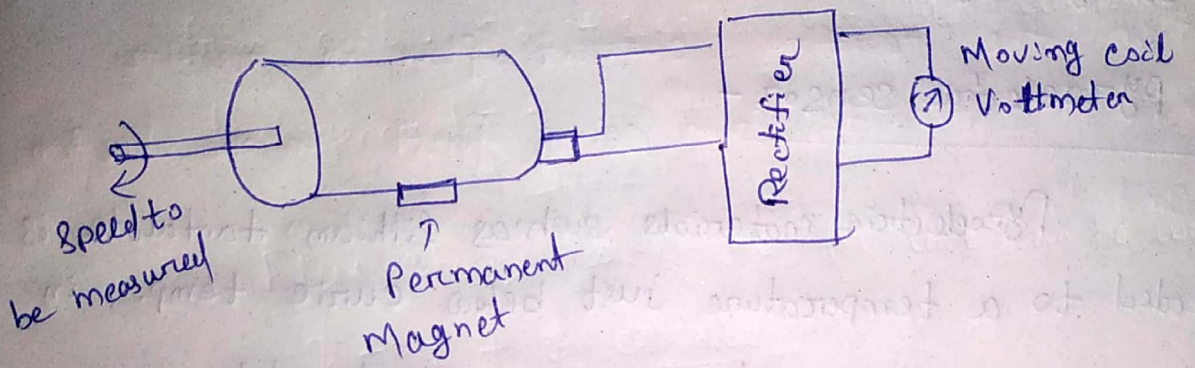
Brushes and commutator require Periodic maintenance. As their ~~cons~~ contact resistace vary which causes error.

③ AC Tachogenerator

→ This is used to measure angular velocity.

→ In order to overcome some difficulties of dc tachogenerator, ac tachogenerator are used.

Construction-



→ The tachogenerator has rotating magnet.

→ The armature is provided with AC winding, either single phase or three phase.

→ It consist of rectifier for converting ac to dc voltage.

Working-

When rotor is stationary and primary winding excited by Ac voltage, the induced voltage in secondary is zero. ~~Due to~~ As rotor rotates, a voltage is induced in secondary winding whose magnitude is proportional to rotor speed.

→ The o/p voltage is rectified and measured with voltmeter.

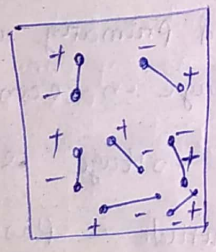
* Motion Sensor

It is an electronic device that is used to detect and measure movement.

These are used primarily in home and business security system.

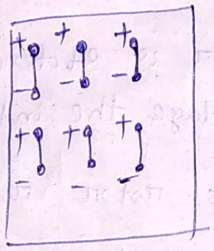
Pyroelectric sensor -

Pyroelectric materials such as lithium tantalate, is heated to a temperature just below curie temp., in an electric field and material cooled while ~~remaing~~ remaining in field, electric dipoles within material line up and become polarised. When the field is then removed the materials retains its polarisation.



(a)

(The material before polarisation)

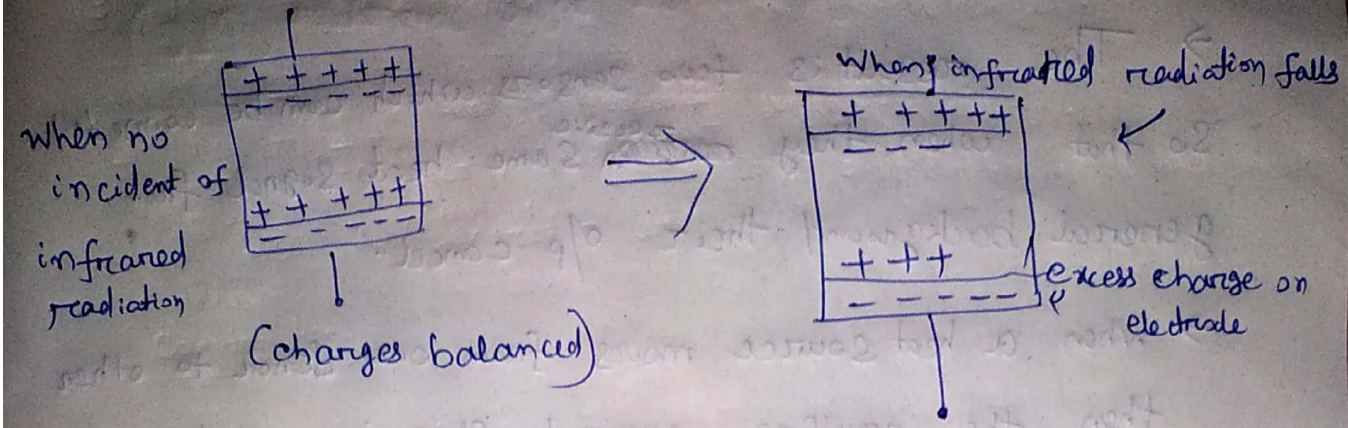


(b)

(material after polarisation)

→ pyroelectric sensor consist of polarised pyroelectric crystal with metal electrodes on opposite side.

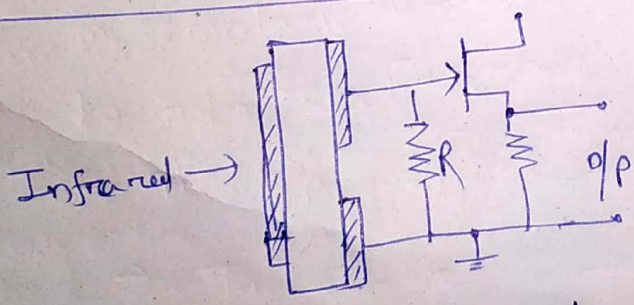
→ Ions are drawn from surrounding air and electron from measurement circuit connected to sensor to balance surface charge.



→ If infrared radiation is incident on crystal and changes its temperature, the polarisation is reduced and consequently there is a reduction in charge at surfaces. Which results, there are excess charges on metal electrode. This excess charge leaks through away through measurement circuit.

→ Thus pyroelectric sensor behave as charge generator which generates charge when there is change in temperature as a incidence of infrared radiation.

Dual pyroelectric sensor

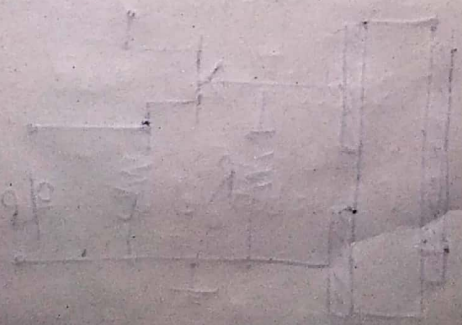


→ It can distinguish between general background heat radiation and motion of human or other moving heat source.

→ It consist of single front electrode and two back electrode.

→ The result is two sensors which can be connected so that when they receive same heat signal from general background their o/p cancel.

→ When a heat source moves from one sensor to other then the resulting current flow in resistor and it alternates from being first in one direction and then reversed to other direction.

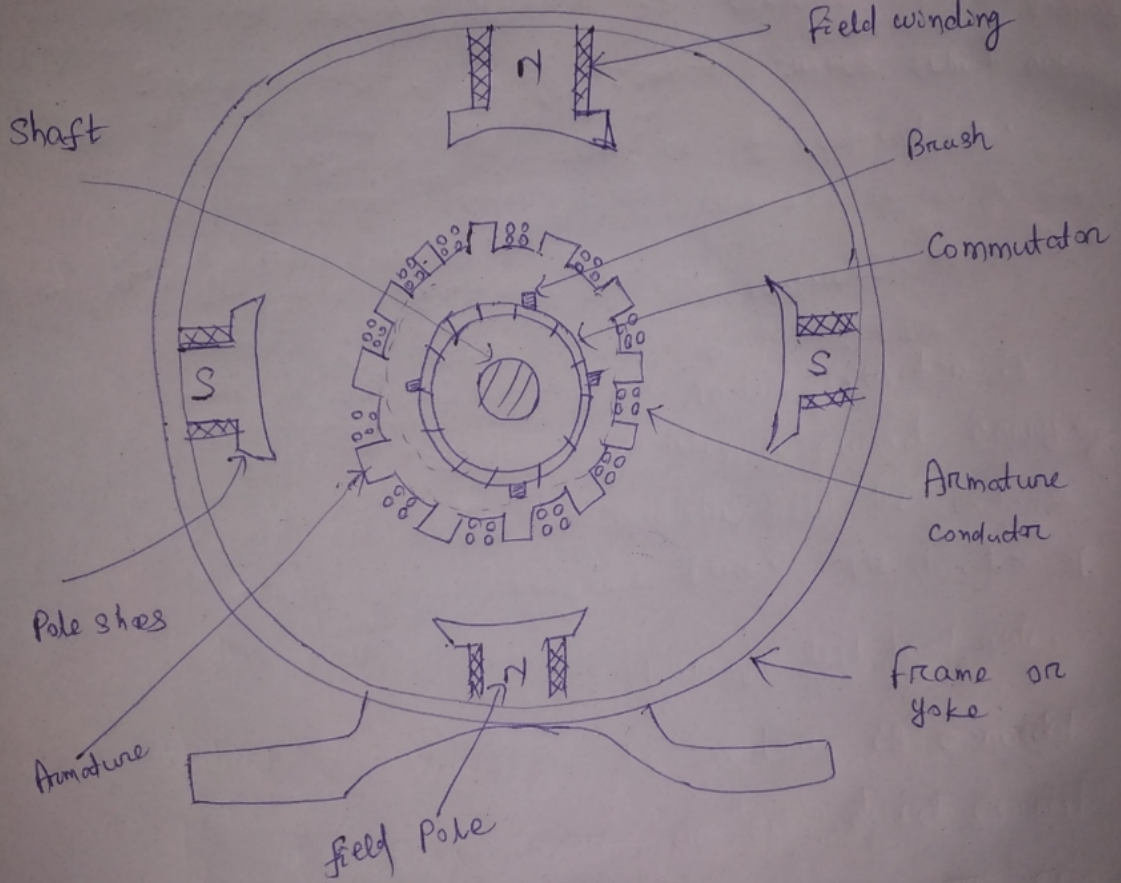


D.C. Motor

An electric motor is a machine which converts electrical energy into mechanical energy.

*D.C Motor — Construction —

DC motor look just like dc generator.



It consist of (i) Yoke
(ii) Field poles and pole shoes
iii) Field coil or winding
iv) Armature assembly
v) Brush

i) Yoke- The yoke or outer frame is of cylindrical shape and serves three main purpose.

a) It supports magnetic pole and field coil which produce magnetic flux.

b) It carries the magnetic flux that passes from field poles to armature.

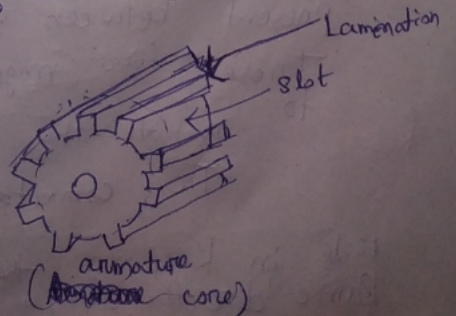
c) It protect the whole machine.

ii) Field pole and pole shoes- These are made of highly magnetic alloys. The become electromagnet when current is passed through field winding.

iii) Field coil/ winding - These coils consist of copper wire. When direct current is passed through them, they electromagnetise the field poles which produce strong magnetic field around the armature.

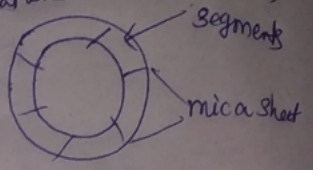
iv) Armature assembly - The armature assembly consists of a shaft, armature core, armature winding and a commutator.

→ Armature core is laminated to reduce eddy current loss and has slots ~~to receive~~ for armature winding.



→ The shaft supports entire armature assembly.

→ Commutator is made up of copper segments. These segments are insulated by thin mica sheet. Commutator plays role in keeping armature rotating in same direction.



V) Brush ~~& bearing~~ -

The ~~brushe~~ current is conducted from voltage source to armature by carbon brushes which are held against the surface of commutator.

* Principle and operation of d.c motor -

D.C motor principle - DC motor operation is based on principle that when a current carrying conductor placed in magnetic field, the conductor experiences a mechanical force. The direction of this force is given by Fleming's left hand rule.

Working - When a d.c motor is connected to dc voltage source, ~~dc cw~~ direct current flows through armature conductor. The flow of current produces ~~ar~~ armature field. ~~Now~~, there are two magnetic field in air-gap present between field shoes and armature core. These two magnetic field react with eachother to rotate the armature.

The commutator ~~plays a~~ plays a important role in keeping the armature rotating in the same direction.

~~Same direction~~

Back emf —

When motor armature rotates, its conductor cut the magnetic flux. Therefore e.m.f is induced in them. This is known as back emf. The back emf opposes the applied voltage.

$$E_b = \frac{P\phi ZN}{60A}$$

where $\phi \rightarrow$ ~~useful~~ flux/pole in weber

$Z \rightarrow$ Total no. of armature conductor

$P \rightarrow$ no. of pole

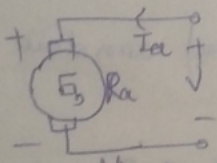
$N \rightarrow$ armature speed in r.p.m

$A \rightarrow$ no. of parallel path in armature

For a Lapwinding motor $A = P$

wave winding motor $A = 2$

* Equivalent circuit of a D.C motor armature —



$V_b \rightarrow$ brush voltage drop

$V \rightarrow$ applied voltage

$R_a \rightarrow$ armature resistance

$I_a \rightarrow$ armature current

$$V = E_b + I_aR_a + V_b$$

Neglecting brush voltage drop

$$\boxed{V = E_b + I_aR_a}$$

* Torque equation of motor —

P_a = Power developed in armature $= E_b I_a$

As $P_a = T \times \omega$

$\Rightarrow P_a = T \times \frac{2\pi N}{60}$

$$\Rightarrow T = \frac{60 P a}{2\pi N} = \frac{60\ E_b \times I_a}{2\pi N}$$

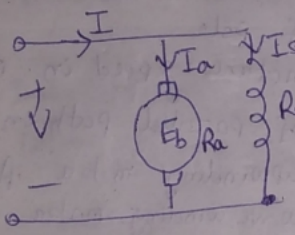
$$\Rightarrow T = \frac{30}{\pi N} \times \left(\frac{P \phi Z N}{60 A}\right) I_a$$

$$\Rightarrow T = 0.159\, \phi Z I_a \left(\frac{P}{A}\right) \quad \text{N-m}$$

* Types of D.C motor-

(i) Shunt wound motor-

→ Field ~~Shunt~~ winding and armature ~~winding~~ are connected parcallel.



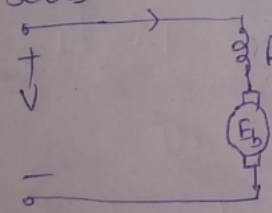
$$I = I_a + I_{sh}$$

$$V = E_b + I_a R_a$$

$$= I_{sh} R_{sh}$$

ii) Series wound motor-

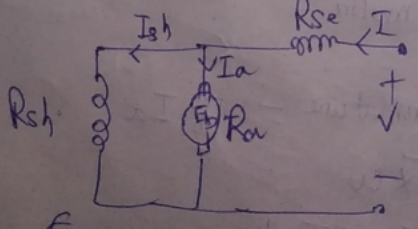
→ field winding and armature are in series.



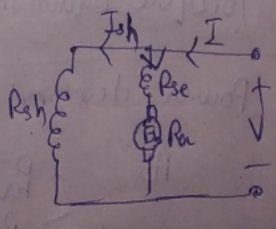
$$V = E_b + I(R_a + R_{se})$$

iii) Compound wound motor-

Compound motor has both series and shunt winding.



(Short - shunt compound d.c motor)



(Long - shunt compound d.c motor)

* Characteristic of series motor -

1) Torque and armature current (T_a / I_a) characteristic -

$T \propto \phi I_a$

For series motor upto saturation

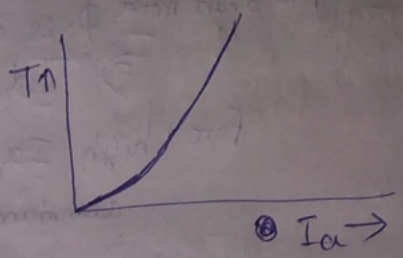
$\phi \propto I_a$

$\Rightarrow T \propto I_a^2$

After saturation

ϕ = constant

$T \propto I_a$



2) Speed and Force armature current (N / I_a) characteristic -

$N \propto \frac{E_b}{\phi}$, &

$N \propto \frac{V_t}{\phi}$

As, V_t is fixed

$N \propto \frac{1}{\phi}$

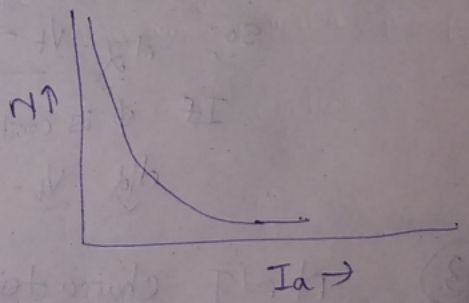
As $\phi \propto I_a$

$\Rightarrow N \propto \frac{1}{I_a}$

$E_b = V_t - I_a (R_a + R_{se})$

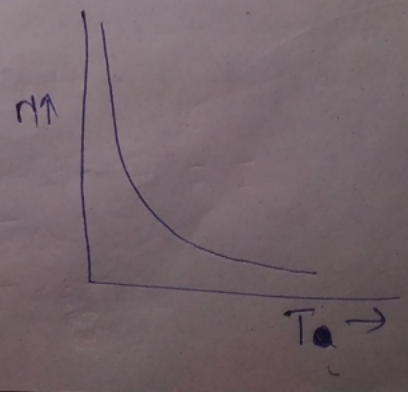
For low value of I_a,

$I_a(R_a + R_{se})$ is negligible



3) Speed and Torque (N / T) characteristic -

It is found from above (T / I_a) & (N / I_a) characteristic that when speed is high, torque is small & vice versa.



Characteristic of Shunt motor -

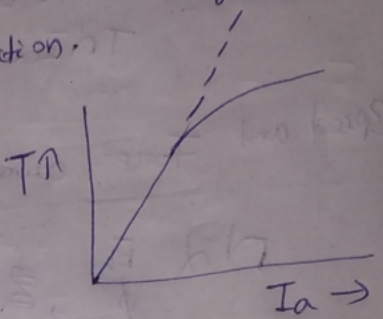
① T_a / I_a characteristic -

$$T \propto \phi I_a$$

For shunt motor, ϕ is constant,

$$\Rightarrow T \propto I_a$$

For high I_a, ϕ decreases slightly due to armature reaction.



② N / I_a characteristic -

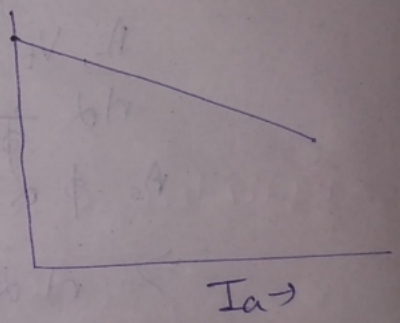
$$N \propto \frac{E_b}{\phi}$$

As $E_b = V_t - I_a R_a$

So; $N \propto \frac{V_t - I_a R_a}{\phi}$

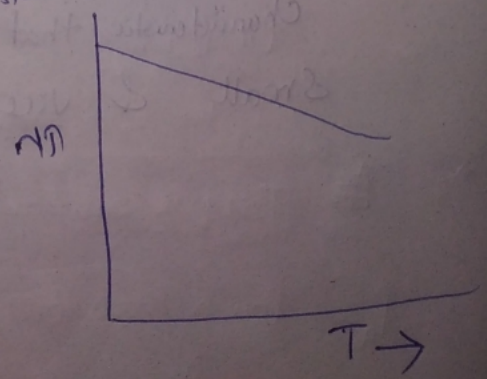
If ϕ is constant then

$N \propto V_t - I_a R_a \uparrow$



③ N ~ T characteristic -

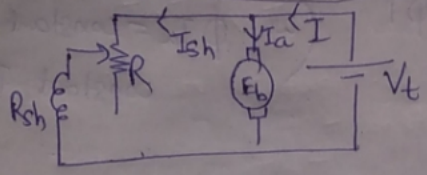
- The characteristic can be drawn from (T_a / I_a), (N / I_a) characteristic.



* Speed control of D.C. Motor -

Speed control of Shunt motor -

(i) Variation of flux or Flux control method -

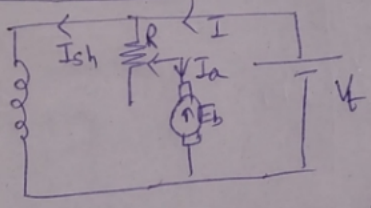


The method of varying the speed of motor by controlling the field current.

$N \uparrow \propto \frac{E_b}{\phi \downarrow}$

$\phi \downarrow \propto \uparrow \uparrow$ The connection of R reduces field current and hence flux(ϕ) decreases. So speed increases.

ii) Armature Rheostatic control method -



The method of varying the speed of motor by varying the armature voltage (back Emf E_b) ~~by~~ by keeping flux constant.

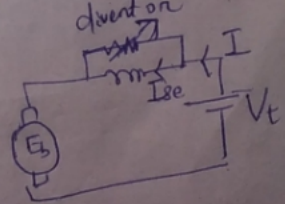
$E_b = V_t - I_a(R_a + R_e)$

As E_b decrease speed of motor decreases. ($\because N \propto \frac{E_b}{\phi}$)

Speed control of series method

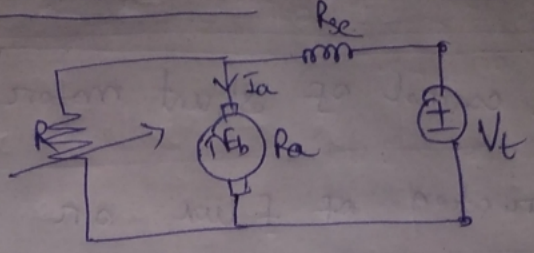
(i) Flux control method -

(a) Field diventor -



Due to diventor, Ise decreases So, flux decrease. As a result speed can be increased. ($\because N \uparrow \propto \frac{E_b}{\phi \downarrow}$)

(b) Armature diversion-

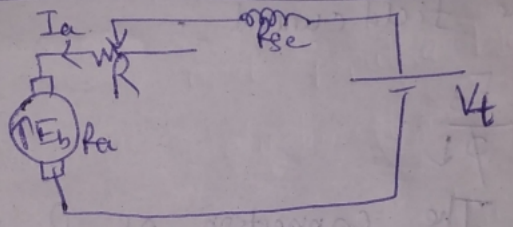


For a constant torque, if $I_a \downarrow$ then $\phi \uparrow$ (as ϕI_a = constant for constant Torque)

then $N \propto \frac{E_b}{\phi \downarrow}$

(ii) Armature Rheostatic method-

$E_b \downarrow = V_t - I_a(R \uparrow + R_a)$



By increasing resistance R, E_b decreases. So speed is reduced.

Stepper Motor

→ The stepper motor is a device that produces rotation through equal angle, the so called steps, for each digital pulse supplied to its input.

Thus for example, if one pulse produces a rotation of 6° then 60 pulse produce a rotation of 360°.

→ There are three most popular types of stepper motor

1) Variable Reluctance type
2) Permanent magnet type
3) Hybrid type

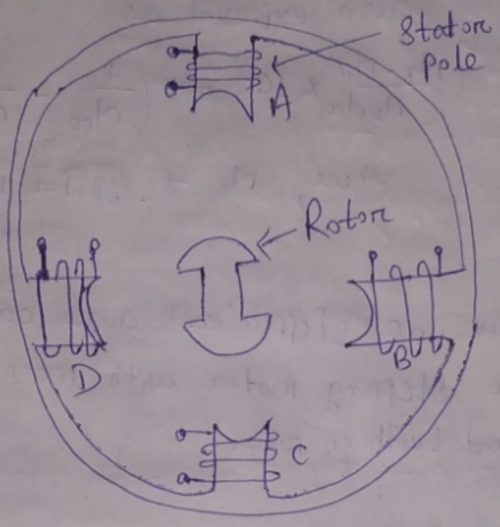
1) Variable Reluctance type

The principle of operation of this type of stepper motor is based on property that flux line to occupy low reluctance path. The stator and rotor therefore get alligned such that magnetic reluctance is minimum.

Construction-

→ It has salient-pole stator. The stator has concentrated winding placed over poles. The no. of phase of stator depends upon connection of stator. These phase are excited with DC source through electronic switching device.

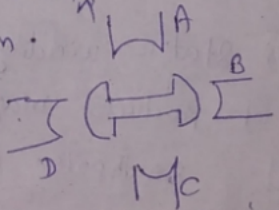
→ The rotor is made from ferromagnetic material and carries no winding.



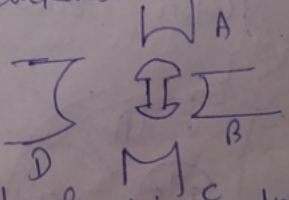
operation-

→ When winding 'A' is excited, the rotor aligns with axis of phase A where reluctance of flux path is minimum.

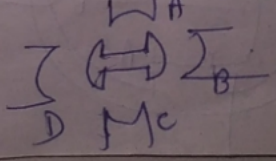
→ When phase B is excited & 'A' is disconnected the rotor moves 90° in clock wise direction.



→ When phase 'C' is excited & 'B' is disconnected, the rotor moves, 90° in clockwise direction.



→ When phase 'D' is excited & 'C' is disconnected, the rotor again moves 90° in clockwise direction.



→ The magnitude of any ~~st~~ permanent or variable ~~reel~~ reluctance stepper motor is given by,

$$\alpha = \frac{360^\circ}{m N_r}$$

where, m → no. of stator phase

N_r → no. of rotor teeth

→ step angle is also expressed as

$$\alpha = \frac{N_s - N_r}{N_s N_r} \times 360^\circ = \left(\frac{1}{N_r} - \frac{1}{N_s}\right) 360^\circ$$

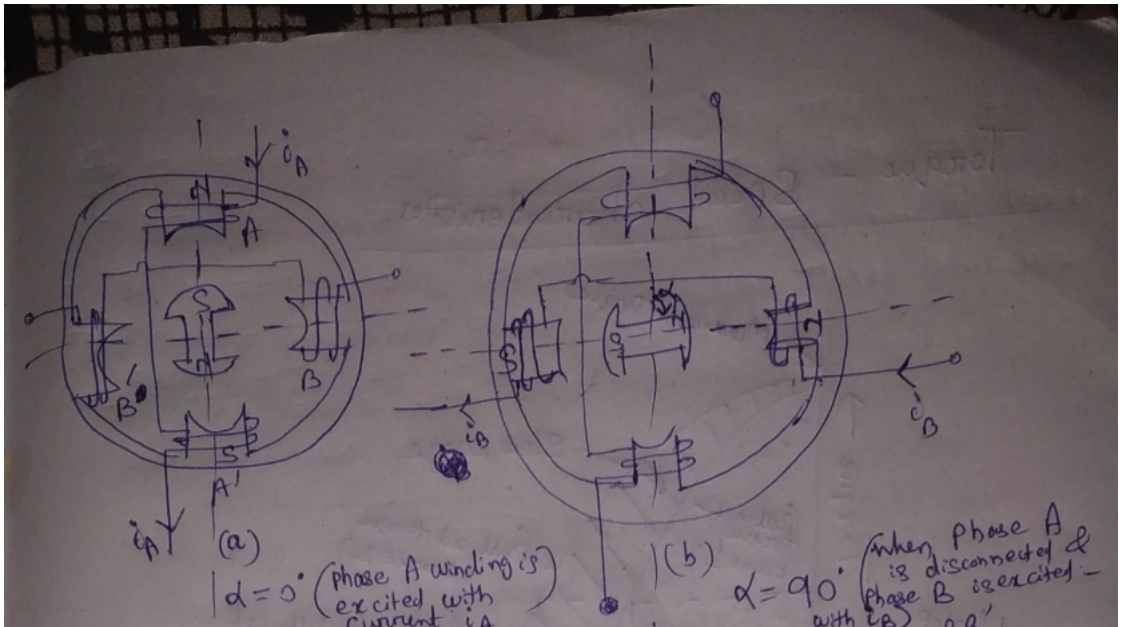
where, N_s → stator poles (or stator teeth)

→ Lower value of stepper ~~mot~~ angle can be obtained by using a stepping motor with more no. of poles on stator and teeth on rotor.

2) Permanent magnet stepper motor -

→ Here stator is similar to variable reluctance type motor but ~~motor~~ rotor poles are permanent magnet.

→ When stator windings are are excited with DC supply, it produces magnetic flux and establishes north and south pole. Due to force of attraction and repulsion between permanent magnet rotor & stator poles, rotor starts moving.



$\alpha = 0°$ (phase A winding is excited with current i_A)

$\alpha = 90°$ (when phase A is disconnected & phase B is excited with i_B)

→ The two coil A-A' connected in series and BB' connected in series.

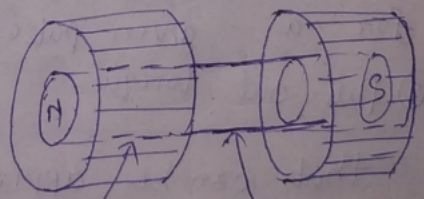
Hybrid stepper motor

→ A hybrid stepper motor combines the features of variable reluctance and permanent magnet stepper motor.

→ The permanent magnet is placed axially along the rotor in form of annular cylinder.

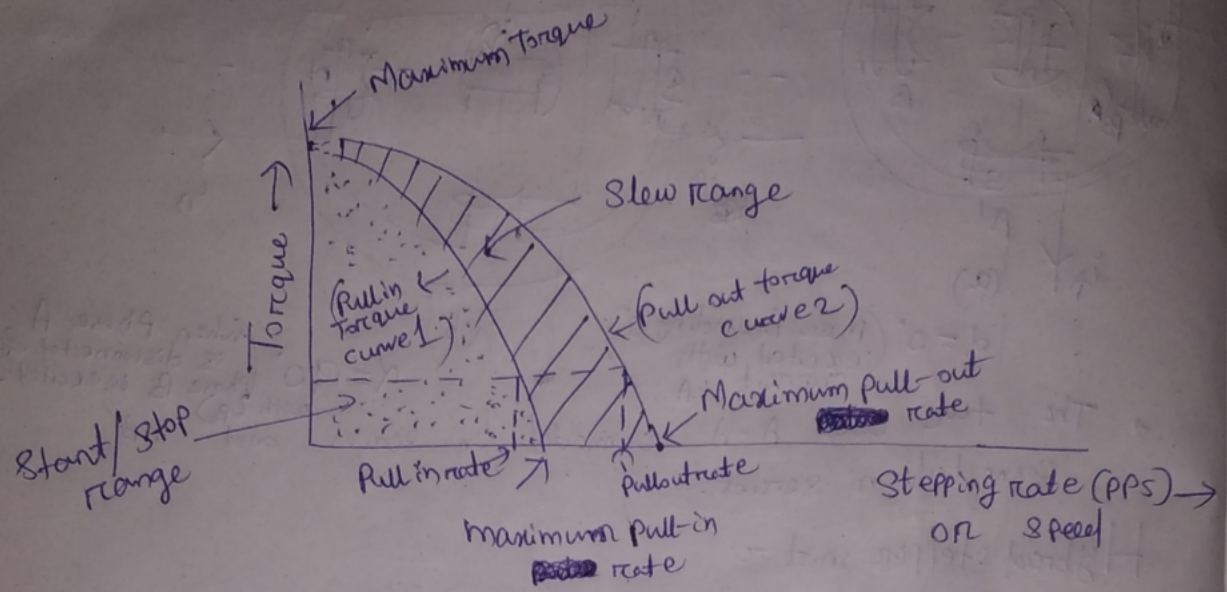
→ The stack at each end of rotor are toothed.

~~→ The stack at each end of rotor~~



→ The rotor sets itself in minimum reluctance position in response to a pair of stator coil being energised.

Torque - Speed characteristics



Specification-

① Holding Torque — This is maximum torque that can be applied to a powered motor without moving it from its rest position and causing spindle rotation

② Pull-in torque- This is the maximum torque against which a motor start, ~~synchronise~~ for a given pulse rate and reach synchronise.

③ Pull-out torque- This is maximum torque that can be applied to a motor, running at a given pulse rate, without losing synchronisation.

④ Pull-in rate - This is the maximum stepping rate at a given load torque, motor can start, synchronise, stop or reverse without missing pulses.

⑤ Pull-out rate - This is the maximum stepping rate at a given load torque, motor remain in synchronism without missing pulses. Beyond this motor loose synchronism.

⑥ Slew range - It is the range between pullin & pull-out curve within which motor runs in synchronism but can not start or reverse.

Application of stepper motor -

→ paper feed motors in printers
→ used in computer disk drives
→ positioning of work table in controlled machining equipments
→ used to perform various function such as cutting, bending, mixing in commercial, medical application.

Q) Calculate step angle for 3-phase, 16-tooth variable reluctance motor.

Soln- $m = 3$
$N_r = 16$.
$$\alpha = \frac{360}{m N_r} = \frac{360}{3 \times 16} = 7.5^\circ \quad \text{(Ans)}$$

Servo motor

Servo motor are also called control motor.

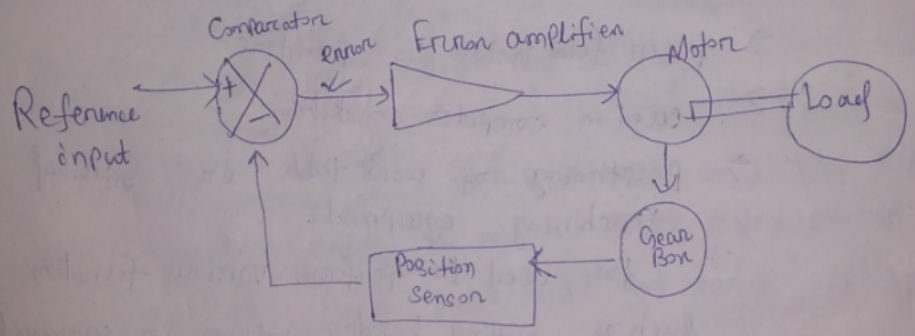
Servo motor controls position and speed precisely.

These motors are used in feedback control system as output actuators.

→ They have low rotor inertia and therefore, they have a high speed of response.

→ Servomotors are widely used in roadcar, computer, robot, machine tools, tracking ~~system~~ & guidance system etc.

Working Principle of servo motor –



A servo motor has four major components.

i) Motor
ii) Position sensor
iii) Gear assembly
iv) control circuit

- Position sensor provides a feedback signal corresponding to the present position of load. This sensor is normally a potentiometer that produces the voltage corresponding to position. Then the feedback voltage is applied to ~~error amp~~ comparator.

The comparator compares reference input to feedback signal and gives error signal which is then applied to motor after amplification.

① AC Servomotor

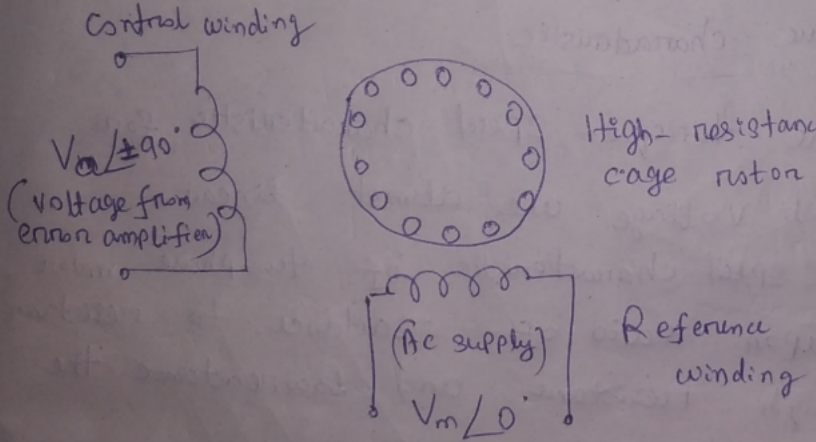
Twophase AC Servomotor -

→ It consist of (i) stator, (ii) Rotor

→ The stator has two distributed windings which are displaced from each other by 90° electrical.

→ one winding is called reference winding and is excited by constant ac voltage.

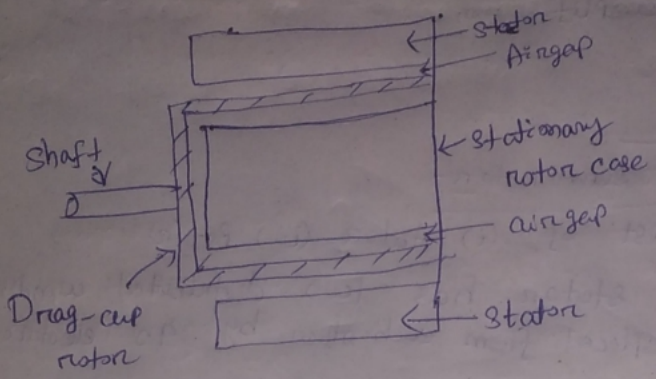
→ The other winding is called control winding and is excited by variable control voltage of same frequency as the reference winding but have phase displacement of 90° electrical.



→ The control winding is supplied from error amplifier.

→ The direction of rotation of rotor can be reversed by reversing phase difference between reference winding & control winding.

Rotor of AC Servomotor -

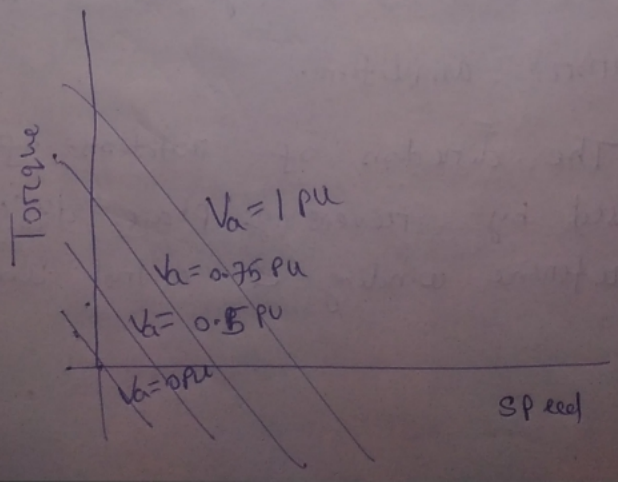


(Drag cup servomotor)

In dragcup type there are two air gap. for rotor a cup of non-magnetic material is used. A stationary iron core at middle of conducting cup completes the magnet circuit.

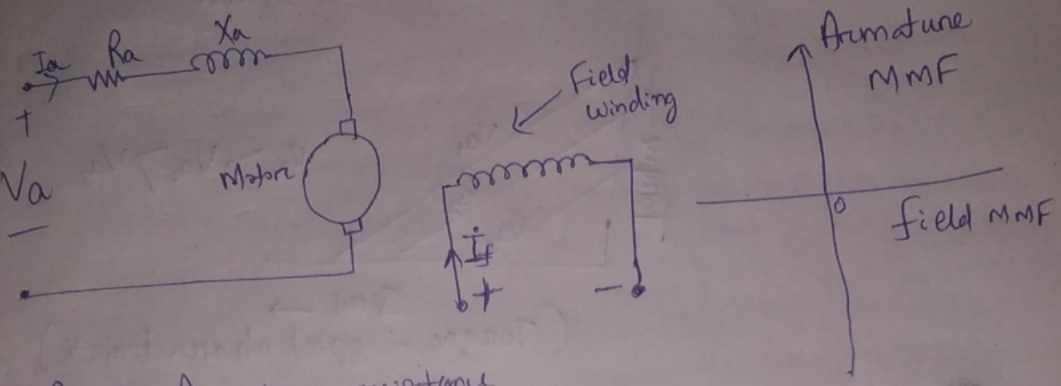
Speed - Torque characteristic

The torque- speed characteristic for various control voltage are almost linear. The torque speed characteristic of two phase motor depends upon ratio of reactance to resistance. For high resistance and low reactance the characteristic is linear.



② DC Servomotor –

DC servomotor are separately excited DC Motor.



Ra → Armature resistance

Xa → Armature reactance

Ia → armature current, If → field current

There are two method to control speed of DC servomotor

(i) Armature control method

(ii) Field flux control method.

(i) Armature control method –

Error signal is given to armature and keeping field current constant.

We know that $T \propto \phi I_a$

$\Rightarrow T \propto I_f I_a$ $(\because \phi \propto I_f)$

As I_f is constant

$$\boxed{T \propto I_a}$$

Torque

(ii) Field flux control method –

Error signal is given to field winding and keeping armature current constant.

$$T \propto \phi I_a$$

$$\Rightarrow T \propto I_f I_a$$

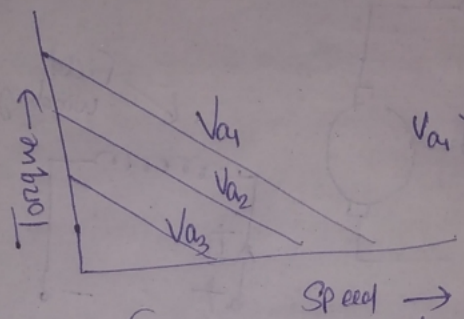
As I_a is constant

$$\Rightarrow \boxed{T \propto I_f}$$

→ In field controlled DC servomotor time response is slow and hence they are not commonly used.

→ The armature of DC servo motor has large resistance and ~~therefore~~ small reactance.

So torque-speed characteristic is linear.



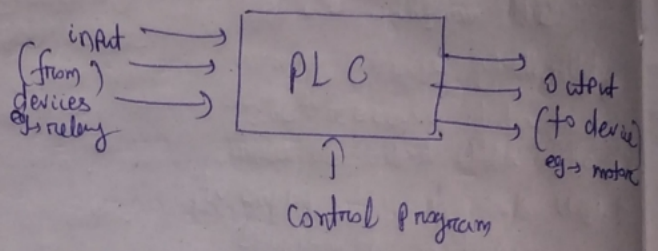
$V_{a_1} > V_{a_2} > V_{a_3}$

(Torque - speed characteristic)

Programmable logic controller (PLC)

→ PLC is a digital electronic device that uses a programmable memory to store instruction and to implement function such as logic, sequencing, timing, counting and airthmatic in order to control machine and processes.

→ It has been specifically designed to make programming easy.



Advantage-

→ It is possible to modify a control system without having rewire the connections to input and output devices.

→ PLC are also much faster than relay-operated system.

Special Features

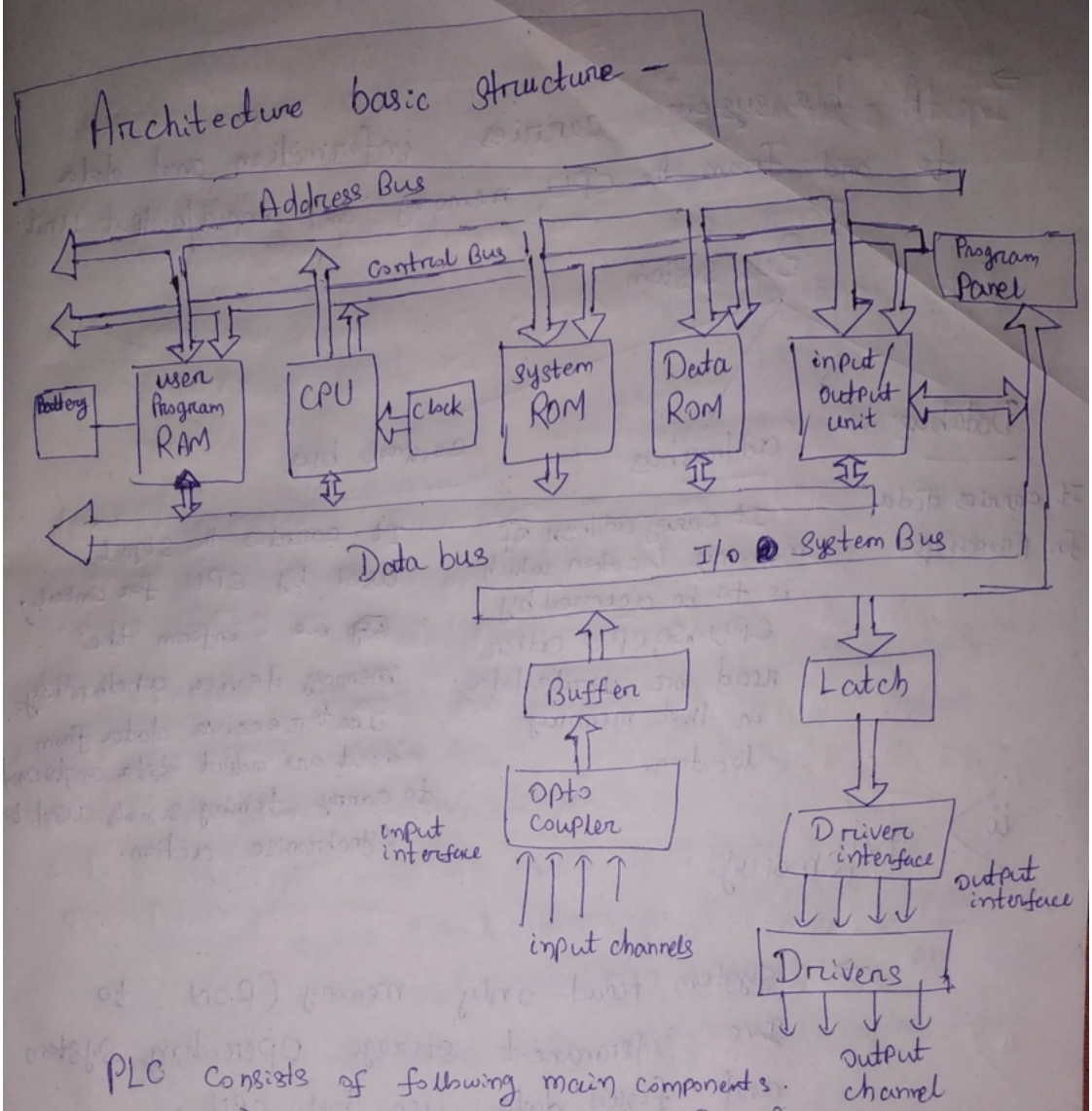
Although PLC are similar to computers, yet they have following specific features.

i) The interfacing for input and output is inside the controller.

ii) Easily programmable.

iii) Rugged and designed to withstand vibration, temperature, humidity and noise.

Architecture basic structure –



PLC consists of following main components.

i) Central processing unit (CPU)

ii) Memory

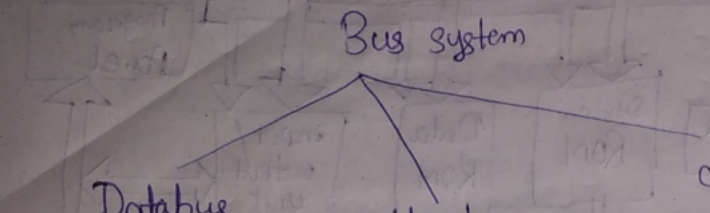
iii) i/p and o/p circuitry

i) CPU –

→ It controls and processes all the operation within the PLC.

→ It is provided with a "clock" with a frequency of typically between 1 and 8 MHz. This frequency determines the operating speed of PLC and provides timing and synchronisation for all element in the system.

→ A "bus system" carries information and data to and from the CPU, memory and input/output unit.



Databus

It carries data for processing.

Addressbus

It carry address of memory location which is to be accessed by CPU. So, CPU either read or write data in that memory location.

Control bus

It carries the signal used by CPU for control, i.e inform the memory device whether they are to receive data from input or output ~~data and to~~ and to carry timing signals used to synchronise action.

ii) Memory

→ System read-only-memory (ROM to give permanent storage Operating system and fixed data use by CPU.

→ Random-access-memory (RAM) for storing user's program.

→ Data RAM - This where information is stored on status of input and output devices and values of timer and counters.

iii) input/output (I/O) circuitry

→ The I/O unit provides the interface between PLC system and outside world.

→ The I/O interface provide isolation and signal conditioning function so that ~~Sensors~~ input or output device can directly connected to them without need for other circuitry. Optocouple gives the electrical isolation.

→ The digital signal which is compatible with microprocessor in PLC is 5 V d.c.
However signal conditioning in input channel, with isolation, enables a wide range of i/p signals i.e 5V, 12V, 110V, 240V.

→ The o/p will be digital with level of 5V.
However, after signal conditioning with relay, transistor or triac, the output can be 24V, 100mA or ~~110V~~ dc voltage of 110V, 1A or a.c voltage of 240V, 1A.

Relay type output

→ Relatively slow
→ can be used both for a.c and d.c switching
→ no need of optoisolator
eg→ 24V, 100mA.

Transistor type output

→ Faster
→ only for dc switching
→ need optoisolator
eg→ d.c 110V, 1A

Triac type output

→ only for a.c switching
→ need opto isolator
eg. a.c 240V, 1A

Input/output processing –

There are two methods that can be used for input/output processing. i) continuous updating
ii) mass input/output copying.

i) continuous updating –

→ CPU is continuously running through its program and updating it as a result of input signal. Each such loop is called cycle. Each input channels are scanned and its effect on program determined and output correspondily changed. This mode of operation is termed continuous updating. There will be built-in delay, when each input is examined in order to ensure that only valid input signals are read by CPU.

ii) Mass input/output copying –

→ Because with continuous updating, the time taken to examine several hundred input/output points can become comparatively long. To allow a more rapid execution of a program, a specific area of RAM is used as a buffer store.

→ At start of each program cycle, the CPU scan all inputs and copies their status onto RAM. After the program is executed the outputs s/g are stored in RAM. At end of program cycle all outputs are transferred from RAM to output channels.

The sequence is

a) Scall all inputs and copy onto RAM

b) fetch and decode and execute Program instruction, copying output to RAM.

c) update all outputs.

d) Repeat all sequence

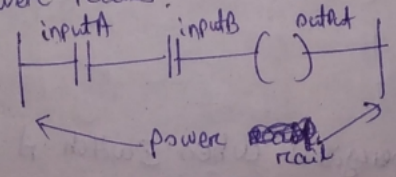
Ladder Programming

→ This involves each Program task being specifically as though a rung of a ladder.

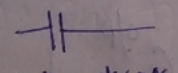
→ The sequence followed by a PLC when carrying out a Program

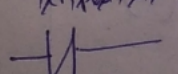
1) Scan i/p with one rung of ladder Program
2) Solve logic operation of that rung
3) Set/Reset the output for that rung
4) Move on to next rung and repeat operation 1,2,3 and so on untill the end of Program with each rung of ladder scanned. The PLC then goes back to begining of Program and starts again.

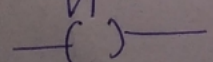
→ The ladder diagram consists of two vertical lines representing power rails.

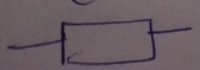


Ladder symbol

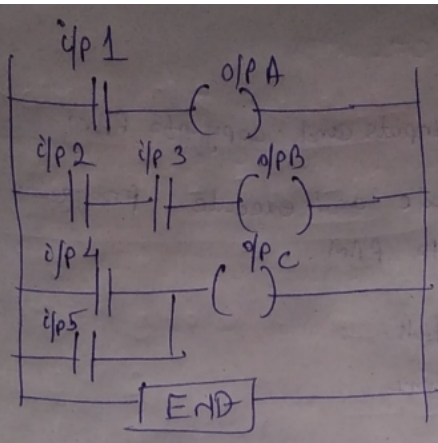

(normally open contact)


(normally closed contact)


(output)


(Special instruction)

eg →



o/p A occurs when i/p 1 occurs

o/p B occurs when i/p 1 and i/p 3 occurs

o/p C occurs when i/p 4 or i/p 5 occurs

end of program

Logic functions -

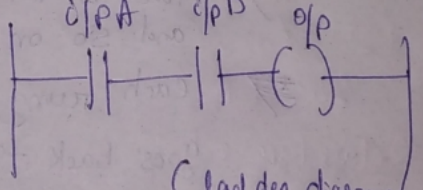
The logic functions can be obtained by combination of switches.

i) AND

Normally switch A and B ~~both~~ have both to be closed to energise output.

Truth Table -

A	B	(o/p = AB)
0	0	0
0	1	0
1	0	0
1	1	1



(ladder diagram of AND)

Here 1 represent ON s/g

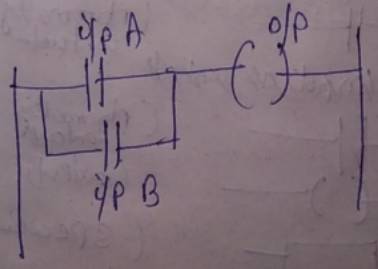
0 " OFF s/g

ii) OR

o/p is energised when switch A or B or both are closed.

Truth table -

A	B	(o/p = A+B)
0	0	0
0	1	1
1	0	1
1	1	1

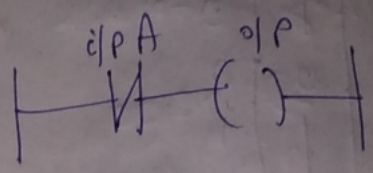


iii) NOT

→ Here there is o/p when there is no i/p and no o/p when there is an i/p.

Truth table-

A	(o/p = $\bar{A}$)
0	1
1	0

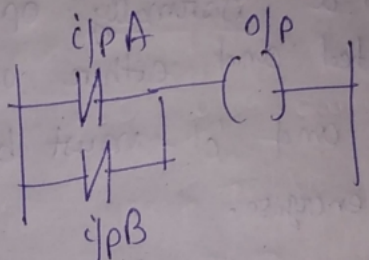


iv) NAND

→ AND gate is followed by a NOT gate.

Truth table

A	B	(o/p = $\overline{AB} = \bar{A}+\bar{B}$)
0	0	1
0	1	1
1	0	1
1	1	0

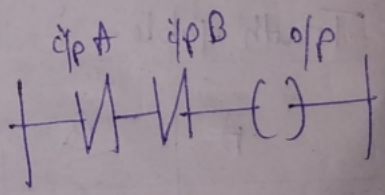


v) NOR

→ OR gate is followed by a NOT gate.

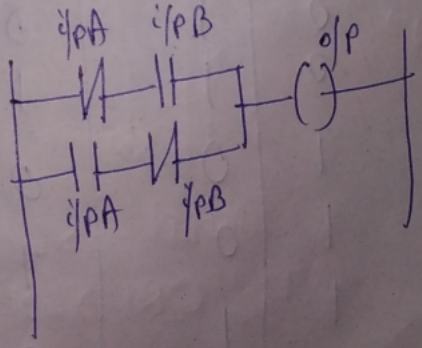
Truth table

A	B	(o/p = $\overline{A+B} = \bar{A}\cdot\bar{B}$)
0	0	1
0	1	0
1	0	0
1	1	0



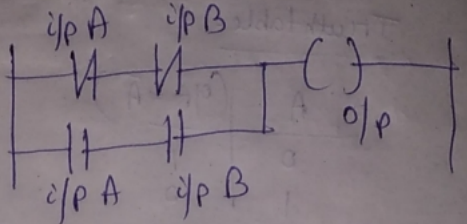
vi) Exclusive OR (XOR) -

A	B	o/p = $\bar{A}B + A\bar{B}$
0	0	0
0	1	1
1	0	1
1	1	0



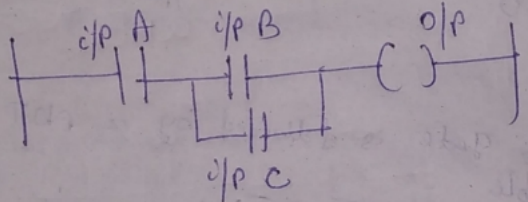
vii) Exclusive NOR (XNOR):-

A	B	O/P = $\bar{A}\bar{B} + AB$
0	0	1
0	1	0
1	0	0
1	1	1



Q) Draw the truth table and ladder diagram. When a normally open switch 'A' must be activated and either of two, normally open, switches 'B' and 'C' must be activated for a coil to energise.

Ans:-



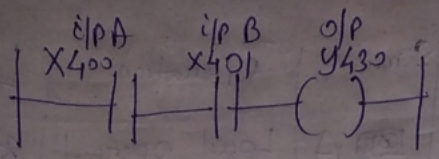
Truth table:-

A	B	C	O/P
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

Instruction lists

IEC 1131-3	Mitsubishi	OMRon	Simens	Operation	Ladder Diagram
LD	LD	LD	A	Load operand into result register	Start a rung with open contact
LDN	LDI	LD NOT	AN	Load negative operand into result register	Start a rung with closed contact
AND	AND	AND	A	Boolean AND ~~with~~	A series element with open contact
ANDN	ANI	AND NOT	AN	Boolean AND with negative operand	A series element with closed contact
ORN	ORI	OR NOT	ON	Boolean OR with negative operand	A parallel element with open contact
OR	OR	OR	O	Boolean OR	A parallel ~~its~~ element with open contact
ST	OUT	OUT	=	Store result register into operand	An O/P

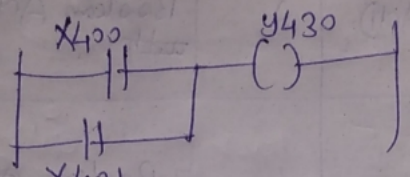
eg→



Using mitasubishi mnemonics,

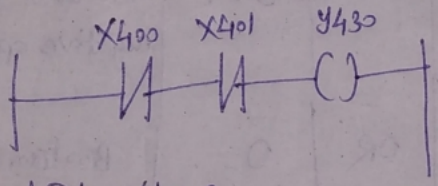
LD X400
AND X401
OUT Y430

eg→



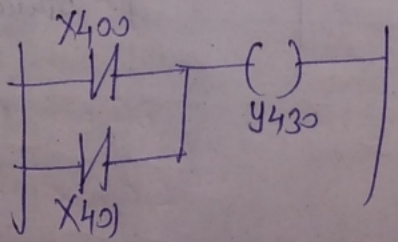
LD X400
OR X401
OUT Y430

eg→



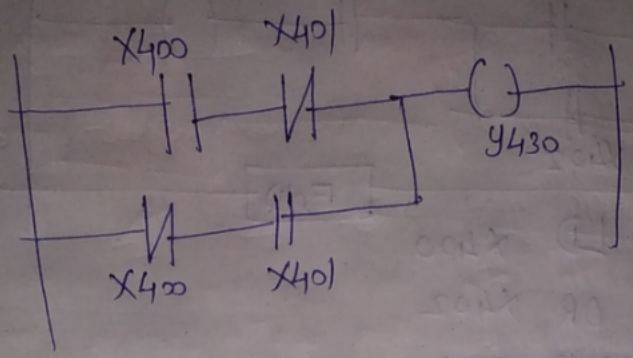
LDI X400
ANI X401
OUT Y430

eg→



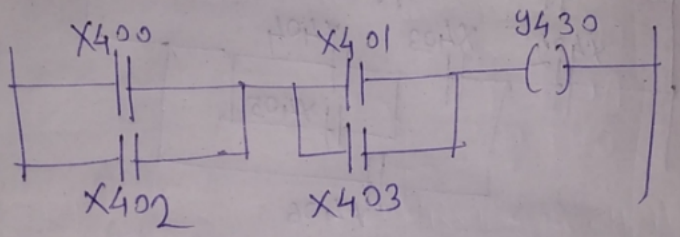
LDI X400
ORI X401
OUT Y430

eg→



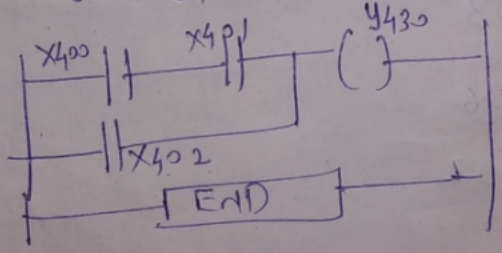
LD X400
AN| X401
LD| X400
AND X401
ORB
OUT Y430

eg→



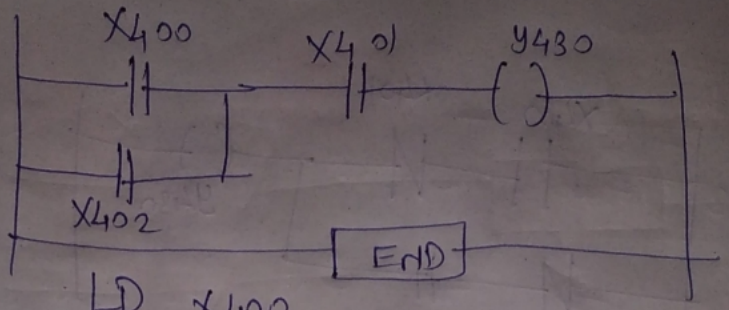
LD X400
OR X402
LD X401
OR X403
ANB
OUT Y430

eg→



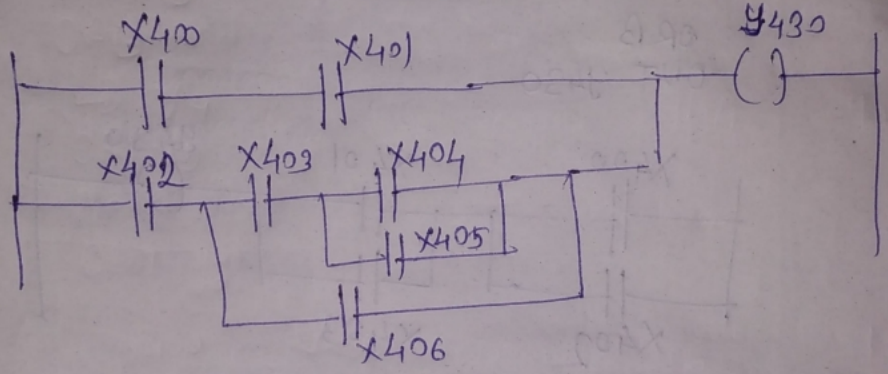
LD X400
AND X401
OR X402
OUT Y430
END

eg→



LD X400
OR X402
AND X401
OUT Y430
END

eg→

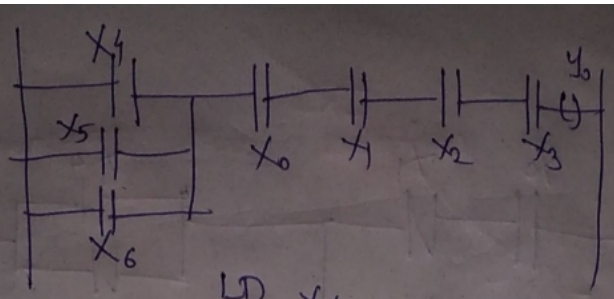


LD X400
AND X401

LD X404
OR X405
AND X403
OR X406
AND X402

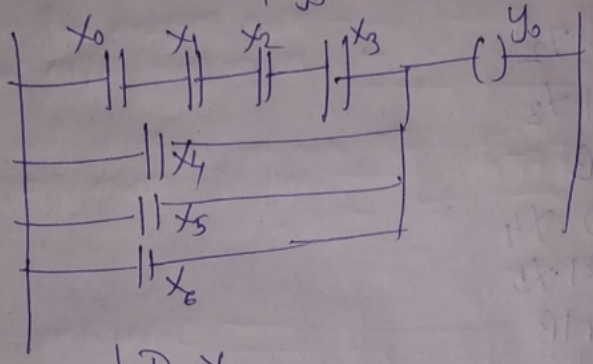
ORB
OUT Y430

eg →



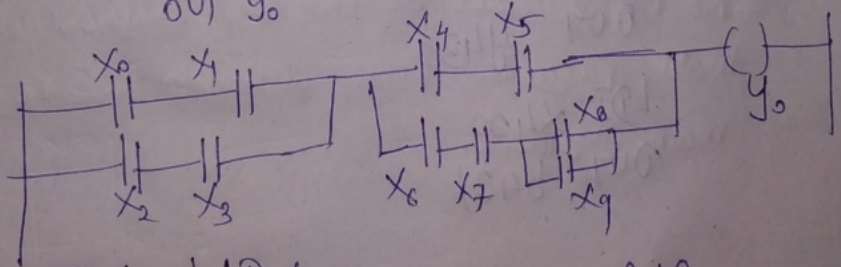
LD X4
OR X5
OR X6
AND X0
AND X1
AND X2
AND X3
OUT Y0

eg →



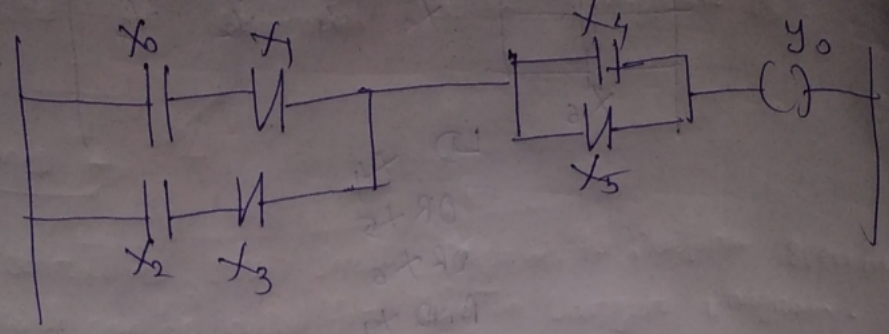
LD X0
AND X1
AND X2
AND X3
OR X4
OR X5
OR X6
OUT Y0

eg →



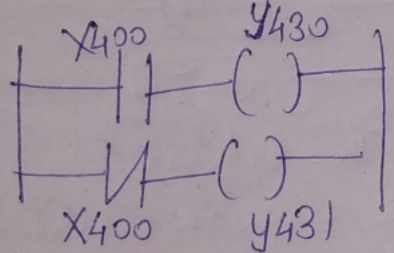
LD X0	LD X4	LD X8	ANB
AND X1	AND X5	OR X9	OUT Y0
LD X2	LD X6	ANB	
AND X3	AND X7	ORB	
ORB			

eg:-




```
LD  X0
ANI X1
LD  X2
ANI X3
ORB
 LD  X4
 ORI X5
 ANB
 OUT Y0
```

eg:-




```
LD   X400
 OUT  Y430
 LDI  X400
 OUT  Y431
```

Jump and call

→ Jump instruction enables part of a program to be jumped over and the way in which subroutine programmes can be called up.

It describes as,

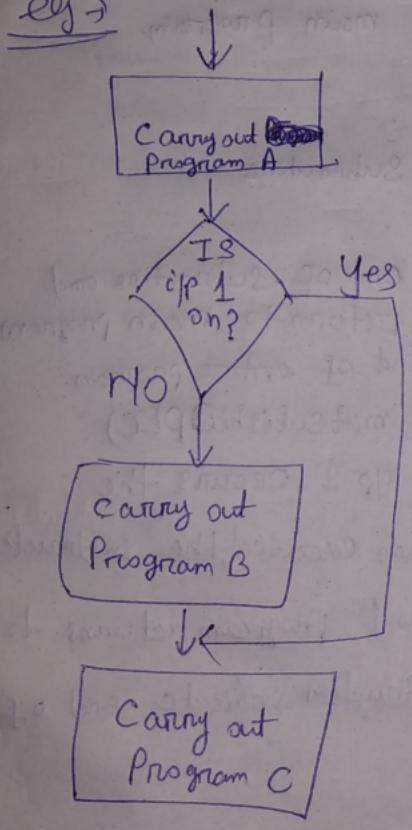
If (some condition occurs) Then

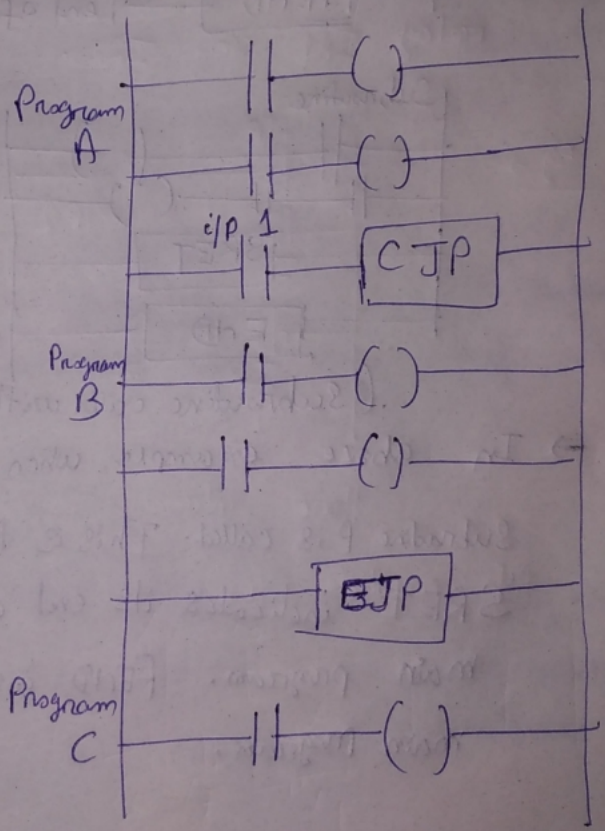
Perform some instruction

ELSE

perform some other instruction.

eg →





→ Jump instruction is denoted by CJP (conditional Jump) and the place to which jump occurs is denoted by EJP (end of jump).

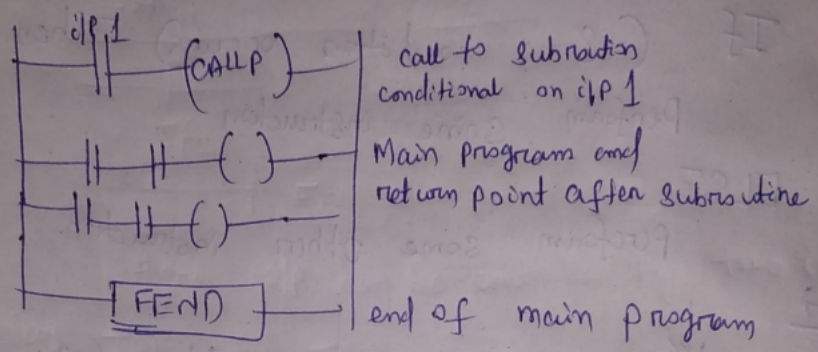
→ In above example when i/p 1 is ON then Program jumps to rung with the end of jump relay coil EJP and so continues with Program 'C'.

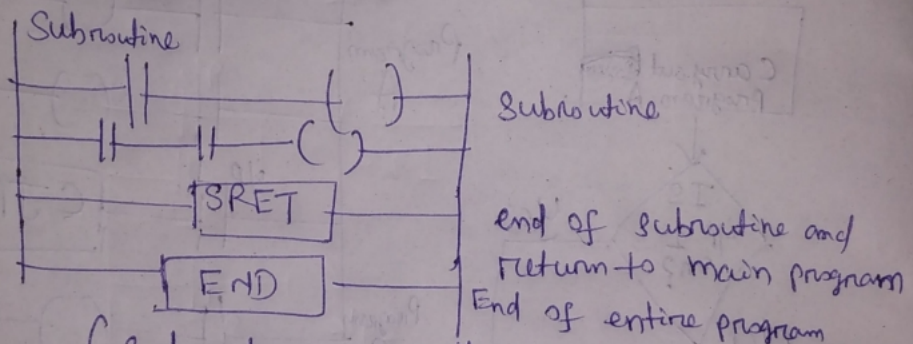
Otherwise it continues with program B.

Subroutines -

Subroutines are small programs to perform specific tasks which can be called for use in larger program.

eg →





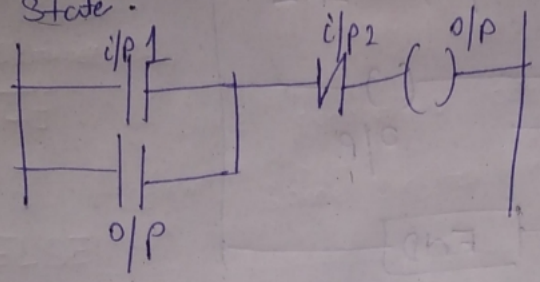
(Subroutine call with mitsubishi PLC)

→ In above example, when i/p 1 occurs the subroutine P is called. This is then executed, the instruction 'SRET' indicates its end and program returns to main program. FEND instruction indicate end of main program.

Latching

→ Latch circuit is a self-maintaing circuit, after being energised, it maintains that state Untill another input is received. It remembers last state.

eg→



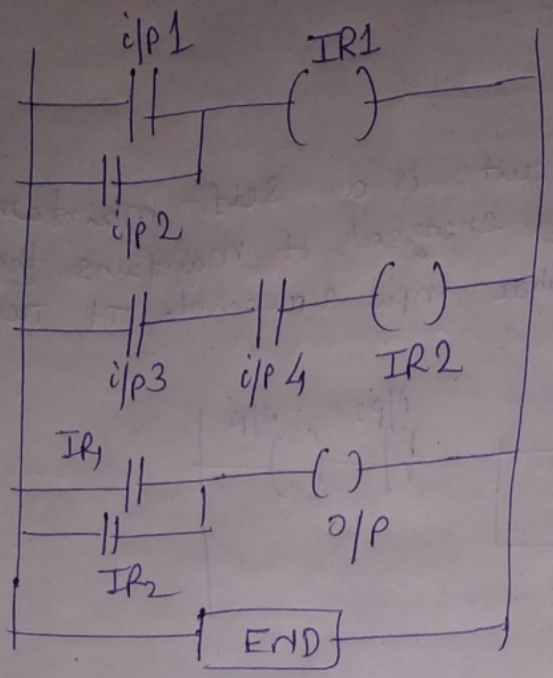
→ When i/p 1 is energised and closes, there is an o/p. However, when there is an o/p, a set of contact associated with o/p is energised and closes. These contact OR the i/p 1 contact.

→ Thus, even if i/p 1 contacts open, the circuit remain. the o/p energised. The only way to release the o/p is by operating the normally closed contact i/p 2.

Internal relays

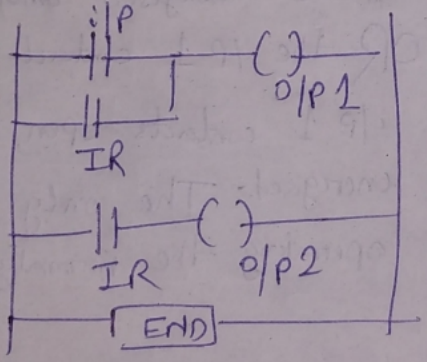
These are not actual relay but simulation by the Software of PLC. Internal relays are often used when there are programs with multiple i/p condition.

eg →



Here o/p can be controlled by two internal relay IR1 and IR2.

eg →



Here internal relay IR is used for starting of multiple o/ps.