GOVERNMENT POLYTECHNIC, SIRSA

BRANCH : MECHANICAL ENGINEERING
SUBJECT : CNC MACHINES AND AUTOMATION
SEMESTER : 5th

CONTENTS

2.15 MANAGEMENT OF A TOOL ROOM

3. SYSTEM DEVICES

3.1 CONTROL SYSTEM

3.2 FEEDBACK CONTROL CLASSIFICATION(OPEN LOOP, CLOSED LOOP)

3.3 ACTUATORS, TRANDUSCER AND SENSOR

3.4 CHARACTERISTICS OF SENSORS

3.5 TECHOMETER

3.6 LINEAR VARIABLE DIFFERENTIAL TRANSFORMER (LVDT)

3.7 OPTO INTERRUPTER

3.8 POTENTIOMETER FOR LINEAR AND ANGULAR POSITION

3.9 ENCODER AND DECODER

3.10 AXIS DRIVES

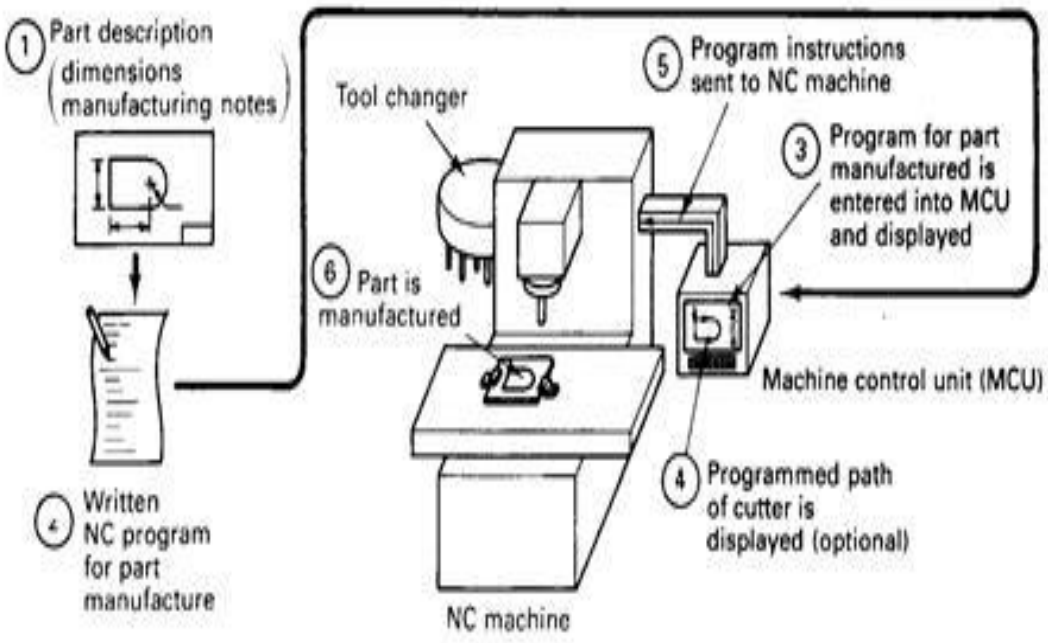
3.11 OTHER CLASSIFICATIONS OF CNC MACHINES-FEEDBACK, MOTION, POSITIONING

CHAPTER-1

SIMPLE MECHANISMS

1.1 INTRODUCTION TO NC

NC is a method of automatically operating a manufacturing machine based on a code of letters, numbers, and special characters. A complete set of coded instructions for executing an operation is called a program. The program is translated into corresponding electrical signals for input to motors that run the machine. NC machines can be programmed manually. If a computer is used to create a program, the process is known as computer-aided programming. The approach taken in this text will be in the form of manual programming.



1.2 BASIC COMPONENTS OF NC

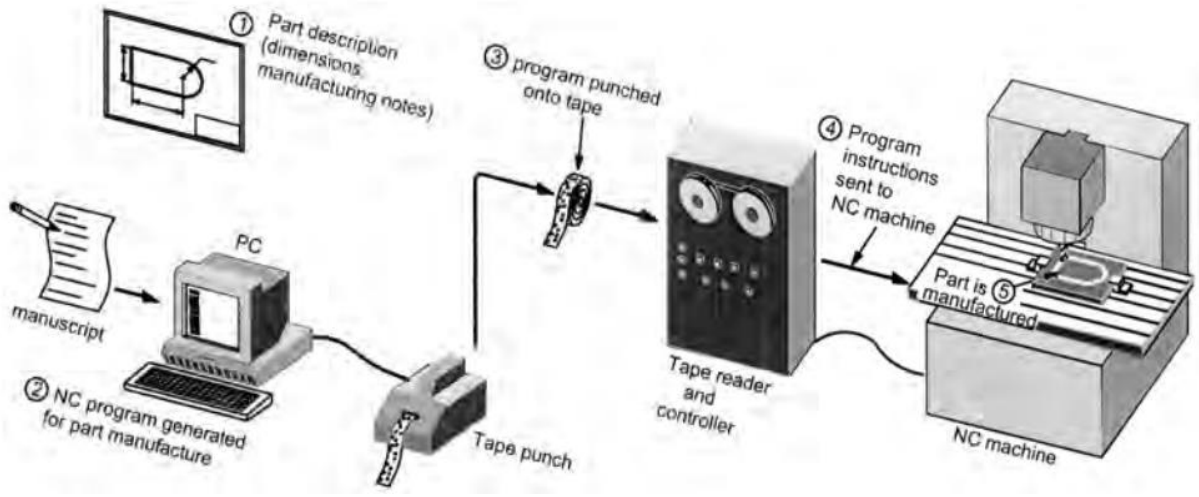
NC systems have been composed of the following components:

Tape punch: Converts written instructions into a corresponding hole pattern. The hole pattern is punched into tape which is passed through the tape punch. Much older units used a typewriter device called a Flexowriter, and later devices included a microcomputer coupled with a tape punch unit.

Tape reader: Reads the hole pattern on the tape and converts the pattern to a corresponding electrical signal code.

Controller: Receives the electrical signal code from the tape reader and subsequently causes the NC machine to respond.

NC machine*:* Responds to programmed signals from the controller. Accordingly, the machine executes the required motions to manufacture a part (spindle rotation on/off, table and or spindle movement along programmed axis directions, etc.). See Figure.



Components of NC Machine

1.3 BINARY CODING

In the coding, when numbers, letters or words are represented by a specific group of symbols, it is said that the number, letter or word is being encoded. The group of symbols is called as a code. The digital data is represented, stored and transmitted as group of binary bits. This group is also called as binary code. The binary code is represented by the number as well as alphanumeric letter.

Advantages of Binary Code

Following is the list of advantages that binary code offers.

- Binary codes are suitable for the computer applications.
- Binary codes are suitable for the digital communications.
- Binary codes make the analysis and designing of digital circuits if we use the binary codes.
- Since only 0 & 1 are being used, implementation becomes easy.

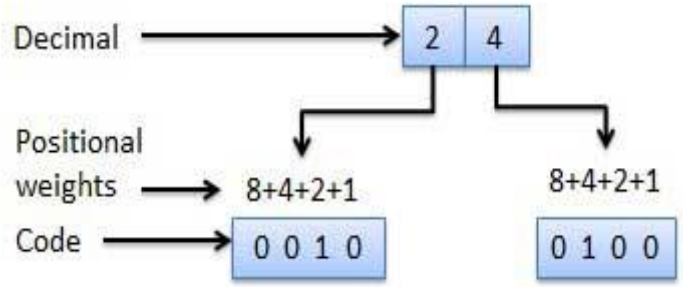
Classification of binary codes

The codes are broadly categorized into following four categories.

- Weighted Codes
- Binary Coded Decimal Code

Weighted Codes

Weighted binary codes are those binary codes which obey the positional weight principle. Each position of the number represents a specific weight. Several systems of the codes are used to express the decimal digits 0 through 9. In these codes each decimal digit is represented by a group of four bits.



Binary Coded Decimal (BCD) code

In this code each decimal digit is represented by a 4-bit binary number. BCD is a way to express each of the decimal digits with a binary code. In the BCD, with four bits we can represent sixteen numbers (0000 to 1111). But in BCD code only first ten of these are used (0000 to 1001). The remaining six code combinations i.e. 1010 to 1111 are invalid in BCD.

Decimal	0	1	2	3	4	5	6	7	8	9
BCD	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001

Advantages of BCD Codes

- It is very similar to decimal system.
- We need to remember binary equivalent of decimal numbers 0 to 9 only.

Disadvantages of BCD Codes

- The addition and subtraction of BCD have different rules.
- The BCD arithmetic is little more complicated.
- BCD needs more number of bits than binary to represent the decimal number. So BCD is less efficient than binary.

1.4 MACHINE CONTROL UNIT (MCU)

The machine control unit (MCU) is the heart of a NC and CNC system. It is used to perform the following functions:

- To read the coded instructions.
- To decode the coded instructions.
- To implement interpolations (linear, circular, and helical) to generate axis motion commands.
- To feed the axis motion commands to the amplifier circuits for driving the axis mechanisms.
- To receive the feedback signals of position and speed for each drive axis.
- To implement auxiliary control functions such as coolant or spindle on/off and tool change.

Types of MCU:-

There are three types of MCU.

- Swing Around MCU
- Housed MCU
- Stand Alone MCU

Housed MCU: This MC you may be generally house in a separate cabinet like body or may be mounted on the machine as shown in figure.

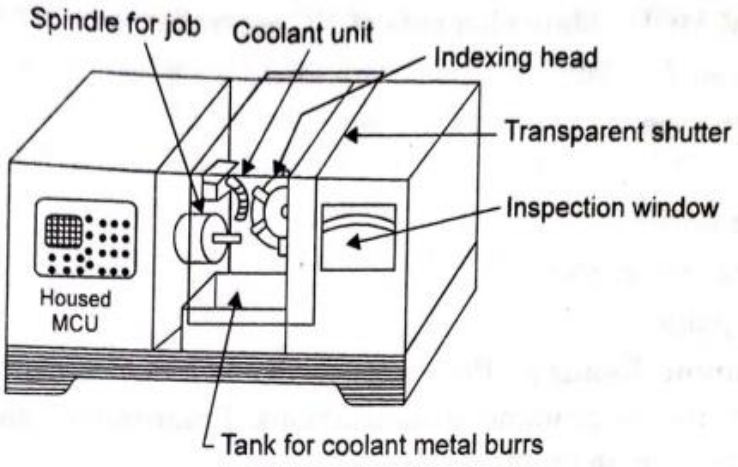


Fig. 1.12 : Housed MCU

Swing Around MCU: This MC is directly mounted on the machine can swing around and it can be adjusted as per requirement of the operators position

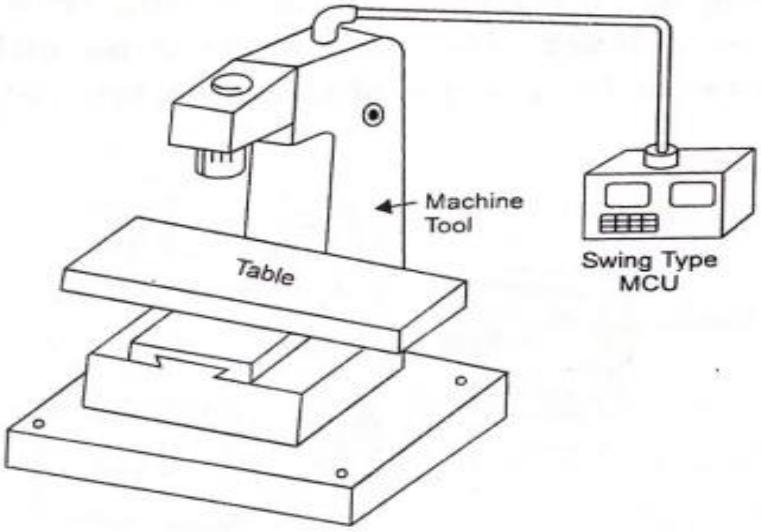


Fig. 1.13 : Swing Around MCU

Stand Alone MCU: In this MCU is enclosed in a separate cabinet which is installed at from remote or some place near to the machine as shown in figure

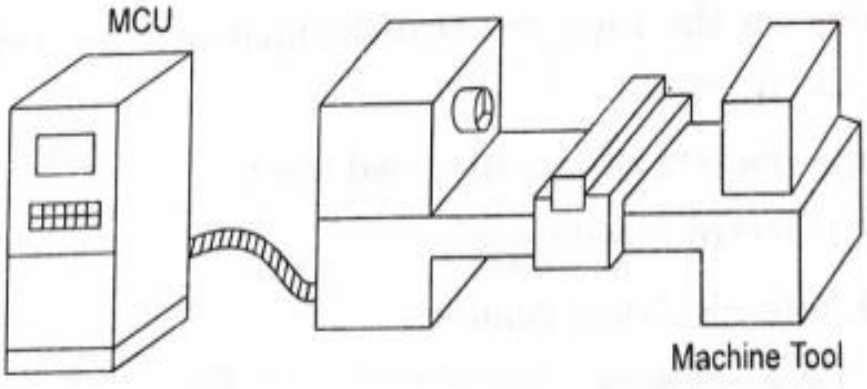


Fig. 1.14 : Stand Alone MCU

1.5 INPUT DEVICES

Modern technology uses an array of new devices for storing and loading programs written with the aid of a microcomputer or larger mainframe computer. These are explaining below.

Disks: These devices store a program in the form of a magnetic pattern on a plastic disk. During operation, the disk spins and the pattern is read by recording heads in the disk drive unit. Disks, also known as “floppy” disks, can store up to 1.44 megabytes (MB) of information.

CD-ROM: The compact disc (CD) is a popular device for storing information in the form of a pattern of etched pits. An optical laser is used to read the pit pattern on the spinning disc. CDs offer many advantages over other types of storage devices: they are a very stable and durable medium, ensuring almost indefinite storage life. Additionally, they are capable of storing large amounts of information. A typical CD has a storage capacity of 680 MB. Recordable (CD-R) discs can have data written on them only once. Re-writeable disks (CD-RW) can be erased and rewritten with new data. The CD drive used for this purpose must also be a CD “burner” capable of re-writing data to the CD.

Disks and CD-ROMs are used with personal computers (PCs) and workstations.

Portable Hard Drive: These palm 1-1 size devices store data in the form of a magnetic pattern on a spinning disk, and are connected directly to any USB port on a PC or workstation. The USB bus power is utilized so no additional power cords or adapters are needed. They dramatically increase the amount of digital data that can be stored. The smaller pocket hard drive units have a storage capacity of between 2.5 GB and 5 GB. The slightly larger portable units can store data starting in the 40 GB range all the way up to 120 GB. In essence, they act as additional hard drives.

1.6 ADVANTAGE /DISADVANTAGE OF NC MACHINES OVER CONVENTIONAL MACHINES

CNC Machine	Conventional Machine
Automated operation	Manual operation
Operation is controlled with a computer	Operation is controlled by operator.
Very complicated profiles can be generated easily	Difficult to make complicated profiles
High accuracy can be easily achieved by simple setting	Very difficult setting is needed to achieve high accuracy
Many working axes can be controlled easily at a time	Difficult to control more than one axis at a time.
Position control of axes is by closed loop system	Either a stopper or manually controlling the position.
Servomotors are used to drive each axis	Axis movement is either by feed box or rack and pinion arrangement
Constant surface speed (CSS) cutting is possible	Only step by step speeds by manual shifting is posible
Only a cycle start button pressing is enough to complete a machining operation	Manual intervention is needed for each movement and completion of a machining operation
Very high positioning accuracy	Position accuracy is poor and depend on the skill of operator
Very high repeatability for components	Poor repeatability and depend on the skill of operator.
Accuracy and repeatability are independent of operator	Accuracy and repeatability are of operator dependent
Productivity can be pre estimated as cycle time is definite.	Productivity cannot be pre estimated as cycle time is not definite as it depend on the attitude and mood of the operator on each day.
Production line can be automated	Production line cannot be automated

1.7 CNC & DNC, THEIR TYPES, THEIR ADVANTAGES, DISADVANTAGES AND APPLICATION

CNC: Computer Numerical control (CNC) is the automation of machine tools that are operated by precisely programmed commands encoded on a storage medium, as controlled by Computer.

In modern CNC systems, end-to-end component design is highly automated using computer-aided design (CAD) and computer-aided manufacturing (CAM) programs.

Advantages

- CNC machine can produce jobs with highest accuracy and precision than any other manual machine. It eliminates human errors.
- It can be operated for 24 hours of a day. Higher flexibility also.
- The parts manufactured by it have the same accuracy. There is no variety in parts manufactured by CNC machines.
- A highly skilled operator is not needed to run a CNC machine.
- A semi-skilled operator can also operate accurately and more precisely.
- Operators can easily make changes and improvements and reduce the delay time and Reduce inspection cost.
- It has the capability to produce a complex design with high accuracy in minimum possible time with minimum wastage.
- Modern design software allows the designer to emulate the creator of his idea.
- And this removes the need for making a prototype or models a saves time and money.

- Fewer workers are required to operate a CNC machine and save labour cost.
- It is suitable for batch production.
- It requires less space for its operations
- More operational safety.

Disadvantages

- The cost of a CNC machine is much higher than a manually operated machine.
- The initial cost is high.
- The parts of the CNC machines are costly.
- Maintenance costs are significantly higher in the case of CNC.
- It does not eliminate the need for costly tools.
- CNC machine requires skilled programmers.
- It is not suitable for small scale production
- Maintenance cost is more.

Applications

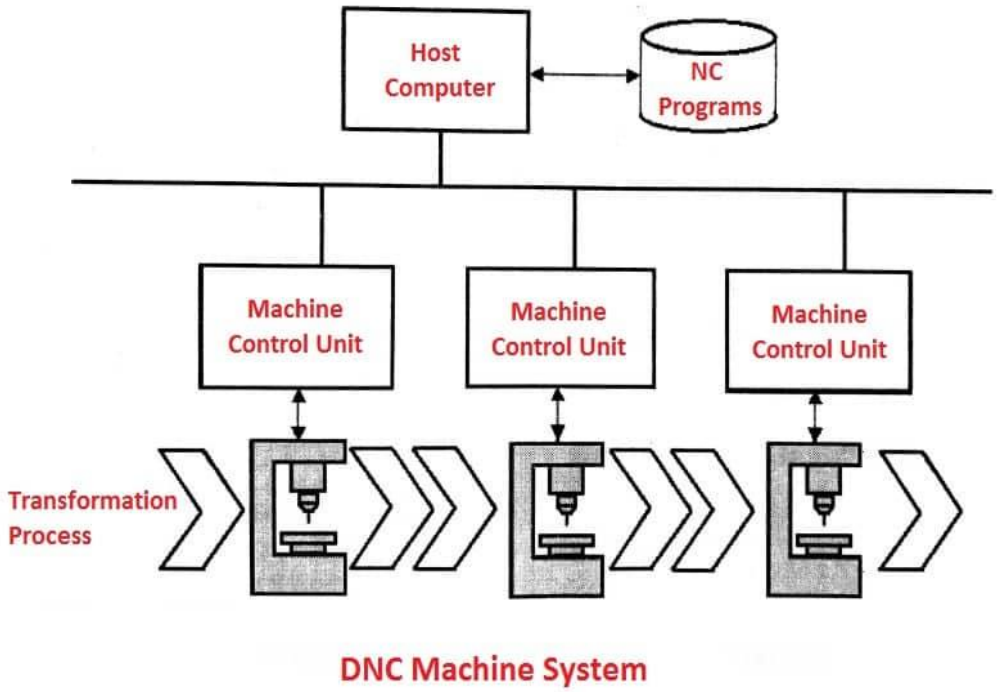
- CNC Lathe Machine
- CNC Milling Machine
- CNC laser cutting machine
- CNC router Machine
- CNC Plasma Cutting Machine
- CNC Drilling machine
- CNC Machining Center
- CNC Punch Press
- CNC Electric Discharge Machine

Profitable Applications

- 5- axis machine
- 3-D Printer
- Pick and Place Machine
- Laser Cutting Machine
- Aerospace equipment.
- Automobile parts.
- Electronic industry uses CNC e.g. Printed circuit board.
- Electrical industry uses CNC e.g. Coil winding.
- Pipe Bending Machine.
- Boring Machine.
- Knitting Machine
- Riveting Machine.
- Assembly Machine.
- Drafting Machine.

DNC: Direct numerical control (DNC) can be described as a various type of a manufacturing system in which that multiple NC machine or CNC machines are remotely controlled from a host computer or DNC control of multiple machines tools by a single computer through a direct connection. It is shown in the diagram below. Direct numerical control (DNC) is defined "as a system that integrates multiple machines by direct connection through a central computer".

The central computer is designed to provide instructions on demand to each machine tools. The central computer also retrieves data from machines. Therefore, there is two-way information is exchanged between the central computer and each of the machine tool.



DNC Machine System

Components Used in DNC Machine

Following are the main components used in CNC machine:

- Central computer
- Bulk memory for storing programs
- Communication network
- NC machine

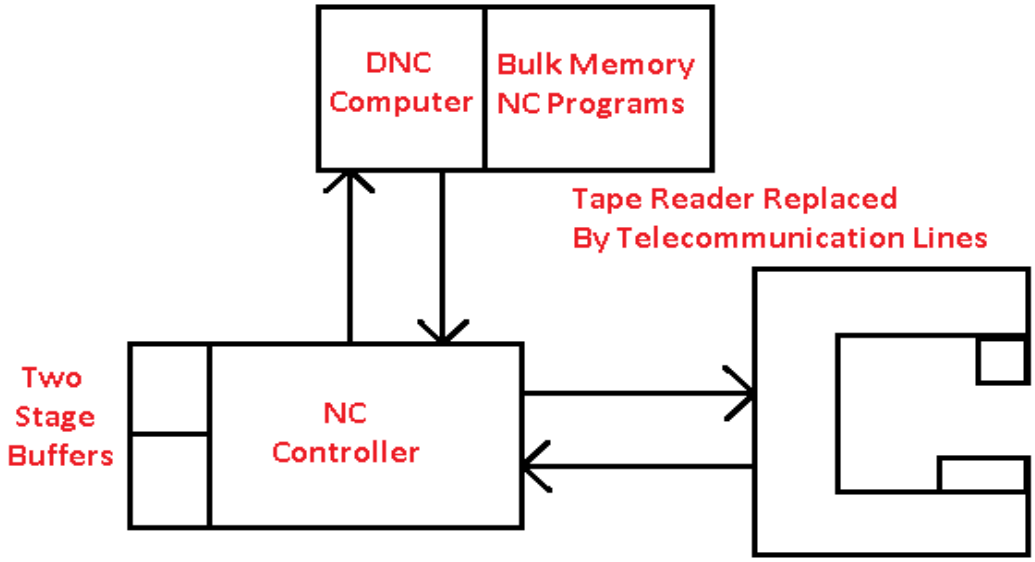
Types of DNC system

Following are the main two types of DNC system:

- Behind the Tape Reader (BTR) system
- Specialized MCU

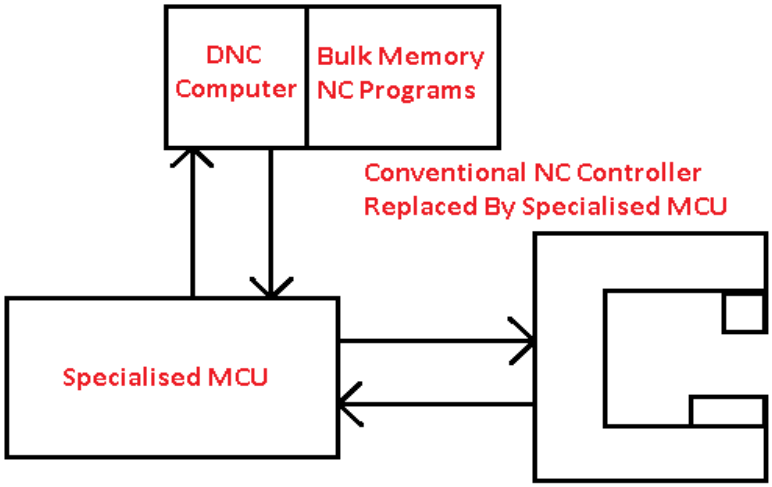
Behind the Tape Reader (BTR) System: In this type of system, the computer is connected directly to the regular NC controller unit. The operation of the system is similar to conventional NC, except for the source of command instructions.

The controller unit employs two temporary storage buffers to get the blocks of instructions from the DNC computer and turn them into machine operations. The one buffer is getting a block of data; the other is providing control instructions to the specific machine tool. This system cost is very low.



Behind The Tape Reader (BTR) System

Specialized MCU: In specialized MCU system, replace the normal controller unit with the special machine control unit. The special control unit is created to help communication between machine tools and computers. The specialized MCU configuration achieves a better balance between the accuracy of interpolation and the faster removal rate of the metal than is usually possible with the BTR system.



Advantages of DNC System

Following are the advantages of the DNC system:

- The DNC rejects the use of tape readers, which are absolutely the weakest component of the NC system.
- Time-sharing by central control makes it possible to keep close control over the entire machine shop.
- The huge memory of DNC allows it to store a large number of part programs for subsequent use. It also receives the memories of NC control unit.
- Presence of a central bulk memory allows the same program to be run on different machines at the same time without duplicating it at individual places.

Disadvantages of DNC System

Following are the disadvantages of the DNC system:

- DNC uses a central control and in an event of computer failure, the complete activities of the machine shop would come to a standstill.
- DNC is expensive and its use is practical in areas where high automation is required.

1.8 SELECTION OF PARTS TO BE MACHINED ON CNC MACHINES

A variety of components can be machined on CNC machine it is widely used in metal cutting industries and below listed Products.

1. Aerospace Equipments.
2. Automobile Parts.
3. Parts with Complicated Contours
4. Parts Requiring expensive Jigs and fixtures if produced on conventional Machine.
5. In cases where human error could be extremely costly.
6. Parts that are needed in hurry.
7. For small to medium batch quantity.
8. The operations are very complex
9. Where setups are very large.
10. When inspection is required 100%.
11. Where tool storage is problem.
12. Where much material needs to be removed.

1.9 PROBLEMS WITH CONVENTIONAL NC

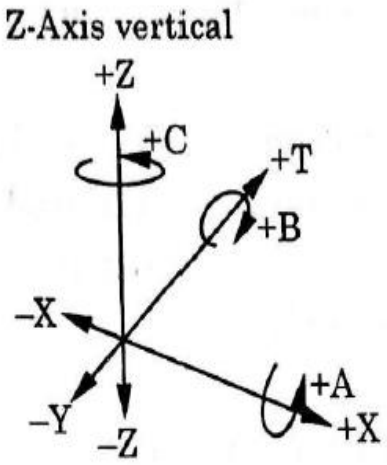
There are some following problems with conventional NC.

- These machines require more time for setting up.
- These are manual Controlled machines.
- More floor are required
- Ordinary motors are used.
- These are less flexible machines.
- Accuracy and finishing is dependent on Operator’s Concentration.
- Not suitable for large productions.
- Not suitable for complex Products.

1.10 RULES FOR AXIS IDENTIFICATIONS

There are three axis of movement identified as X, Y, Z axis. The possible linear and rotary movements of machines slides/work piece are shown in fig. rotary movements about X, Y, Z axis are designated as A, B, C respectively.

Z -axis: the Z- axis of motion is always the axis of the main spindle of the machine. It does not matter whether the spindle carries the work piece or the cutting tool.

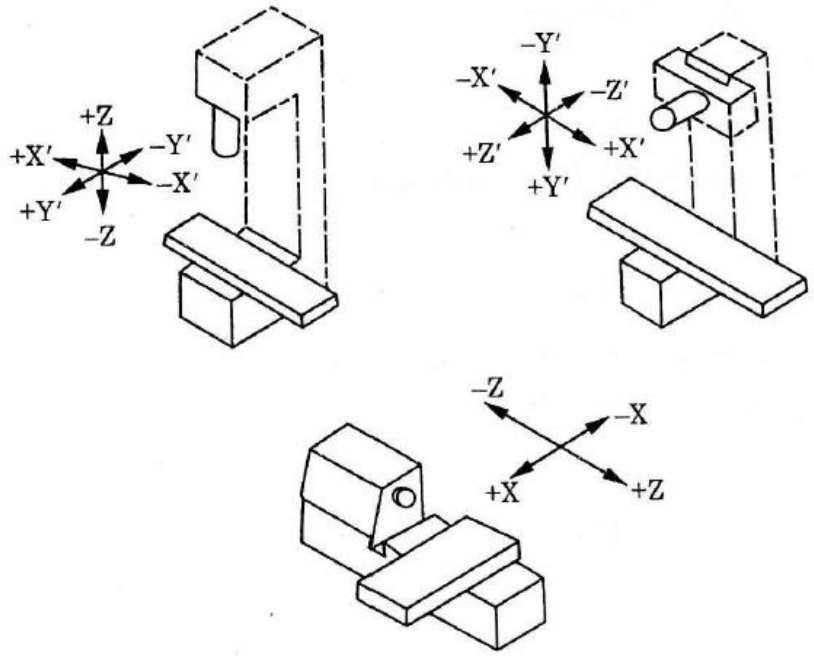


Possible Linear and Rotary Movements of Machine Slides

X- axis: the X-axis is always horizontal and is always parallel to the work holding surface. If the Z is vertical as in vertical milling machining, Positive X axis movement is identified as being to right, when looking from spindle towards its column.

If Z axis is horizontal as in turning process positive X axis motion is to the right, when looking from the spindle towards the work piece.

Y-axis: Y-axis is always right angles both the X-axis and Z-axis.



1.11 NEW DEVELOPMENTS IN CNC

- **Adaptive hardware architecture:** Modern CNC machines make use of advanced electronics due to very large scale integration (VLSI), the number of IC chips being used in control circuit have reduced.
- **Software Modularity:** The CNC machines make use of modular software so that in future, if there is a need to change any module suitable change can be incorporated easily.
- **Conversational Programming:** The operator can interact with the machine and can get suitable guidance from the software itself while preparing the part program.
- **Programming Flexibility:** Most of the CNC machines can work with a no of programming languages. They can perform complex mathematical operations at high speed.
- **Tool Change Device:** A number of tools may be required for making a complex part. The modern CNC machines are equipped with automatic tool changer that can handle no of tools.

1.11 PLC (PROGRAMMABLE LOGIC CONTROL) AND ITS PURPOSE

It is a software oriented interface between the CNC system and the machine tools to control following specific functions such as:

- cool out on/off
- pallet operations
- spindle speed
- tool functions

PLC has some memory capacity like 4kb, 7kb etc. it has a high speed microprocessor to execute sequence programming. It used software's, timers, counters to transfer the data b/w MCU and Machine tool.

CHAPTER-2

CONSTRUCTION AND TOOLING

2.1 DESIGN FEATURES

Many design changes are required for CNC machines as compared to conventional machines tools due to addition requirement for CNC Machine such as:

- Automatic Drive System.
- High Rigidity feed drives.
- Ball Screw.
- ATC.
- Chip Conveyors.
- Tool Magazine. Etc.

2.2 SPECIAL MACHINE DESIGN FEATURES

- Different types of Elements of Motion transmission.
- Contribution of Slide ways.
- Tool and Work Holding devices.
- Swarf removal Mechanism.
- Location of Transducer Elements.
- Safety of CNC Machine and Operators.
- Feedback mechanism.
- Various Types of Drives.

2.3 SPECIFICATION CHART OF A CNC MACHINE

1.	No of controlled axes	:	Two/Four/Eight, etc.
2.	Interpolation	:	Linear/Circular/Parabolic or Cubic/Cylindrical
3.	Resolution	:	Input Resolutions
		:	Programming Resolutions
4.	Feed rate	:	Feed/Min
		:	Feed/revolution
5.	Rapid Traverse rate	:	Feed rate override
		:	Feed/Min
6.	Operating Modes	:	Manual/Automatic/MDI/Input/output
		:	Machine data, setup/Incremental
7.	Type of Feedback	:	Digital
		:	Analog
		:	Both
8.	Part Program Handling	:	No of characters which can be stored
		:	Part program Input Devices: Output Devices
		:	Editing of Part program
9.	Part Programming	:	Through MDI
		:	Graphic Simulation
		:	Blue Print Programming
		:	Background Editing
		:	Menu Driven programming
		:	Conversational programming
10.	Compensations	:	Backlash
		:	Lead Screw Pitch Error

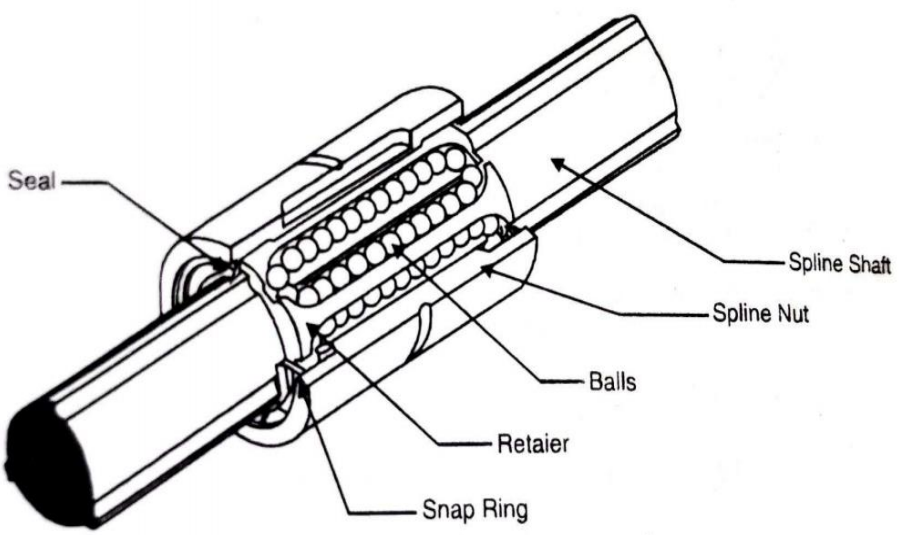
		: Temperature
		: Cutter radius Compensation
		: Tool Length Compensation
11.	PLC	: Built in/External
		: Type of Communication with NC
		: No of inputs, Outputs, Timers, Counters and Flags
		: User Memory
		: Program Organizations
		: Programming languages
12.	Thread Cutting/tapping	: Type of threads that can be cut
13.	Spindle Control	: Analog/Digital Control
		: RPM/Min, Constant , Surface Speed

2.4 TYPE OF SLIDEWAYS- BALLS, ROLLER

These are anti frictional type slide ways used in CNC System.

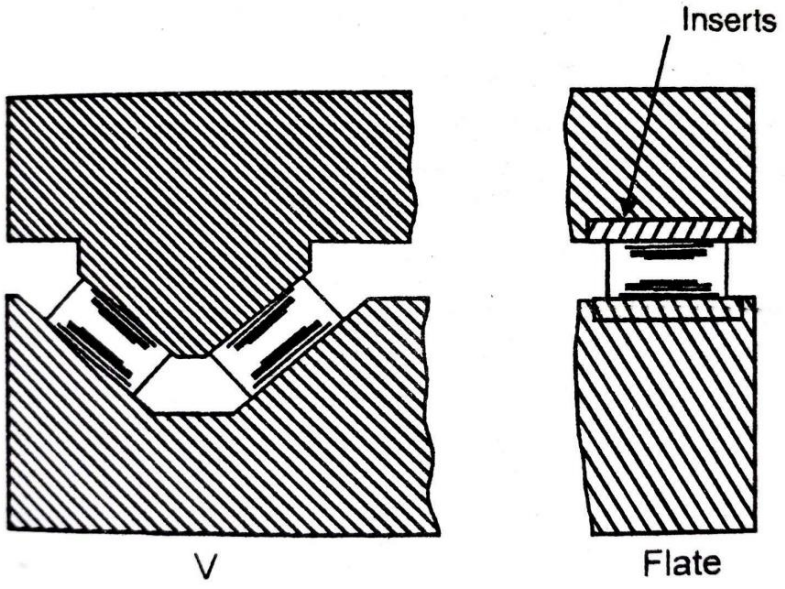
Balls type Slide ways

This is a type of linear motion device is a ball Bush type linear slide where balls are arranged in the track inside of a bush ,which can slide along a rod to provide the linear motion.



Roller type Slide ways

As in case of Roller bearing the roller are guided between inner race and Outer Ring with the help of cage. This guiding element prevents falling out of rollers and sliding between two surfaces. The rollers are in contact with guide ways which are machined on the bed of machine. These arrangements provide both movement of slide and also reduce the friction between bed and slide as shown in figure.



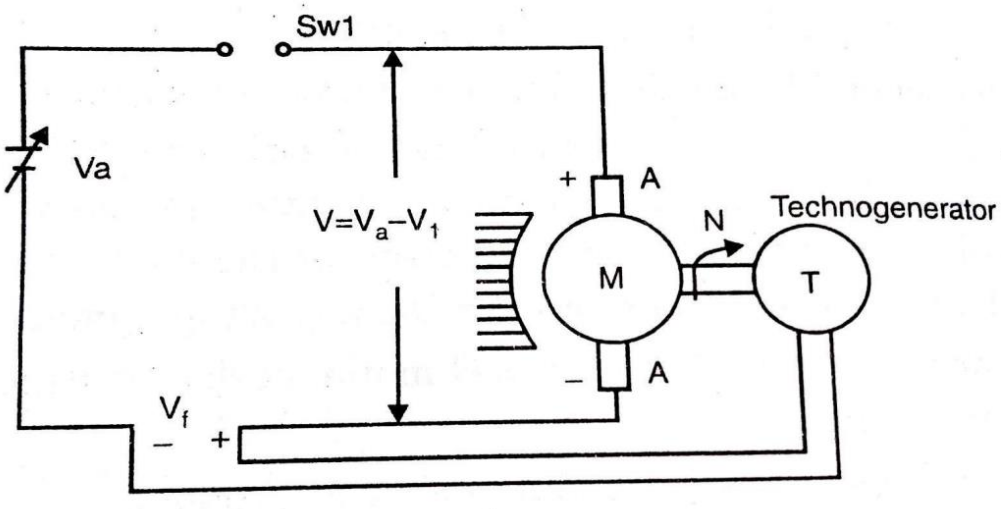
2.5 MOTOR- SERVO/STEPPER MOTORS

There are three types of drives used in CNC machine tool

- DC Servo Motors
- AC Servo Motors
- Stepper Motors

DC Servo Motors

These Motors are generally of the permanent magnet type in which the stator flux remains constant at all levels of armature current and speed torque relationship is linear. The force that rotates the motor armature is the result of the interaction between two magnetic fields. To produce a constant torque from the motor these two fields must remain constant in magnitude and in relative orientation. DC Servo Motors has smooth rotation at speed less than 1 RPM. The brush life is more than 4000 hours. Techno generator directly built into the rotor.



AC Servo Motors

DC Motors are commonly used for variable speed applications they have disadvantages as follows

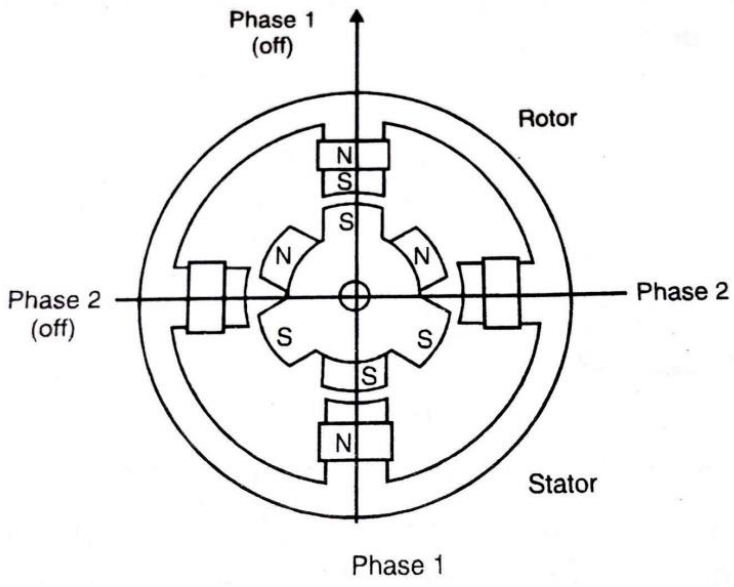
1. Maintenance required is more.
2. Bulky in size.
3. High inertia.
4. Brushes produce sparking.

So to overcome these disadvantages AC Servo Motors are used.

These are three phase permanent magnet synchronous motors with built-in brushless techo and position encoder. The rotor consists of a permanent magnet and the stator contains the three phase. AC Servo Motors has low rotor inertia, high power weight ratio, constant torque and additional cooling of motor is not required.

Stepper motor

A stepper motor rotates in a fixed angular increment that is known as steps stepwise or angle is determined by the construction of motor stepper Motors are used in open loop control system the step resolution is vary from 1.8 degree to .01144 degree.



2.6 AXIS DRIVE AND LEAD SCREW

The following are the requirement of axis drives.

It consists of a feed Servo Motor, having constant torque and positioning characteristics.

Requirement of axis drives

The following are the requirement of axis drives.

- They required constant torque.
- Large speed variation range 1: 20000.
- Low electrical and mechanical time constant.
- Feedback devices should be integral.
- Positioning of smallest positions increment should be possible.

There are three types of axis drives used in CNC machine tool

- DC Servo Motors
- AC Servo Motors
- Stepper Motors

DC Servo Motors: These Motors are generally of the permanent magnet type in which the stator flux remains constant at all levels of armature current and speed torque relationship is linear. The force that rotates the motor armature is the result of the interaction between two magnetic fields. to produce a constant torque from the motor these two fields must remain constant in magnitude and in relative orientation. DC Servo Motors has smooth rotation at speed less than 1 RPM. The brush life is more than 4000 hours. techno generator directly built into the rotor.

AC Servo Motors: DC Motors are commonly used for variable speed applications, they have disadvantages as follows.

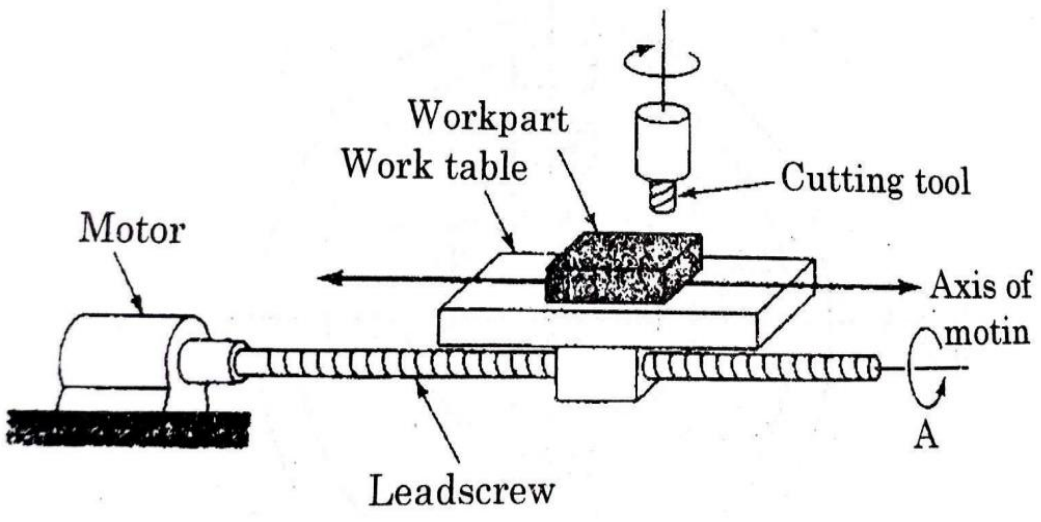
- Maintenance required is more.
- Bulky in size.
- High inertia.
- Brushes produce sparking.

So to overcome these disadvantages AC Servo Motors are used. These are three phase permanent magnet synchronous motors with built-in brushless techo and position encoder. The rotor consists of a permanent magnet and the stator contains the three phase AC Servo Motors has low rotor inertia, high power weight ratio, constant torque and additional cooling of motor is not required

Stepper Motor: A stepper motor rotates in a fixed angular increment that is known as step. stepwise or angle is determined by the construction of motor stepper Motors are used in open loop control system the step resolution is vary from 1.8 degree to .01144 degree.

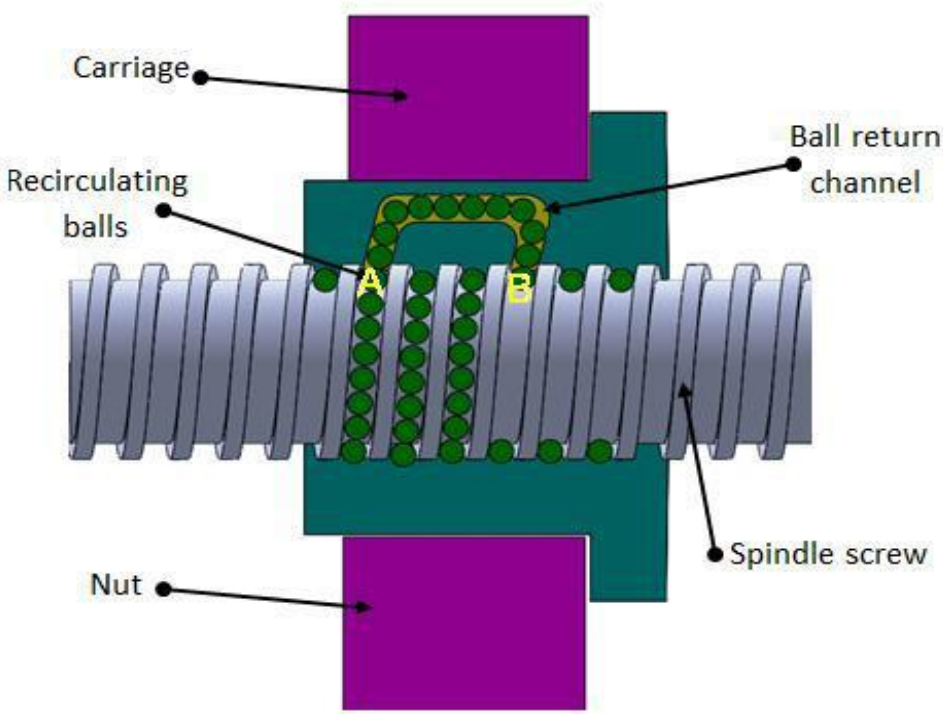
Motor and Lead Screw

The lead screw gets the rotary motion from the motor the work table is mounted on the lead screw both motor and lead screw are the main parts of NC positioning system as shown in figure



2.7 RE-CIRCULATING BALL SCREW AND NUT ASSEMBLY

It consists of a screw spindle, a nut, balls and integrated ball return mechanism a shown in Figure .The flanged nut is attached to the moving part of CNC machine tool. As the screw rotates, the nut translates the moving part along the guide ways. However, since the groove in the ball screw is helical, its steel balls roll along the helical groove, and, then, they may go out of the ball nut unless they are arrested at a certain spot. Thus, it is necessary to change their path after they have reached a certain spot by guiding them, one after another, back to their “starting point” (formation of a recirculation path). The recirculation parts play that role. When the screw shaft is rotating, as shown in Figure, a steel ball at point (A) travels 3 turns of screw groove, rolling along the grooves of the screw shaft and the ball nut, and eventually reaches point (B).Then, the ball is forced to change its pathway at the tip of the tube, passing back through the tube, until it finally returns to point (A).Whenever the nut strokes on the screw shaft, the balls repeat the same recirculation inside the return tube.



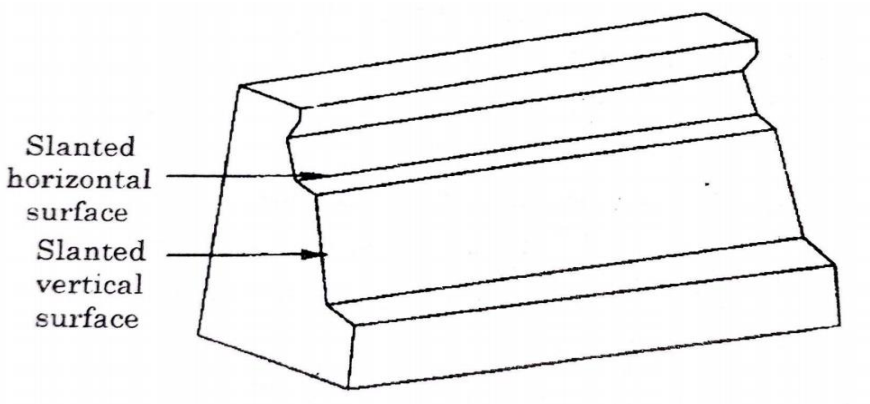
When debris or foreign matter enter the inside of the nut, it could affect smoothness in operation or cause premature wearing, either of which could adversely affect the ball screw's functions.

To prevent such things from occurring, seals are provided to keep contaminants out. There are various types of seals viz. plastic seal or brush type of seal used in ball-screw drives.

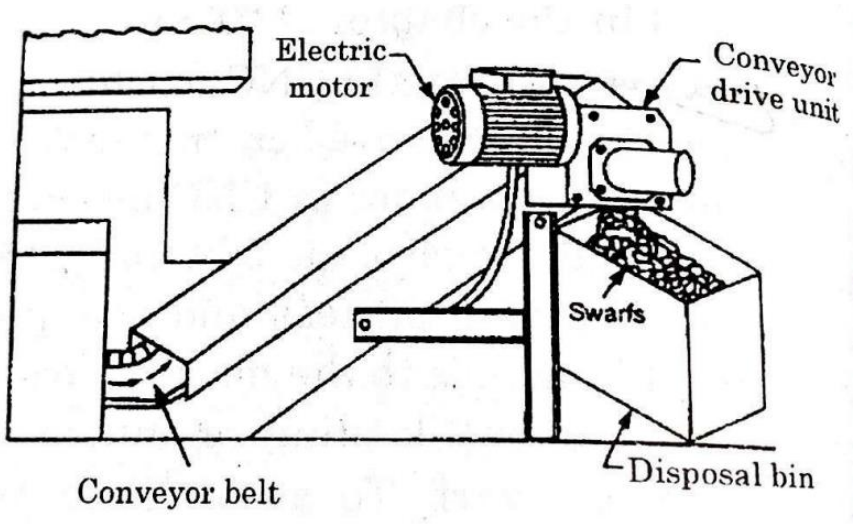
2.8 SWARF REMOVAL

CNC machines are designed to work at optimum cutting conditions with the improved cutting tools. On a continuous operation basis the cutting time is much more in CNC machine. The volume of swore generated is also more unless the swarf is quickly and efficiently removed from the cutting zone. it can affect the cutting process and the quality of finished product. to avoid this problem an efficient Swarf control system should be provided with the CNC machine tools with some mechanism to remove the swarf from the cutter and cutting zone.

Slanting the Bed for Swarf Removal: The swarf removal from the cutting zone is generally taken care by the design configuration of the machine. Slant bed and vertical bed turning centers have the advantages over flat bed or horizontal bed configuration in that swarf does not accumulate on the guide ways.



Conveyor System: Rotary conveyors are used for removing the swarf from machine tools; the system is such that the swarf from the cutting zone falls directly on the conveyor and is immediately taken away. The Swarf from the conveyor is taken to the disposal bins which can be collected and removed from the machine area.



2.9 SAFETY AND GUARDING DEVICES

Since the CNC machines are under continuous automatic operation, there is a need to protect the machine guide ways and to ensure safety of the operator.

(a) Protection of Machine Guide Ways: the protections of machine guide ways drive screws and transducers, etc. is very important for efficient working and long life of the machine. Different types of collapsible guards and covers are used to protect those elements. Some common instruments which are used to provide safety of machine tool are:

(i) Overload protection sensor: These sensors are installed or fitted to the main motors. As the machine overloaded it gives the signal with a light or a beep. In some cases it stops the machine.

(ii) Clamping sensors: These sensors are very useful for machine tools as well as for operator. These are fitted in clamps and gives signal to MCU to ensure the closer of clamps before the cutting operation starts.

(iii) Work-table control sensors: These sensors are used to control the movement of work-table. Due to these sensors the work-tables are automatically slowed down as the limits are reached.

(iv) Measuring device safeguards. These are used to protect the measuring devices from the swarfs or any other heavy dust particles.

(b) Safety of Operator: Safety of operator is very important aspect which cannot be overlooked. To ensure safe working conditions the CNC machine tools are provides with metallic or plastic guards. Where it is not possible to provide effective guards, proximity protection is provided by pressure mats or light barriers.

(i) Perimeter Guards: The overall guards or perimeter guards serve as on enclosure for the machine tool. The perimeter guards protect the operator against flying swarf and from any accident by hitting against the moving components when the machine is working.

(ii) Pressure mats: The pressure Mats are used on milling drilling or grinding machines where the machine table can move to the either side of the machine. Since the table moves at Rapid rate it may cause some accident of the operator is standing Too Close to the machine. The pressure Mats are placed around the machine and if someone crosses the mat a warning signal is generated.

(iii)Light barriers*:* Light barriers are also provided on milling drilling and grinding machines the light barrier consists of a light source usually infrared sending a beam two light sensitive cells if anything obstructs the light beam a warning signal is generated

(iv)Safety Clutches: these are simply friction clutches. These are activated or come into working when the transmitted torque or speed exceeds the limiting value.

2.10 VARIOUS CUTTING TOOLS FOR CNC MACHINE

The cutting tools can be classified on the basis of setting up of tool, tool construction and cutting tool material:

On the Basis of Setting up of Cutting Tool

(a) Preset tools.

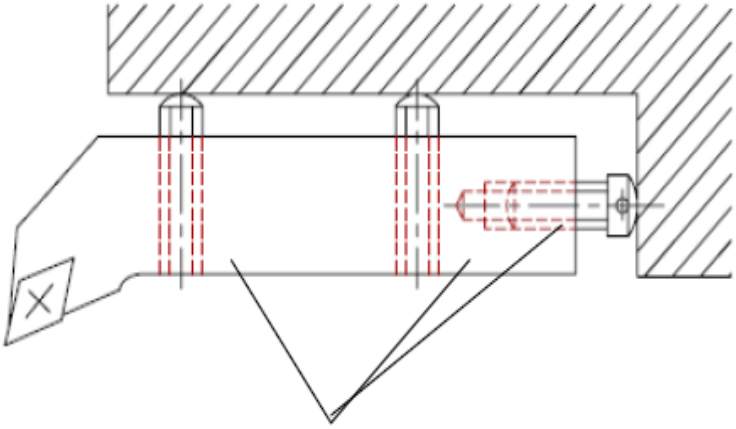
(b) Qualified tools.

(c) Semi qualified tools.

Preset Tools: The setting of tools in advance at a place away from the machine tool or offline, in special holders is known as preset tools.

Qualified Tools: The Tool which fits into a location on the machine, where its cutting edge is accurately positioned within close limits relative to a specified datum on the tool holder or slide, is known as qualified tool.

Semi-Qualified Tools: The qualified tools which can be adjusted to the dimensions by using several adjustable buttons on the tool shank are known as semi qualified tools.



Adjustable Buttons

On the Basis of Cutting Tool Construction

(a) Solid tools.

(b) Brazed tools.

(c) Inserted bit tools.

Solid Tools: Solid tools are usually made of High speed steel or high carbon steel. These tools are used on high speeds with sufficient quantity of cutting fluid to get good surface finish and longer tool life.

Brazed Tools: A forged shank of high strength steel with belt of high speed steel, tungsten carbide satellite brazed to the shank on the cutting edge.

Inserted Bit Tools: The tool with indexible inserts of harder and special grade carbide or ceramic materials. A wear resistant layer of Titanium nitride of Titanium carbide is coated on the insert it reduces the cost of tool. Inserts can be easily removed from the tool holder. So tool changing time and cost of machining are less.

On the Basis of Cutting Tool Material

(a) High speed steel (HSS).
(b) High carbon tool steel (HCS).
(c) Cast alloy.
(d) Cemented carbide.
(e) Ceramics.
(f) Cubic Boron Nitride.
(g) Diamond.

High Speed Steel: The H.S.S. is carbon steel to which alloying elements like tungsten, chromium, vanadium, cobalt and molybdenum to be added to increase their hardness and wear resistance.

High Carbon Tool Steel: High carbon tool steel is suitable for low cutting speeds and low temperatures. The hardness of this tool is determined by the carbon contents.

Cast Alloy: This is a non-ferrous alloy and gives high machining performance than that of H.S.Steel. Its hardness and toughness are high at higher temperatures.

Cemented Carbides: It contains 5% carbon, 13% cobalt and 81%tungsten. This tool is widely used in modern costly machines as tip tools. The tool setting time is reduced.

Ceramics: It can be used for higher cutting speed, superior surface finish and great machining flexibility. The Aluminum oxides, boron carbides, silicon carbide, titanium borides and titanium carbides are known as ceramics.

Boron Nitride

(a) High wear resistance.

(b) Used for machining hardened steel and high temperature alloys.

Diamond

(a) Low friction and high wear resistance.

(b) Good cutting edge.

(c) Single crystal diamond is used to machine copper to a high surface finish.

2.11 OVERVIEW OF TOOL HOLDER

A tool holder can be defined as follows a device that acts as an interchangeable interface between machine tool spindle and cutting tool such that the efficiency of the either element is not diminished. To hold with this definition four separate elements are essential.

Concentricity: The rotation axis of the machine spindle of the cutting tool must be maintained concentrically.

Holding strength: The cutting tool must be held securely to with stand rotation within the tool holder.

Gauges: The tool holder must be consistent application of proper gauges a shows consistency from holder to holder.

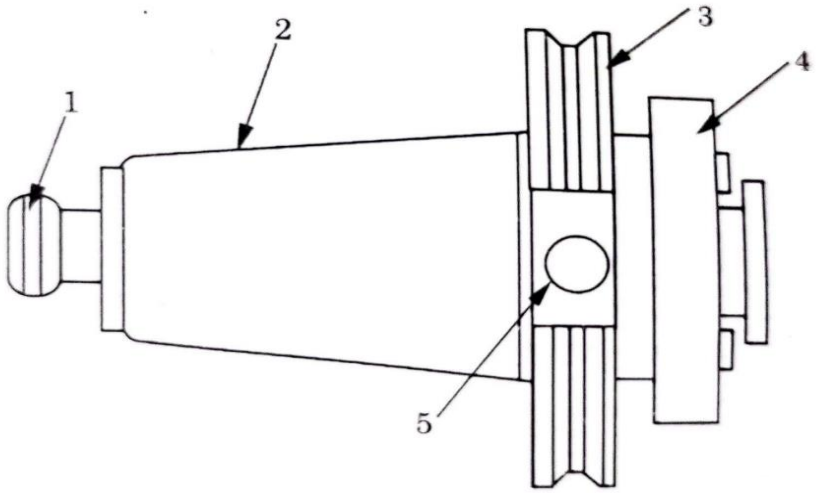
Balancing: Tool holder must be balanced as finaly as the spindles in which they are installed.

The holder Can Be split into three separate parts

1) Spindle
2) Balancing device
3) Clamp the tool

A tool holder consists of five basic components

1) Pull stud
2) Tapered Shank
3) Flange
4) Adaptor
5) oppose slot



Tool holding devices for CNC

The tool holding devices are used in CNC machines are classified in two categories.

1. Spindle tooling
2. flexible tooling

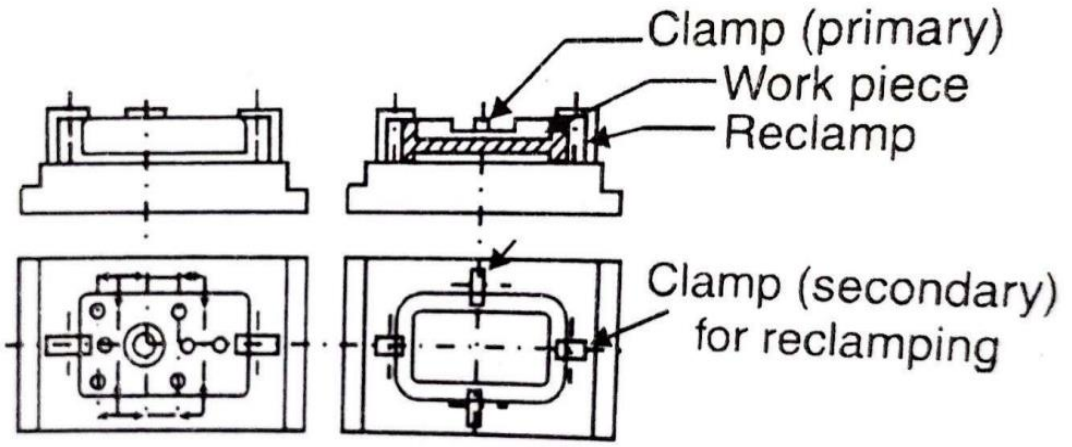
Spindle type tooling: Spindle type tooling is mainly employed on milling drilling and boring machine. A variety of tool holding devices are used which listed below:

- Collet chuck
- Adaptor
- Boring head
- Morse taper adaptor
- Spade drill
- Tapping head

Flexible tooling: A set of Universal tools tool holding mechanism and automatic tool changing and Programmable device controller which are used to compensate the flexibility in the production process is called flexible tooling. It consists of actuators, vacuum, hydraulic, electric and pneumatic end effectors along with tool holder.

2.12 DIFFERENT PALLET SYSTEMS.

Pallet fixture is a work holder that is designed to be transported by the material handling system. The part is hold on upper face of pallet and lower face of the pallet is designed to be moved, located and clamped in position at work table of the machine.



2.13 AUTOMATIC TOOL CHANGER SYSTEM.

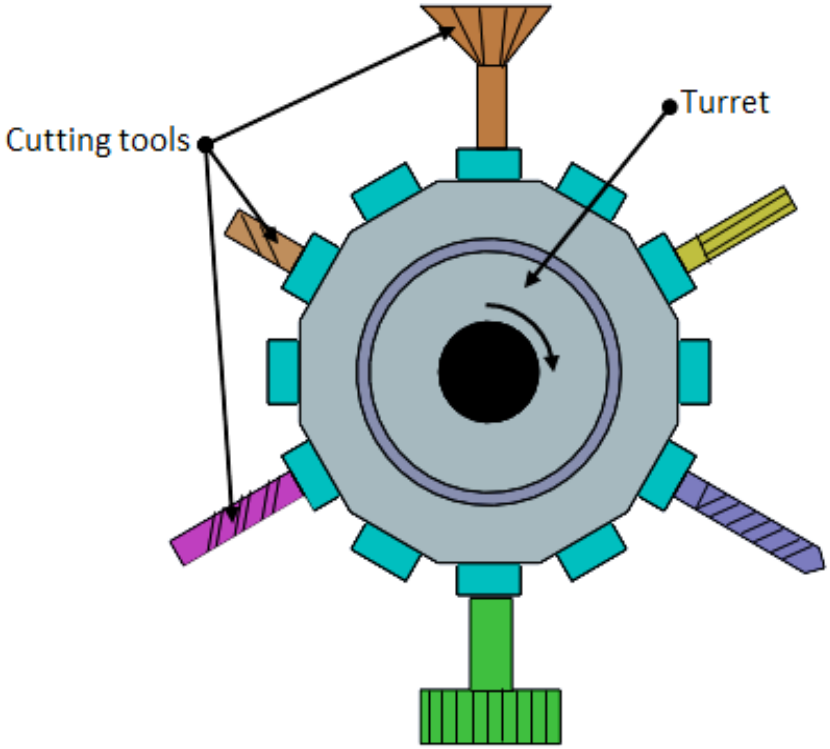
The CNC machines are designed to perform a number of operations in a single setting of the job. A number of tools may be required for making a complex part. In a manual machine, the tools are changed manually whenever required. In a CNC machine, tools are changed through program instructions. The tools are fitted in a tool magazine or drum. When a tool needs to be changed, the drum rotates to an empty position, approaches the old tool and pulls it. Then it again rotates to position the new tool, fits it and then retracts. This is a typical tool changing sequence of an automatic tool changer (ATC).

The concept of the ATC is that the range of tools for a specific job shall be made available for automatic selection and positioning. ATC can be

Turret Head Type

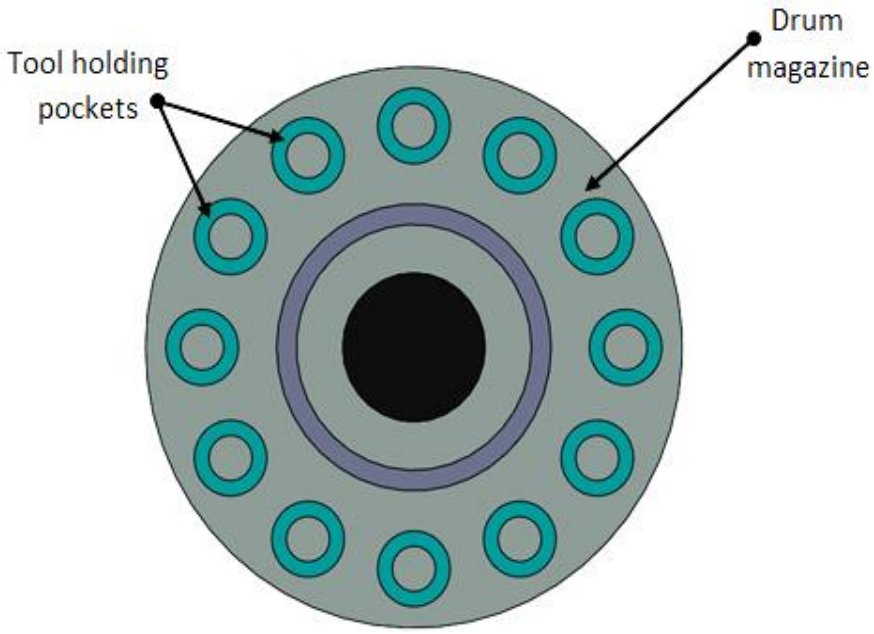
In this type of ATC tools will be mounted on Turret head as shown in Fig. there will be vacancy at the turret head of the ATC in which we can Store the Tools. It is the simplest form of tool magazine. Figure the schematic of a turret with a capacity to hold twelve tools. It consists of tool storage without any tool changer. The turret is indexed in the required position for desired machining

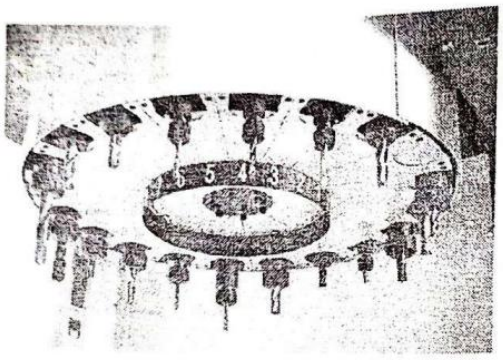
operation. Advantage of the turret is that the tool can easily be identified, but the time consumed for tool change is more unless the tool is in the adjacent slot.

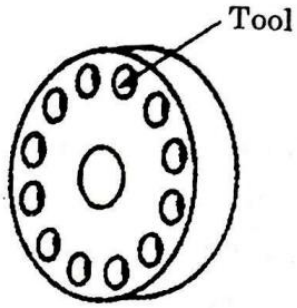


Drum Type

For holding small number of tools usually not more than 30, Stored on periphery of drum and tool search speed is faster. The disc type tool magazine rotates to get the desired tool in position with the tool change arm (Fig.). Larger the diameter of the disc/drum more the number of tools it can hold. It has pockets where tool can be inserted. In case of drum type magazine which can store large amount of tools, the pockets are on the surface along the length. It carries about 12 to 50 tools. If the number of tools are less the disc is mounted on top of the spindle to minimize the travel of tool between the spindle and the disc. If the tools are more then, the disc is wall mounted or mounted on the machining center column. If the disc is column mounted then, it needs an additional linear motion to move it to the loading station for tool change.

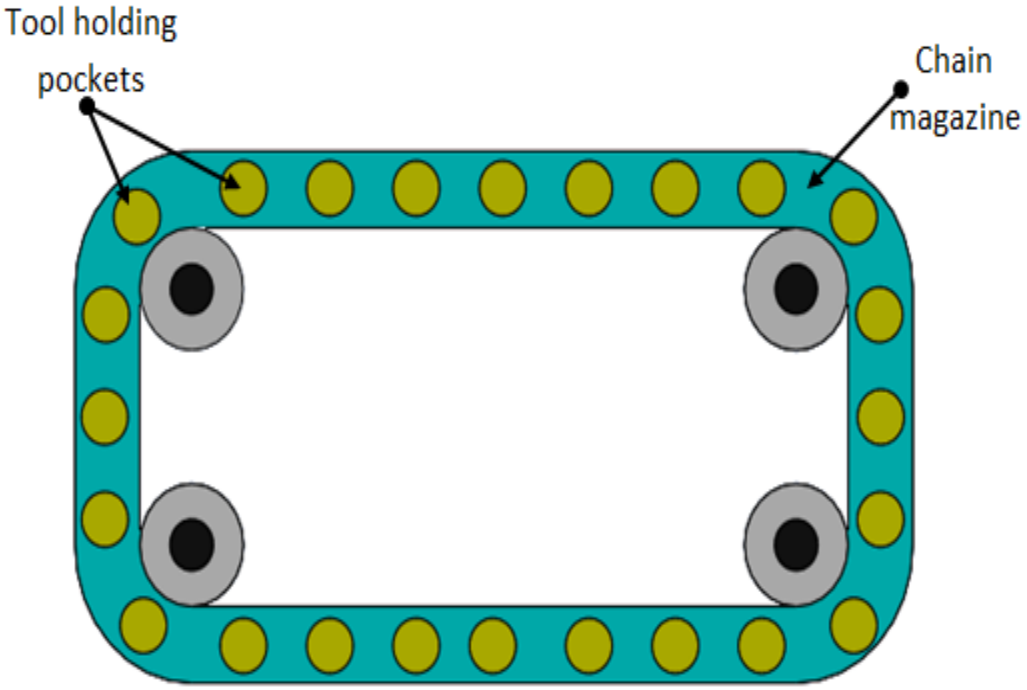






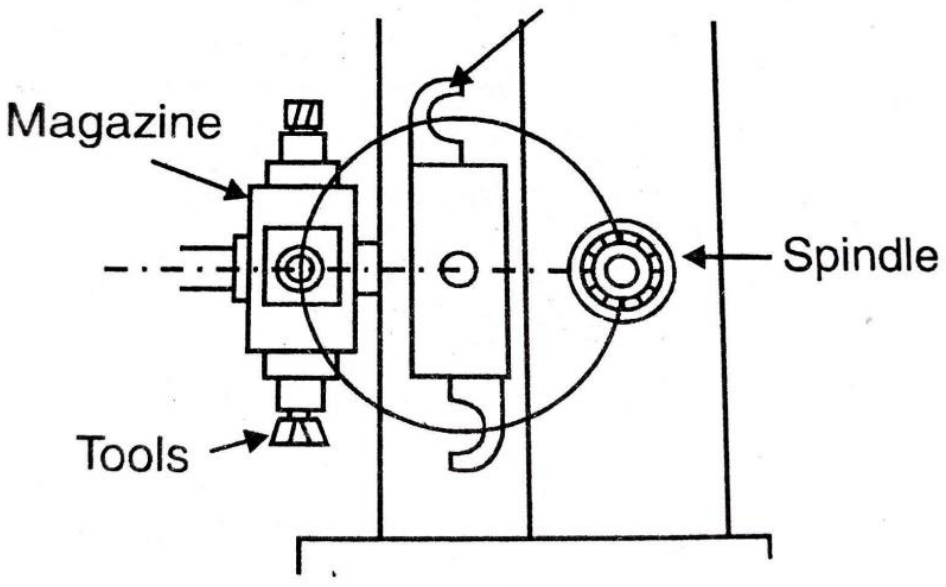
Chain Type

In this type tools search speed is less. When the number of tools is more than 50, chain type of magazines are used (Fig.). The magazine is mounted overhead or as a separate column. In chain magazines the tools are identified either by their location in the tool holder or by means of some coding on the tool holder. These types of magazines can be duplicated. There can be two chain magazines: one is active for machining and the second magazine is used when the duplicate tool is needed since the active tool is worn out.



2.14 TOOL CHANGE CYCLE.

As soon as the tool selection command is received by the system, the selected tool comes to a fixed place known as tool change position. The selected tool is transferred to the spindle from magazine after the previous tool is transferred to the magazine from spindle. This is called tool change cycle.



2.15 MANAGEMENT OF TOOL ROOM.

Tool room is a place in the industry where the different types of tools are stored or placed here management of a tool room means how they are managed such that how they placed used issue etc. Management of a tool room may be defined as a function of receiving storing and issuing of tools to the respective department. The management of a two room generally depends upon the following factors: (i) Size of industries (ii) Types of product to be manufactured (fixed or flexible). Management of a tool room changes if the size of industries changes in small and medium enterprises (SME) it is easy to manage the tool room but in large scale industries it is difficult to manage.

Management of tool room for SME's

Different but limited types of tools are used in SME's. General procedure to manage the toll room is as follows:

Identification of tools: Identification can done by

- Tagging some piece of paper
- By fixing labels on the items
- Painting color coding of items
- By coded numbering

Location coding: Tool room is divided into blocks of storage units and each block is identified by lateral block letter and longitudinal block letter. In each block every row of shelves is given a number each row is divided vertically into column and horizontally into shelves.

Record of receipts: Tools are shipped by the supplier along with the necessary documents and packing slips. The tool room manager unloads the tool and verifies the contents with the packing slip and purchase order

Storage of tools: The most important function of Tool Room department is to store and preserve the tool till they are issued to the production and other departments' different type of containers such as drum pallet boxes are used for storing the different types of tool.

Issue of tools: In small scale industries to use are issued by simply with the token issued by the industry tool room manager simply take them in his custody and issue to the required to the concern button medium scale industry tool are issued by the tool room manager only on the presentation of indent.

Tool return note: This note is used when the tools are returned to tool room.

Management of a Tool Room for Large Scale Industries

In large scale industries there are plenty of products are manufactured .for this different type of processes adopted when you many types of products are manufactured in an industry. Then a tool requirement for this is also become high. In that case it is not easy for the Tool room manager to maintain the record of tools. For this different type of software's are present in the market. In most cases for large Industries software's are used for management of a Tool room. Some record should be Store as listed below in the software.

- Data management
- Tool catalog
- Tool types
- Tool location
- Tool manufacturers
- Tool transactions
- lost and damaged tool report

CHAPTER-3

SYSTEM DEVICES

3.1 CONTROL SYSTEM

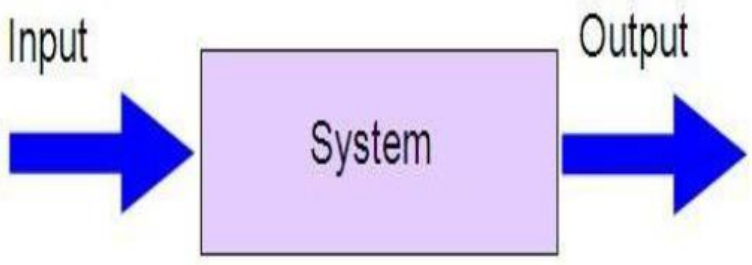
A CNC system requires motor drives to control both the position and the velocity of machine axes. There are two ways to activate the servo drives;

- Open loop control System
- Closed loop control System

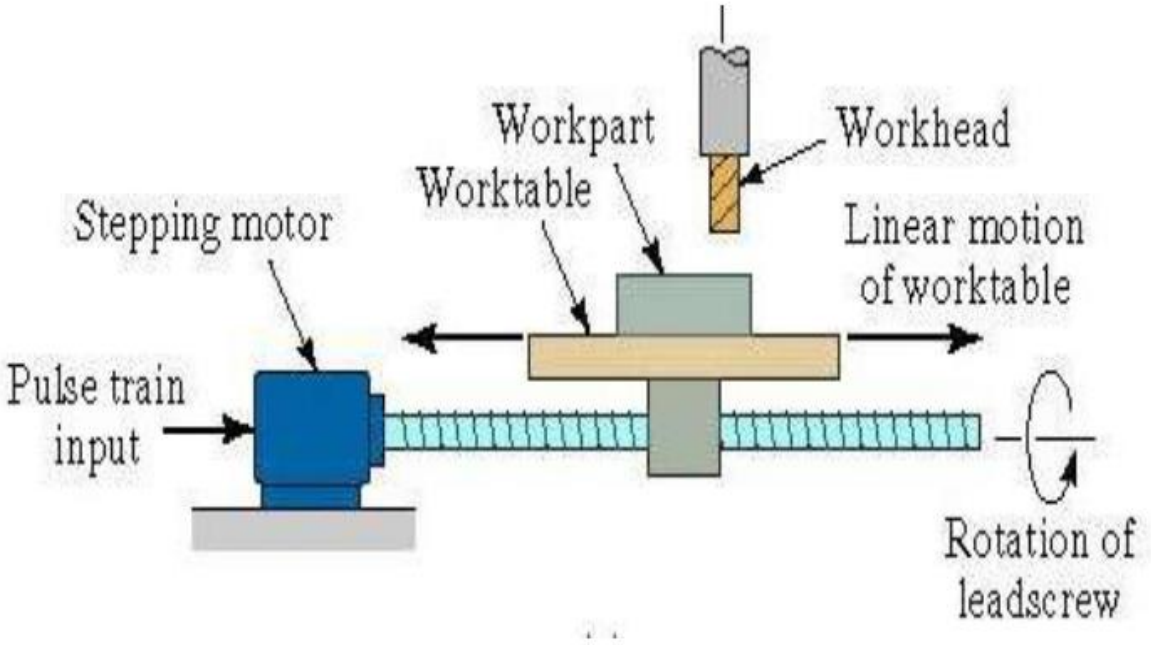
3.2 FEEDBACK CONTROL SYSTEMS

Open Loop Systems

The term open-loop means that there is no feedback, and in open loop systems the motion controller produces outputs depending only on its set points, without feedback information about the effect that the output produces on the motion axes.



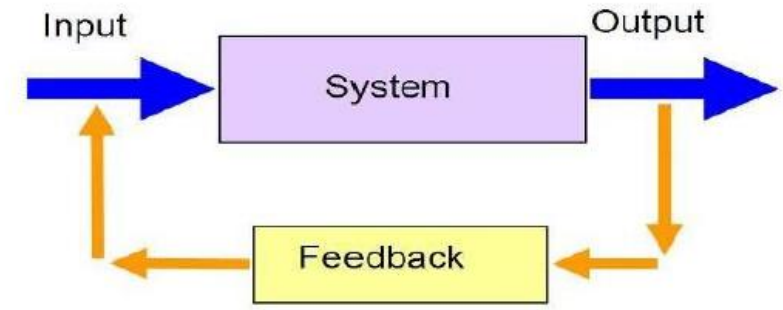
Block Diagram of an Open Loop System.



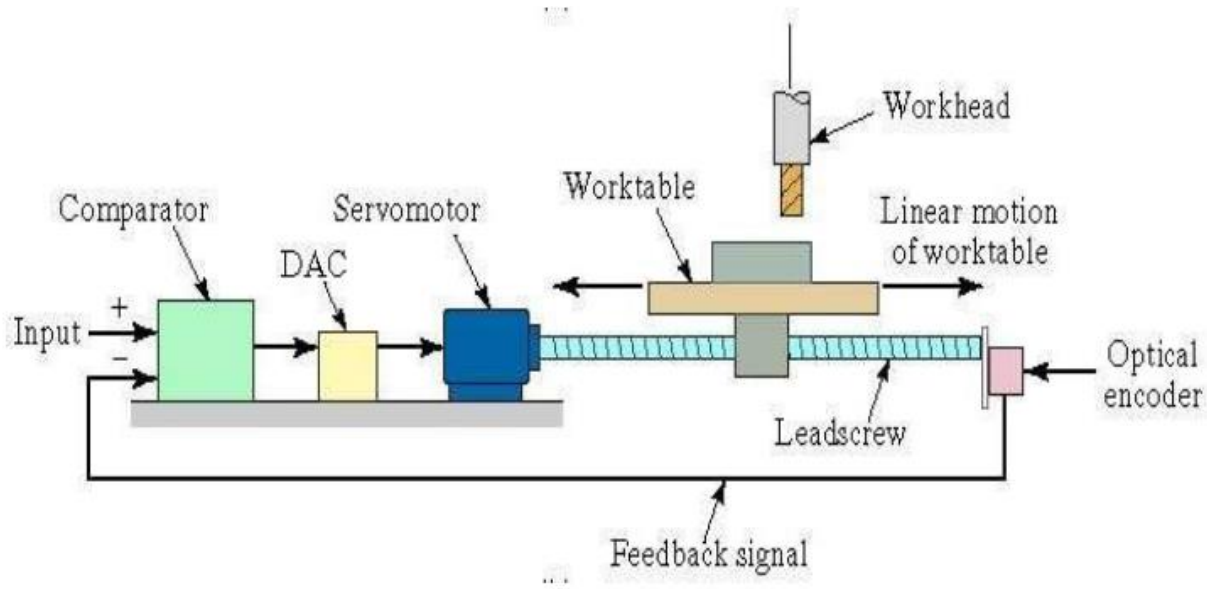
Open Loop Control System

Closed-loop control

As described in the module on controllers, continuously senses the actual position and velocity of the axis, using digital sensors such as encoders or analog sensors such resolvers and tacho-generators and compares them with the set points. In this case the servo motor and its drive system, to achieve motion.



Block Diagram of a Close Loop System



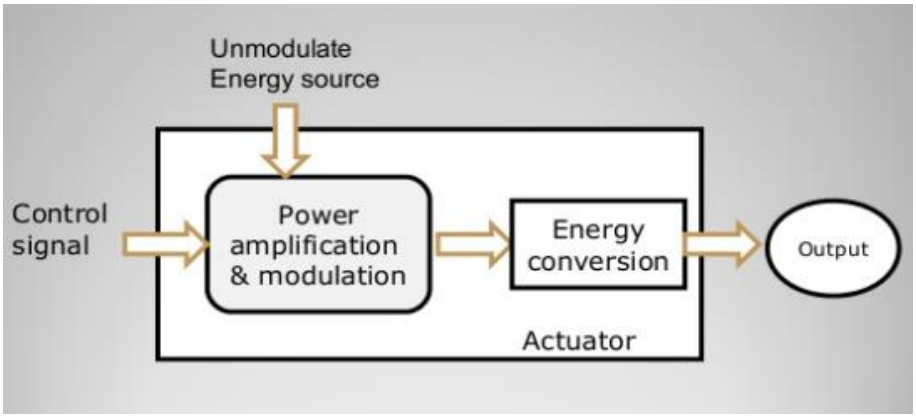
Closed loop Control System

3.3 ACTUATORS, TRANDUSCER AND SENSOR

ACTUATORS

It is a mechanism that converts some type of energy into motion in order to do work (move a force over a distance) .The three common types of energy used in work are electrical current, hydraulic pressure, or pneumatic pressure

An actuator requires control signal and source of energy. Upon receiving control signal, actuator responds by converting energy into mechanical motion. The control system can be simple (fixed mechanical or electric system), software based (e.g. a printer driver, robot control system), a human or any other input.



Types of an Actuator

- Hydraulic Actuators
- Pneumatic Actuators
- Electrical Actuators
- Mechanical Actuators

Hydraulic actuator

This actuator converts mechanical motion into linear, rotary or oscillatory motion. The hydraulic actuator consists of cylinder or fluid motor which uses hydraulic power to help mechanical operation. Liquids are nearly impossible to compress, hydraulic actuator maintains considerable force. Limited acceleration of actuator restricts its usage.

Example: Hydraulic brake in vehicle

Pneumatic actuator

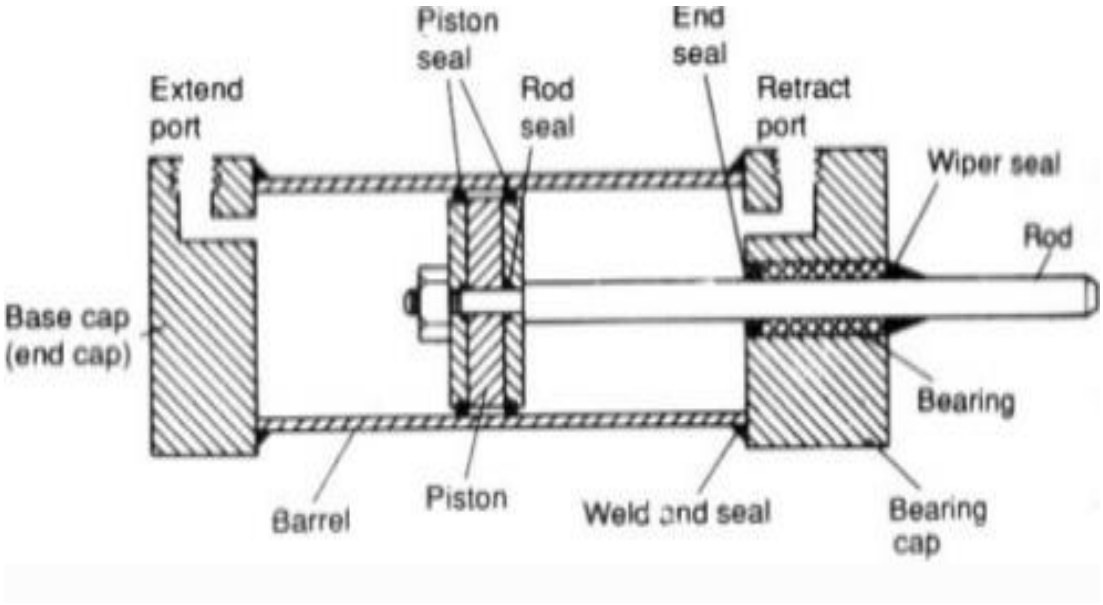
This actuator converts energy formed by vacuum or compressed air at high pressure into linear or rotary motion. They are responsible to convert pressure into force.

Advantages:

- Pneumatic energy responds quickly to start and stop signals.
- It does require power source to be stored in reserve for its operation.
- Pneumatic actuators produce large forces from relatively small pressure changes.

Examples:

- Rack and Pinion actuators used for valve controls of pipes.
- Pneumatic brakes are very responsive to small pressure changes applied by the driver.



Electrical actuator

It is powered by motor which converts electrical energy into mechanical torque. Electrical energy is used to actuate equipments (e.g. solenoid valves) which control water flow in pipes with response to electrical signals.

Advantages: cheap, clean, speedy type of actuator.

Examples: Solenoid based electric bell ringing mechanism

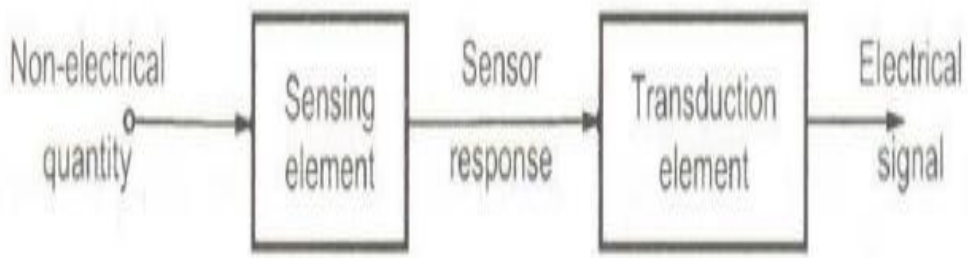
Mechanical actuator

It converts rotary motion into linear motion. It consists of gears, pulleys, rails, chains and other devices for its operation.

Examples: Rack and pinion mechanism and Crank shaft

TRANSDUCER

A device which converts a physical quantity into the proportional electrical signal is called a transducer. The electrical signal produced may be a voltage, current or frequency. A transducer uses many effects to produce such conversion. The process of transforming signal from one form to other is called transduction. A transducer is also called pick up. The transduction element transforms the output of the sensor to an electrical output, as shown in the Fig.



A transducer will have basically two main components. They are

Sensing Element

The physical quantity or its rate of change is sensed and responded to by this part of the transistor.

Transduction Element

The output of the sensing element is passed on to the transduction element. This element is responsible for converting the non-electrical signal into its proportional electrical signal.

There may be cases when the transduction element performs the action of both transduction and sensing. The best example of such a transducer is a thermocouple. A thermocouple is used to generate a voltage corresponding to the heat that is generated at the junction of two dissimilar metals.

Classification of Transducers

The Classification of Transducers is done in many ways. Some of the criteria for the classification are based on their area of application, Method of energy conversion, Nature of output signal, According to Electrical principles involved, Electrical parameter used, principle of operation, & typical applications.

The transducers can be classified broadly

- On the basis of transduction form used
- As primary and secondary transducers

- As active and passive transducers
- As transducers and inverse transducers.

Broadly one such generalization is concerned with energy considerations wherein they are classified as active & passive transducers. A component whose output energy is supplied entirely by its input signal (physical quantity under measurement) is commonly called a “passive transducer”. In other words the passive transducers derive the power required for transduction from an auxiliary source. Active transducers are those which do not require an auxiliary power source to produce their output. They are also known as self generating type since they produce their own voltage or current output. Some of the passive transducers (electrical transducers), their electrical parameter (resistance, capacitance, etc), principle of operation and applications are listed below.

Resistive Transducers

1. Resistance Strain Gauge – The change in value of resistance of metal semi-conductor due to elongation or compression is known by the measurement of torque, displacement or force.

2. Resistance Thermometer – The change in resistance of metal wire due to the change in temperature known by the measurement of temperature.

3. Resistance Hygrometer – The change in the resistance of conductive strip due to the change of moisture content is known by the value of its corresponding humidity.

4. Hot Wire Meter – The change in resistance of a heating element due to convection cooling of a flow of gas is known by its corresponding gas flow or pressure.

5. Photoconductive Cell – The change in resistance of a cell due to a corresponding change in light flux is known by its corresponding light intensity.

6. Thermistor – The change in resistance of a semi-conductor that has a negative co-efficient of resistance is known by its corresponding measure of temperature.

7. Potentiometer Type – The change in resistance of a potentiometer reading due to the movement of the slider as a part of an external force applied is known by its corresponding pressure or displacement.

Capacitance Transducers

1. Variable capacitance pressure gage

Principle of operation: Distance between two parallel plates is varied by an externally applied force.

Applications: Measurement of Displacement, pressure

2. Capacitor microphone

Principle of operation: Sound pressure varies the capacitance between a fixed plate and a movable diaphragm.

Applications: Speech, music, noise

3. Dielectric gauge

Principle of operation: Variation in capacitance by changes in the dielectric.

Applications: Liquid level, thickness

Inductance Transducers

1. Magnetic circuit transducer

Principle of operation: Self inductance or mutual inductance of ac-excited coil is varied by changes in the magnetic circuit.

Applications: Pressure, displacement

2. Reluctance pickup

Principle of operation: Reluctance of the magnetic circuit is varied by changing the position of the iron core of a coil.

Applications: Pressure, displacement, vibration, position

3. Differential transformer

Principle of operation: The differential voltage of two secondary windings of a transformer is varied by positioning the magnetic core through an externally applied force.

Applications: Pressure, force, displacement, position

4. Eddy current gage

Principle of operation: Inductance of a coil is varied by the proximity of an eddy current plate.

Applications: Displacement, thickness

5. Magnetostriction gauge

Principle of operation: Magnetic properties are varied by pressure and stress.

Applications: Force, pressure, sound

Voltage and current Transducers

1. Hall effect pickup

Principle of operation: A potential difference is generated across a semiconductor plate (germanium) when magnetic flux interacts with an applied current. Applications: Magnetic flux, current

2. Ionization chamber

Principle of operation: Electron flow induced by ionization of gas due to radioactive radiation.

Applications: Particle counting, radiation

3. Photo emissive cell

Principle of operation: Electron emission due to incident radiation on photo emissive surface.

Applications: Light and radiation

4. Photomultiplier tube

Principle of operation: Secondary electron emission due to incident radiation on photosensitive cathode. Applications: Light and radiation, photo-sensitive relays.

Self-Generating Transducers (No External Power) – Active Transducers

They do not require an external power, and produce an analog voltage or current when stimulated by some physical form of energy.

1. Thermocouple and thermopile

Principle of operation: An emf is generated across the junction of two dissimilar metals or semiconductors when that junction is heated.

Applications: Temperature, heat flow, radiation.

2. Moving-coil generator

Principle of operation: Motion of a coil in a magnetic field generates a voltage.

Applications: Velocity. Vibration

3. Piezoelectric pickup

An emf is generated when an external force is applied to certain crystalline materials, such as quartz Sound, vibration. Acceleration, pressure changes

4. Photovoltaic cell

Principle of operation: A voltage is generated in a semi-conductor junction device when radiant energy stimulates the cell

Applications: Light meter, solar cell.

Primary Transducers and Secondary Transducers- Bourdon tube acting as a primary detector senses the pressure and converts the pressure into a displacement of its free end. The displacement of the free end moves the core of a linear variable differential transformer (LVDT) which produces an output voltage.

Analog Transducers-These transducers convert the input quantity into an analog output which is a continuous function of time. Strain Gauge, LVDT, Thermocouple, Thermistor.

Digital Transducers-These transducers convert the input quantity into an electrical output which is in the form of pulses. ◦ Glass Scale can be read optically by means of a light source, an optical system and photocells

Transducers and Inverse Transducers- A Transducer can be broadly defined as a device which converts a non-electrical quantity into an electrical quantity. Ex:-Resistive, inductive and capacitive transducers -An inverse transducer is defined as a device which converts an electrical quantity into a non-electrical quantity. Ex:-Piezoelectric crystals

SENSOR

Sensor as an input device which provides an output (signal) with respect to a specific physical quantity (input).

Classification of Sensors

There are several classifications of sensors made by different authors and experts. Some are very simple and some are very complex. The following classification of sensors may already be used by an expert in the subject but this is a very simple classification of sensors.

In the first classification of the sensors, they are divided in to Active and Passive. **Active Sensors** are those which require an external excitation signal or a power signal.

Passive Sensors, on the other hand, do not require any external power signal and directly generates output response.

The other type of classification is ***based on the means of detection*** used in the sensor. Some of the means of detection are Electric, Biological, and Chemical, Radioactive etc.

The next classification is ***based on conversion phenomenon*** i.e. the input and the output. Some of the common conversion phenomena are Photoelectric, Thermoelectric, Electrochemical, Electromagnetic, Thermo optic, etc.

The final classifications of the sensors are ***Analog and Digital Sensors***.

Analog Sensors produce an analog output i.e. a continuous output signal with respect to the quantity being measured.
Digital Sensors, in contrast to Analog Sensors, work with discrete or digital data. The data in digital sensors, which is used for conversion and transmission, is digital in nature.

Different Types of Sensors

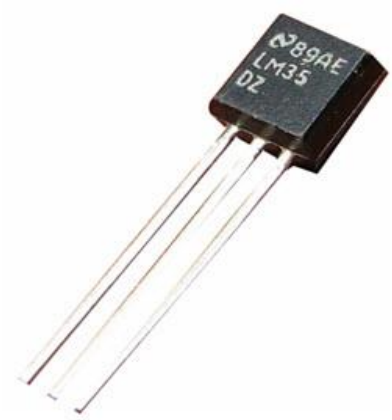
The following is a list of different types of sensors that are commonly used in various applications. All these sensors are used for measuring one of the physical properties like Temperature, Resistance, Capacitance, Conduction, Heat Transfer etc.

- Temperature Sensor
- Proximity Sensor
- Accelerometer
- IR Sensor (Infrared Sensor)
- Pressure Sensor
- Light Sensor
- Ultrasonic Sensor
- Smoke, Gas and Alcohol Sensor
- Touch Sensor
- Color Sensor
- Humidity Sensor
- Tilt Sensor

- Flow and Level Sensor

Temperature Sensor

One of the most common and most popular sensors is the Temperature Sensor. A Temperature Sensor, as the name suggests, senses the temperature i.e. it measures the changes in the temperature.



LM35 - Temperature Sensor IC

10KΩ NTC Thermistor

In a Temperature Sensor, the changes in the Temperature correspond to change in its physical property like resistance or voltage.

There are different types of Temperature Sensors like Temperature Sensor ICs (like LM35), Thermistors, Thermocouples, RTD (Resistive Temperature Devices), etc.

Applications: computers, mobile phones, automobiles, air conditioning systems, industries etc.

Proximity Sensors

A Proximity Sensor is a non-contact type sensor that detects the presence of an object. Proximity Sensors can be implemented using different techniques like Optical (like Infrared or Laser), Ultrasonic, Hall Effect, Capacitive, etc.

Some of the applications of Proximity Sensors are Mobile Phones, Cars (Parking Sensors), industries (object alignment), Ground Proximity in Aircrafts, etc.

Infrared Sensor (IR Sensor)

IR Sensors or Infrared Sensor is light based sensor that are used in various applications like Proximity and Object Detection. IR Sensors are used as proximity sensors in almost all mobile phones.

There are two types of Infrared or IR Sensors: Transmissive Type and Reflective Type. In Transmissive Type IR Sensor, the IR Transmitter (usually an IR LED) and the IR Detector (usually a Photo Diode) are positioned facing each other so that when an object passes between them, the sensor detects the object.

The other type of IR Sensor is a Reflective Type IR Sensor. In this, the transmitter and the detector are positioned adjacent to each other facing the object. When an object comes in front of the sensor, the sensor detects the object.

Different applications where IR Sensor is implemented are Mobile Phones, Robots, Industrial assembly, automobiles etc.

Ultrasonic Sensor

An Ultrasonic Sensor is a non-contact type device that can be used to measure distance as well as velocity of an object. An Ultrasonic Sensor works based on the properties of the sound waves with frequency greater than that of the human audible range.

Using the time of flight of the sound wave, an Ultrasonic Sensor can measure the distance of the object (similar to SONAR). The Doppler Shift property of the sound wave is used to measure the velocity of an object.

3.4 CHARACTERISTICS OF SENSORS

1. Range: It is the minimum and maximum value of physical variable that the sensor can sense or measure. For example, a Resistance Temperature Detector (RTD) for the measurement of temperature has a range of -200 to 800^{o}C.
2. Span: It is the difference between the maximum and minimum values of input. In above example, the span of RTD is 800 – (-200) = 1000^{o}C.
3. Accuracy: The error in measurement is specified in terms of accuracy. It is defined as the difference between measured value and true value. It is defined in terms of % of full scale or % of reading.

$$Absolute\ Error = |Measured\ value - True\ value|$$
$$\Rightarrow E_a = |X_m - X_t|$$

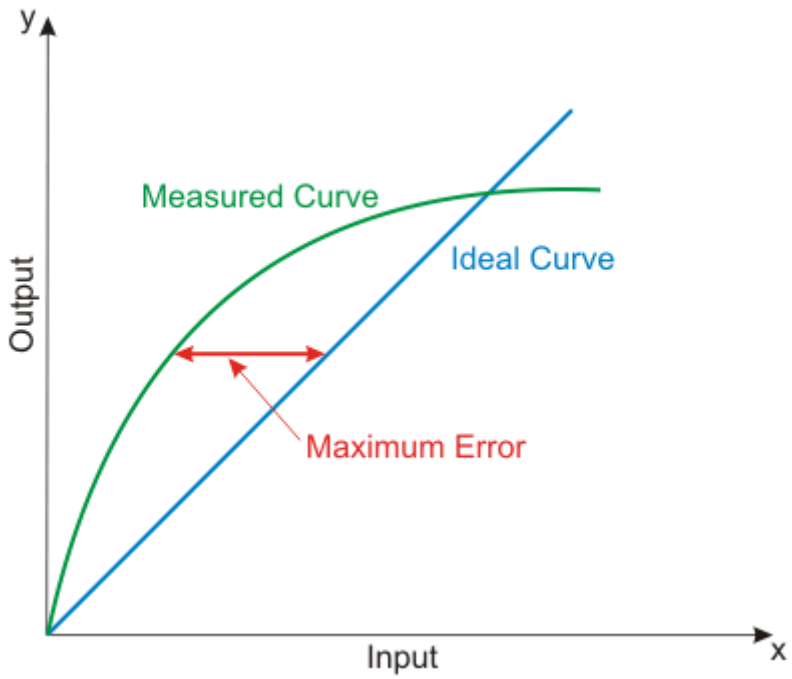
X_t is calculated by taking mean of infinite number of measurements.

$$Relative\ error = \frac{Absolute\ error}{True\ value}$$
$$\Rightarrow E_r = \frac{|X_m - X_t|}{X_t}$$

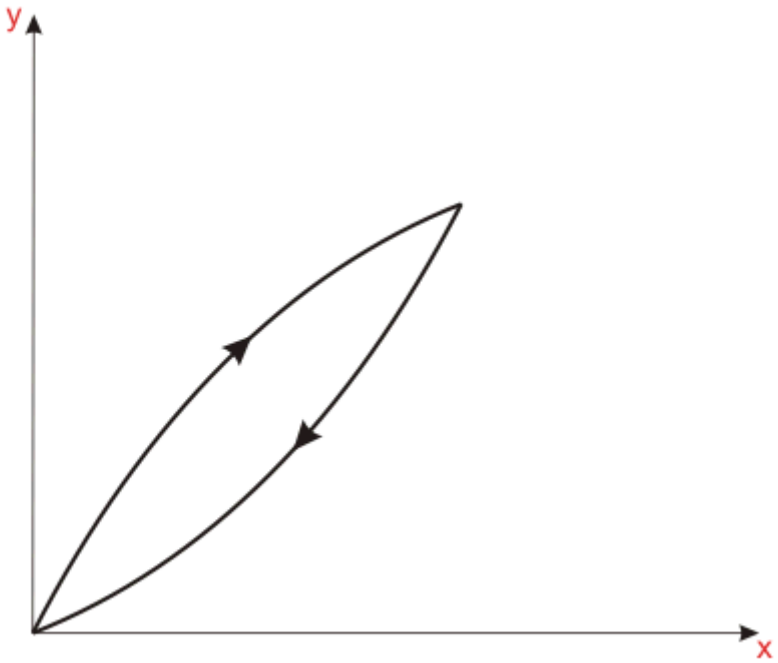
4. Precision: It is defined as the closeness among a set of values. It is different from accuracy.
5. Sensitivity: It is the ratio of change in output to change in input. If Y be the output quantity in response to input X, then sensitivity S can be expressed as

$$S = \frac{dY}{dX} = \frac{\Delta Y}{\Delta X}$$

6. Linearity: Linearity is the maximum deviation between the measured values of a sensor from ideal curve.



7. Hysteresis: It is the difference in output when input is varied in two ways- increasing and decreasing.



8. Resolution: It is the minimum change in input that can be sensed by the sensor.
9. Reproducibility: It is defined as the ability of sensor to produce the same output when same input is applied.
10. Repeatability: It is defined as the ability of sensor to produce the same output every time when the same input is applied and all the physical and measurement conditions kept the same including the operator, instrument, ambient conditions etc.
11. Response Time: It is generally expressed as the time at which the output reaches a certain percentage (for instance, 95%) of its final value, in response to a step change of the input.

3.5 TECHOMETER

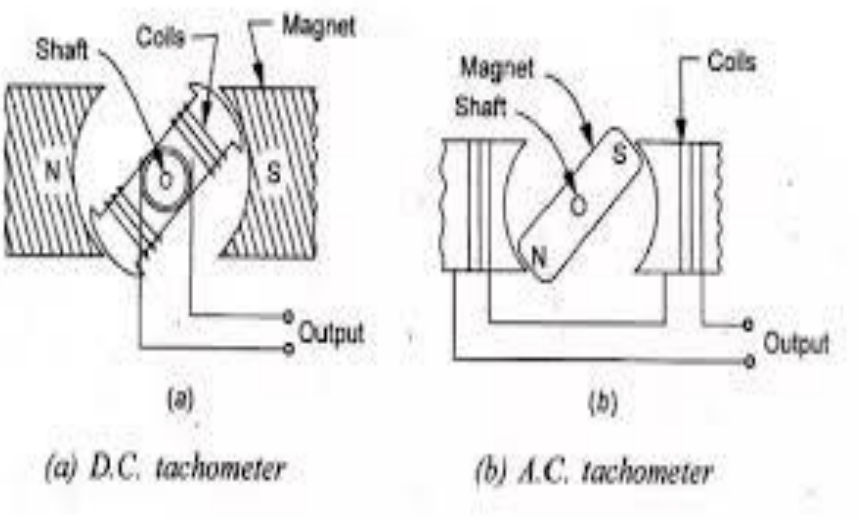
A Tachometer is an instrument measuring the rotation pace of a shaft or disk, as in a motor or different machine. The device generally shows the revolutions in keeping with minute (RPM) on a calibrated analogue dial.

Types of Techometer

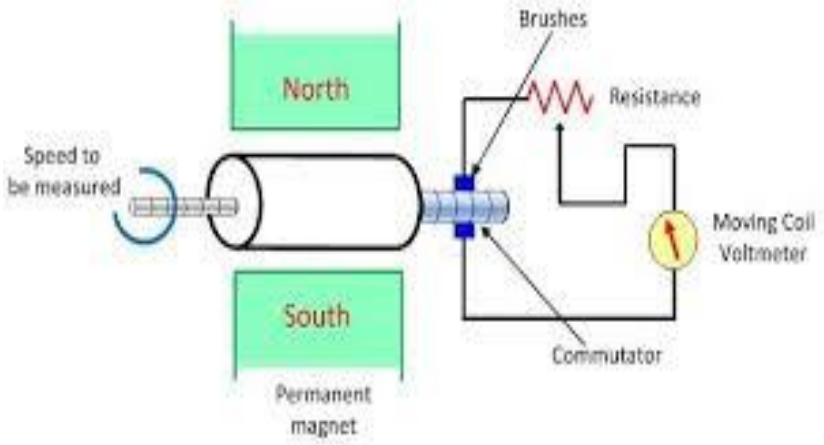
- Analog Techometer
- Digital Techometer

Working

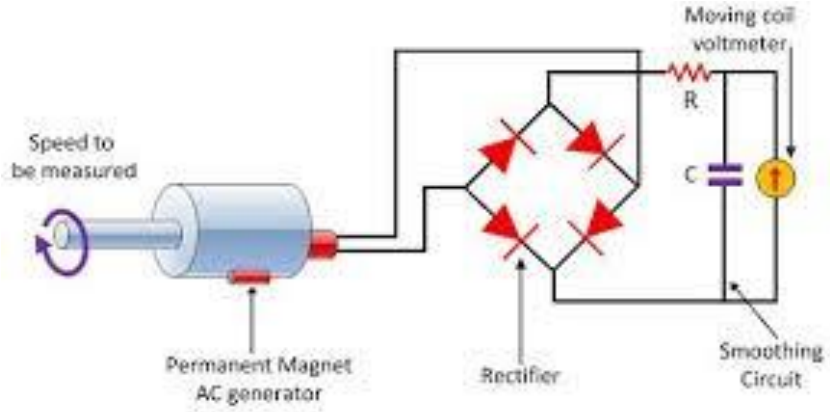
The working principle of an electronic tachometer is quite simple. The ignition device triggers a voltage pulse on the output of the tachometer electromechanical component whenever the spark plugs fires. The electromechanical element responds to the common voltage of the series of pulses. It indicates that the common voltage of the pulse teach is proportional to engine pace. The sign from the notion head is transmitted with the aid of general dual screened cable to the indicator. It's all about revolution. Digital tachometers, and all tachometers, measure the revolutions of a spinning object to determine the rate at which it is spinning.



(a) D.C. tachometer (b) A.C. tachometer



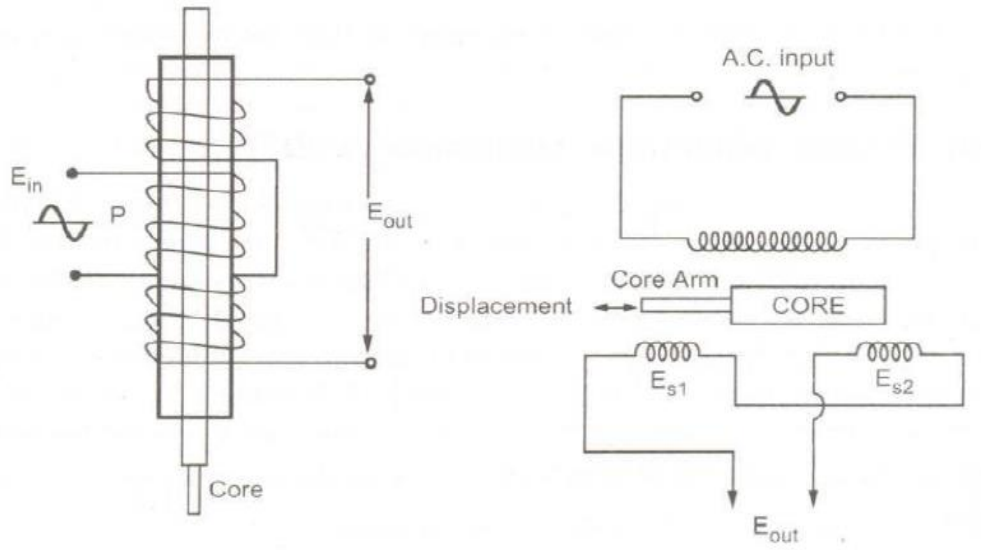
DC Tachometer Generator

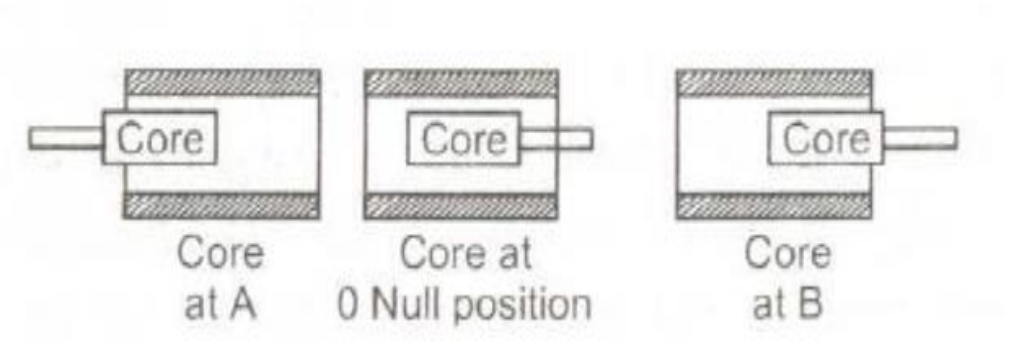


A.C Tachometer Generator

3.6 LINEAR VARIABLE DIFFERENTIAL TRANSFORMER (LVDT)

When an externally applied force moves the core to the left-hand position, more magnetic flux links the left-hand coil than the right hand coil. The e.m.f. induced in the left-hand coil, ES], is therefore larger than the induced e.m.f. of the right-hand [oil, ES^2 the magnitude of the output voltage is then equal to the difference between the two secondary voltages and it is in phase with the voltage of the left-hand coil.





Construction of LVDT

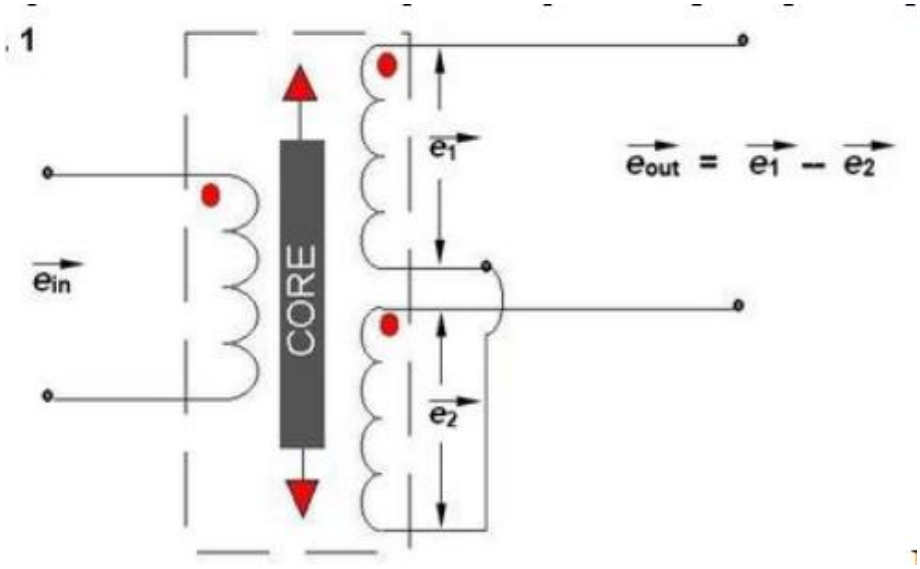
Main Features of Construction are as,

- The transformer consists of a primary winding P and two secondary winding S1 and S2 wound on a cylindrical former (which is hollow in nature and will contain core). Both the secondary windings have equal number of turns and are identically placed on the either side of primary winding
- The primary winding is connected to an AC source which produces a flux in the air gap and voltages are induced in secondary windings.
- A movable soft iron core is placed inside the former and displacement to be measured is connected to the iron core.

- The iron core is generally of high permeability which helps in reducing harmonics and high sensitivity of LVDT.
- The LVDT is placed inside stainless steel housing because it will provide electrostatic and electromagnetic shielding.
- The both the secondary windings are connected in such a way that resulted output is the difference of the voltages of two windings.

Principle of Operation and Working

As the primary is connected to an AC source so alternating current and voltages are produced in the secondary of the LVDT. The output in secondary S1 is e1 and in the secondary S2 is e2. So the differential output is, **eout = e1 - e2.** This equation explains the **principle of Operation of LVDT**.



Now three cases arise according to the locations of core which explains the working of LVDT are discussed below as,

CASE I When the core is at null position (for no displacement) When the core is at null position then the flux linking with both the secondary windings is equal so the induced emf is equal in both the windings. So for no displacement

the value of output e_{out} is zero as e_1 and e_2 both are equal. So it shows that no displacement took place.

CASE II When the core is moved to upward of null position (For displacement to the upward of reference point) In the this case the flux linking with secondary winding S_1 is more as compared to flux linking with S2. Due to this e_1 will be more as that of e_2. Due to this output voltage e_{out} is positive.

CASE III When the core is moved to downward of Null position (for displacement to the downward of reference point) In this case magnitude of e_2 will be more as that of e_1. Due to this output e_{out} will be negative and shows the output to downward of reference point.

Advantages of LVDT

- **High Range -** The LVDTs have a very high range for measurement of displacement. They can use for measurement of displacements ranging from 1.25mm to 250mm
- **No Frictional Losses -** As the core moves inside a hollow former so there is no loss of displacement input as frictional loss so it makes LVDT as very accurate device.
- **High Input and High Sensitivity -** The output of LVDT is so high that it doesn't need any amplification. The transducer possesses a high sensitivity which is typically about 40V/mm.
- **Low Hysteresis -** LVDTs show a low hysteresis and hence repeatability is excellent under all conditions
- **Low Power Consumption -** The power is about 1W which is very as compared to other transducers.
- **Direct Conversion to Electrical Signals -** They convert the linear displacement to electrical voltage which is easy to process

Disadvantages of LVDT

- LVDT is sensitive to stray magnetic fields so they always require a setup to protect them from stray magnetic fields.
- They are affected by vibrations and temperature.

It is concluded that they are advantageous as compared than any other inductive transducers.

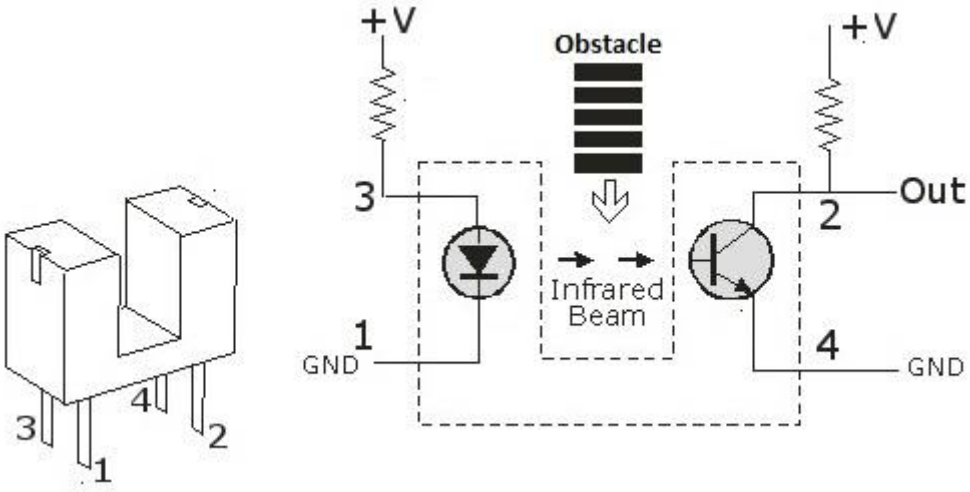
Applications of LVDT

- They are used in applications where displacements ranging from fraction of mm to few cm are to be measured. The LVDT acting as a primary Transducer converts the displacement to electrical signal directly.
- They can also acts as the secondary transducers. E.g. the Bourbon tube which acts as a primary transducer and covert pressure into linear displacement. Then LVDT coverts this displacement into electrical signal which after calibration gives the ideas of the pressure of fluid.

3.7 OPTO INTERRUPTER

The OPTO switch or interrupter is a small U shaped black plastic package which has four legs-2 for infra red LED on one side of the U and 2 for light sensitive transistor on the other.

The principle states that objects opaque to infrared will interrupt the transmission of light between an infrared emitting diode and a photo sensor switching the output from an "ON" state to an "OFF" state.



3.8 POTENTIOMETER

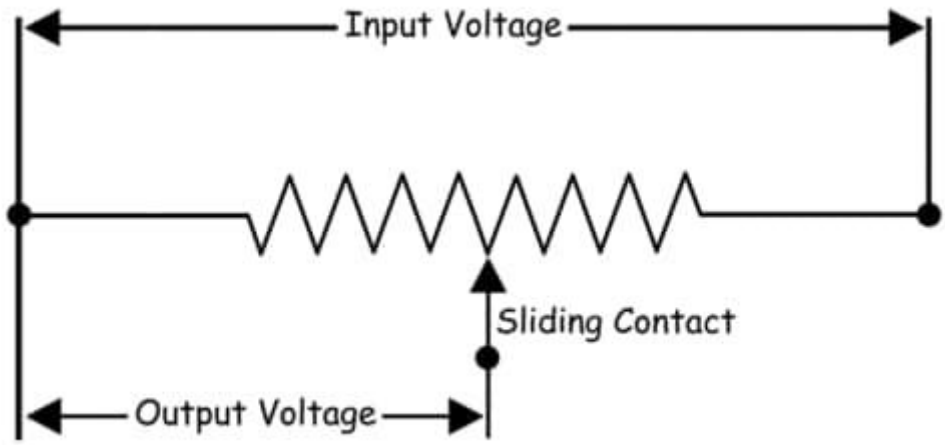
A **potentiometer** (also known as a **pot** or **potmeter**) is defined as a 3 terminal variable resistor in which the resistance is manually varied to control the flow of electric current. A potentiometer acts as an adjustable voltage divider.

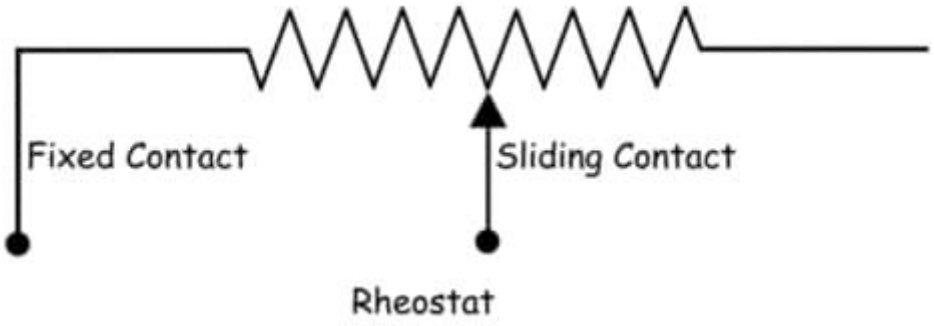
How Does a Potentiometer Work?

A potentiometer is a passive electronic component. Potentiometers work by varying the position of a sliding contact across a uniform resistance. In a potentiometer, the entire input voltage is applied across the whole length of the resistor, and the output voltage is the voltage drop between the fixed and sliding contact as shown below.

A potentiometer has the two terminals of the input source fixed to the end of the resistor. To adjust the output voltage the sliding contact gets moved along the resistor on the output side.

This is different to a rheostat, where here one end is fixed and the sliding terminal is connected to the circuit, as shown below.





Rheostat

Potentiometer Types

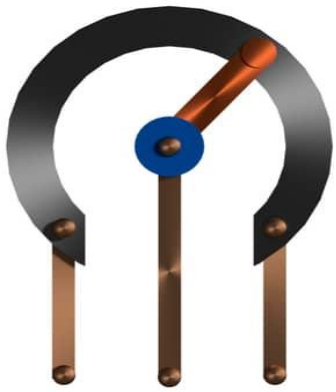
There are two main types of potentiometers:

- Rotary potentiometer
- Linear potentiometer

Although the basic constructional features of these potentiometers vary, the working principle of both of these types of potentiometers is the same. Note that these are types of DC potentiometers – the types of AC potentiometers are slightly different.

Rotary Potentiometers

The rotary type potentiometers are used mainly for obtaining adjustable supply voltage to a part of electronic circuits and electrical circuits. The volume controller of a radio transistor is a popular example of a rotary potentiometer where the rotary knob of the potentiometer controls the supply to the amplifier.



This type of potentiometer has two terminal contacts between which a uniform resistance is placed in a semi-circular pattern. The device also has a middle terminal which is connected to the resistance through a sliding contact attached with a rotary knob. By rotating the knob one can move the sliding contact on the semi-circular resistance. The voltage is taken between a resistance end contact and the sliding contact. The potentiometer is also named as the POT in short. POT is also used in substation battery chargers to adjust the charging voltage of a battery. There are many more uses of rotary type potentiometer where smooth voltage control is required.

Linear Potentiometers

The linear potentiometer is basically the same but the only difference is that here instead of rotary movement the sliding contact gets moved on the resistor linearly. Here two ends of a straight resistor are connected across the source voltage. A sliding contact can be slide on the resistor through a track attached along with the resistor. The terminal connected to the sliding is connected to

one end of the output circuit and one of the terminals of the resistor is connected to the other end of the output circuit.

This type of potentiometer is mainly used to measure the voltage across a branch of a circuit, for measuring the internal resistance of a battery cell, for comparing a battery cell with a standard cell and in our daily life; it is commonly used in the equalizer of music and sound mixing systems.

3.9 ENCODER AND DECODER

Encoder

An **encoder** is a device, circuit, transducer, software program, algorithm or person that converts information from one format or code to another, for the purposes of standardization, speed, secrecy, security, or saving space

A rotary or linear encoder concerts rotary or linear motion to an electronic signal.

Types of Encoders

Linear and rotary encoders are broken down into two main types: the absolute encoder and the incremental encoder. The construction of these two types of encoders is quite similar; however they differ in physical properties and the interpretation of movement.

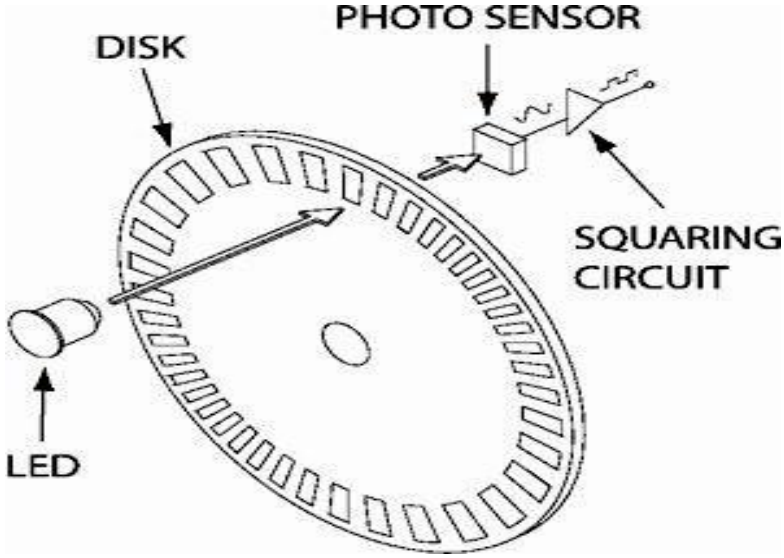
Incremental Encoders

An Incremental rotary encoder is also referred to as a quadrature encoder. This type of encoder utilizes sensors that use **optical**, mechanical or **magnetic** index counting for angular measurement.

Incremental rotary encoders

It utilizes a transparent disk which contains opaque sections that are equally spaced to determine movement. A light emitting diode is used to pass through the glass disk and is detected by a photo detector. This causes the encoder to

generate a train of equally spaced pulses as it rotates. The output of incremental rotary encoders is measured in pulses per revolution which is used to keep track of position or determine speed.



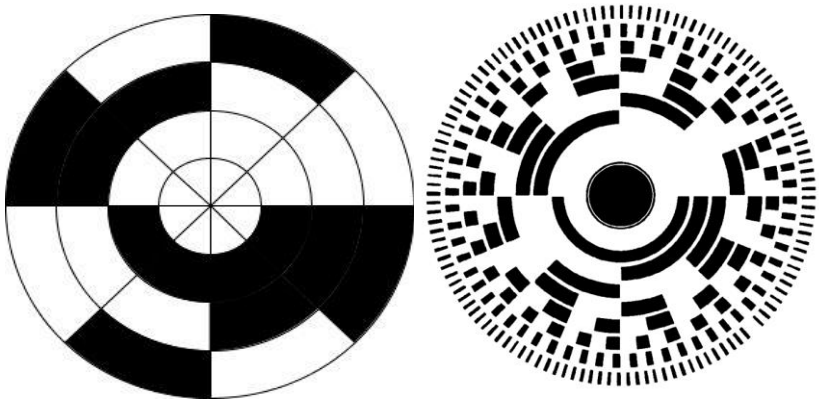
Magnetic Contact Optical

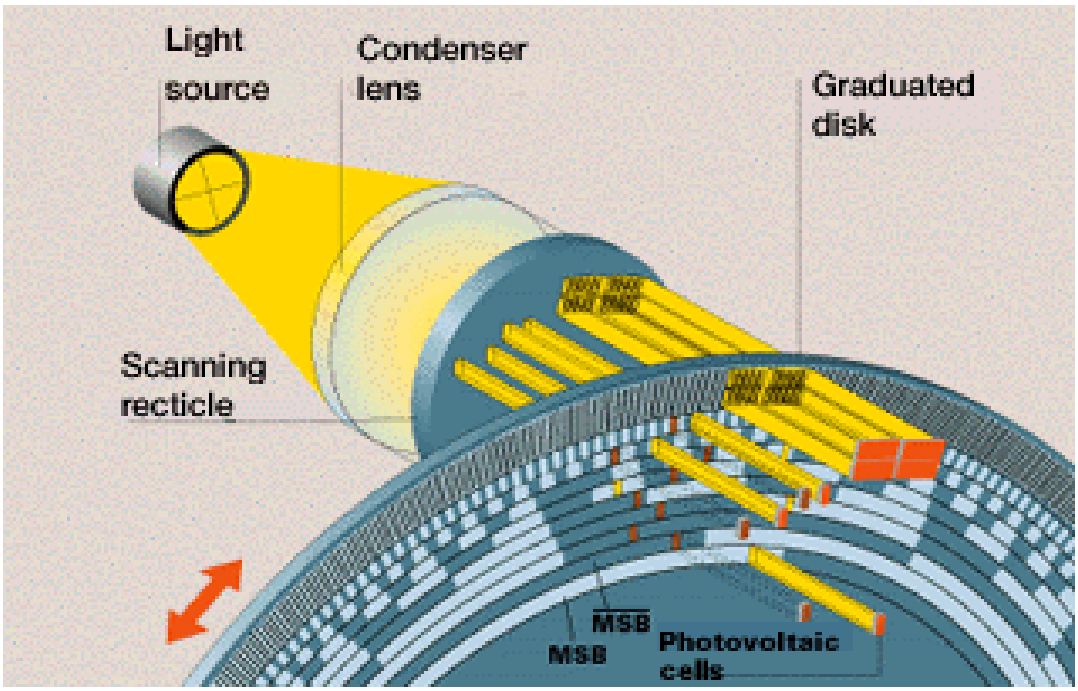
Rotary Absolute Encoders

An absolute encoder contains components also found in incremental encoders. They implement a photo detector and LED light source but instead of a disk with evenly spaced lines on a disc, an absolute encoder uses a disk with concentric circle patterns.

Working

Absolute encoders utilize stationary mask in between the photo detector and the encoder disk as shown below. The output signal generated from an absolute encoder is in digital bits which correspond to a unique position. The bit configuration is produced by the light which is received by the photo detector when the disk rotates. The light configuration received is translated into gray code. As a result, each position has its own unique bit configuration.



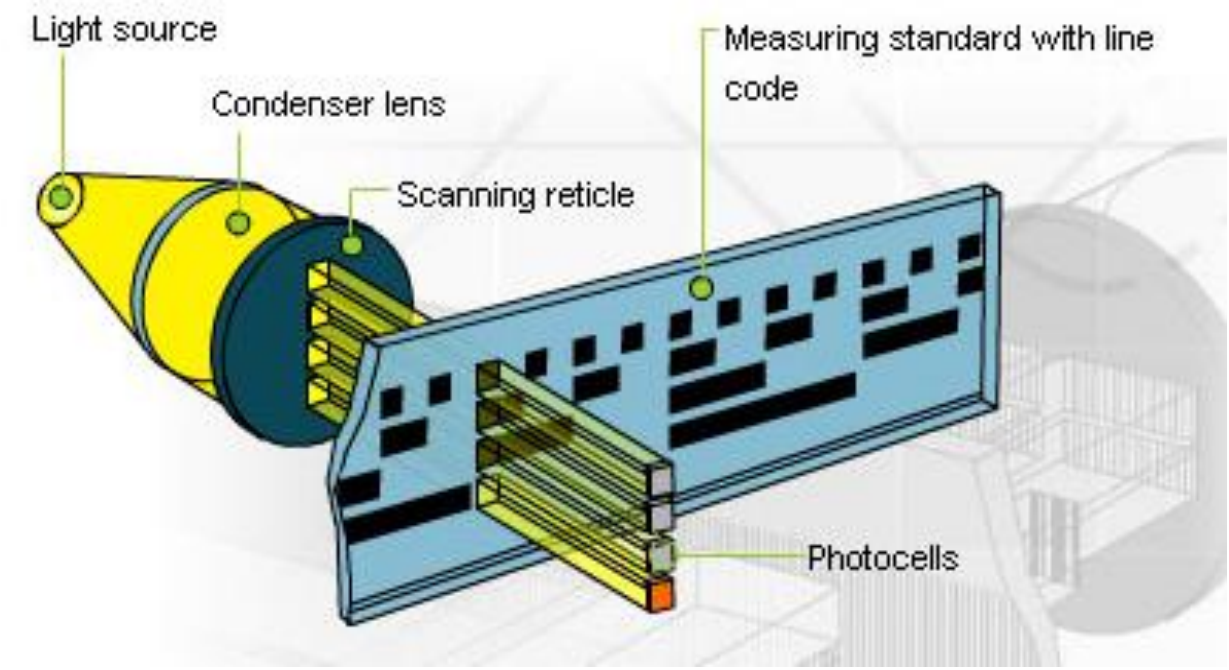


Linear Encoders

A linear encoder is a sensor, transducer or reading-head linked to a scale that encodes position. The sensor reads the scale and converts position into an analog or digital signal that is transformed into a digital readout. Movement is determined from changes in position with time. Both optical and magnetic linear encoder types function using this type of method. However, it is their physical properties which make them different.

Working

The light source and lens produce a parallel beam of light which pass through four windows of the scanning reticle. The four scanning windows are shifted 90 degrees apart. The light then passes through the glass scale and is detected by photo sensors. The scale then transforms the detected light beam when the scanning unit moves. The detection of the light by the photo sensor produces sinusoidal wave outputs. The linear encoder system then combines the shifted signals to create two sinusoidal outputs which are symmetrical but 90 degrees out of phase from each other. A reference signal is created when a fifth pattern on the scanning reticle becomes aligned with an identical pattern on the scale.



DECODER

The decoder is a circuit used to change the code into a set of signals. A decoder is a circuit that changes a code into a set of signals. It is called a decoder because it does the reverse of encoding, but we will begin our study of encoders and decoders with decoders because they are simpler to design

3.10 AXIS DRIVES

In machine tools, power is generally required for driving the main spindle, saddles and carriages and to some auxiliary units. The motors used for CNC system are of two kinds

Electrical - AC , DC or Stepper motors

Fluid - Hydraulic or Pneumatic In CNC,

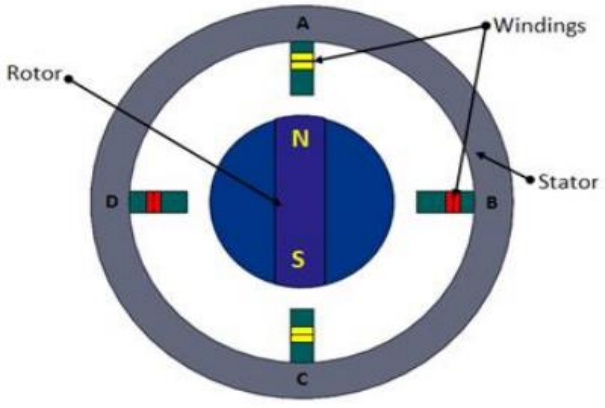
Usually stepper and servo electrical drives are used. They exhibit favorable torque-speed characteristics and are relatively inexpensive.

Stepper motor

A stepper motor is a pulse-driven motor that changes the angular position of the rotor in steps. Due to this nature of a stepper motor, it is widely used in low cost, open loop position control systems.

Permanent magnet (PM) stepper motor

Rotor is a permanent magnet. PM motor rotor has no teeth and is designed to be magnetized at a right angle to its axis. Figure shows a simple, 90° PM motor with four phases (A-D). Applying current to each phase in sequence will cause the rotor to rotate by adjusting to the changing magnetic fields. Although it operates at fairly low speed, the PM motor has a relatively high torque characteristic.



Permanent magnet stepper

These are low cost motors with typical step angle ranging between 7.5^{o} to 15^{0}.Step angle of a stepper motor is given by,

$$\text{Step angle} = \frac{360^{0}}{number\ of\ poles}$$

Advantages of Stepper Motors

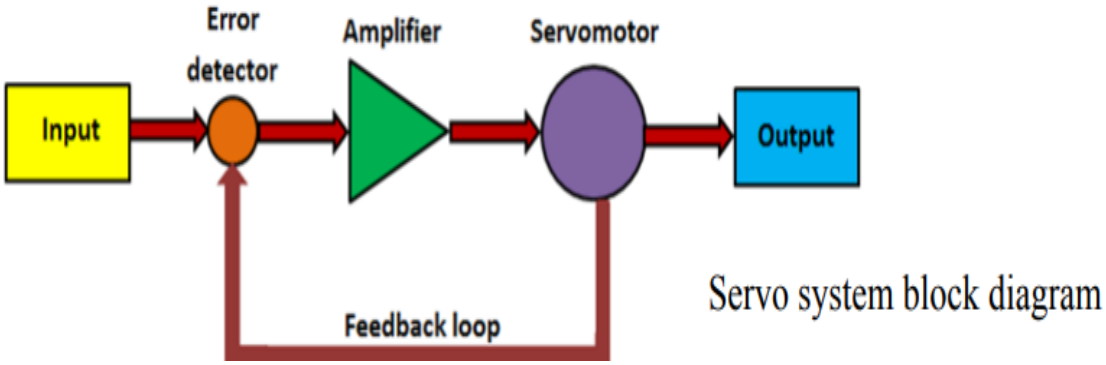
- Low cost
- Ruggedness
- Simplicity of construction
- Low maintenance
- Less likely to stall or slip
- Will work in any environment
- Excellent start-stop and reversing responses

Disadvantages of Stepper Motors

- Low torque capacity compared to DC motors
- Limited speed
- During overloading, the synchronization will be broken. Vibration and noise occur when running at high speed.

SERVO MOTORS

Servomotors are special electromechanical devices that produce precise degrees of rotation. A servo motor is a DC or AC or brushless DC motor combined with a position sensing device. Servomotors are also called control motors as they are involved in controlling a mechanical system. The servomotors are used in a closed-loop servo system as shown in Figure A reference input is sent to the servo amplifier, which controls the speed of the servomotor.



Servo system block diagram

A feedback device is mounted on the machine, which is either an encoder or resolver. This device changes mechanical motion into electrical signals and is used as a feedback. This feedback is sent to the error detector, which compares the actual operation with that of the reference input. If there is an error, that error is fed directly to the amplifier, which will be used to make necessary corrections in control action. In many servo systems, both velocity and position are monitored. Servomotors provide accurate speed, torque, and have ability of direction control.

DC servomotors

DC operated servomotors are usually respond to error signal abruptly and accelerate the load quickly. A DC servo motor is actually an assembly of four separate components, namely:

- DC motor
- gear assembly
- position-sensing device
- control circuit

AC servo motor

Magnetic force is generated by a permanent magnet and current which further produce the torque. It has no brushes so there is little noise/vibration. This

motor provides high precision control with the help of high resolution encoder. The stator is composed of a core and a winding. The rotor part comprises of shaft, rotor core and a permanent magnet. Digital encoder can be of optical or magnetic type. It gives digital signals, which are in proportion of rotation of the shaft.

Advantages of servo motors

- Provides high intermittent torque, high torque to inertia ratio, and high speeds
- Work well for velocity control
- Available in all sizes
- Quiet in operation
- Smoother rotation at lower speeds

Disadvantages of servo motors

- More expensive than stepper motors
- Require tuning of control loop parameters
- Not suitable for hazardous environments or in vacuum
- Excessive current can result in partial demagnetization of DC type servo motor

3.11 OTHER CLASSIFICATIONS OF CNC MACHINES-FEEDBACK, MOTION, POSITIONING

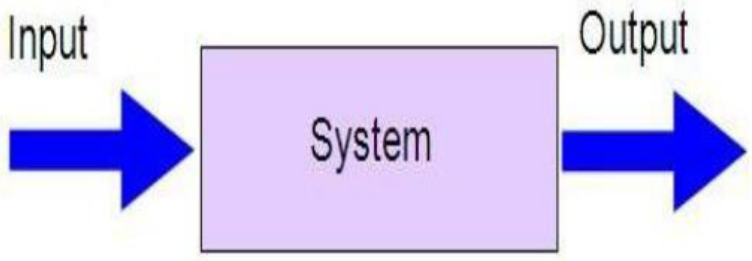
Types of CNC machines

Based on Feedback:

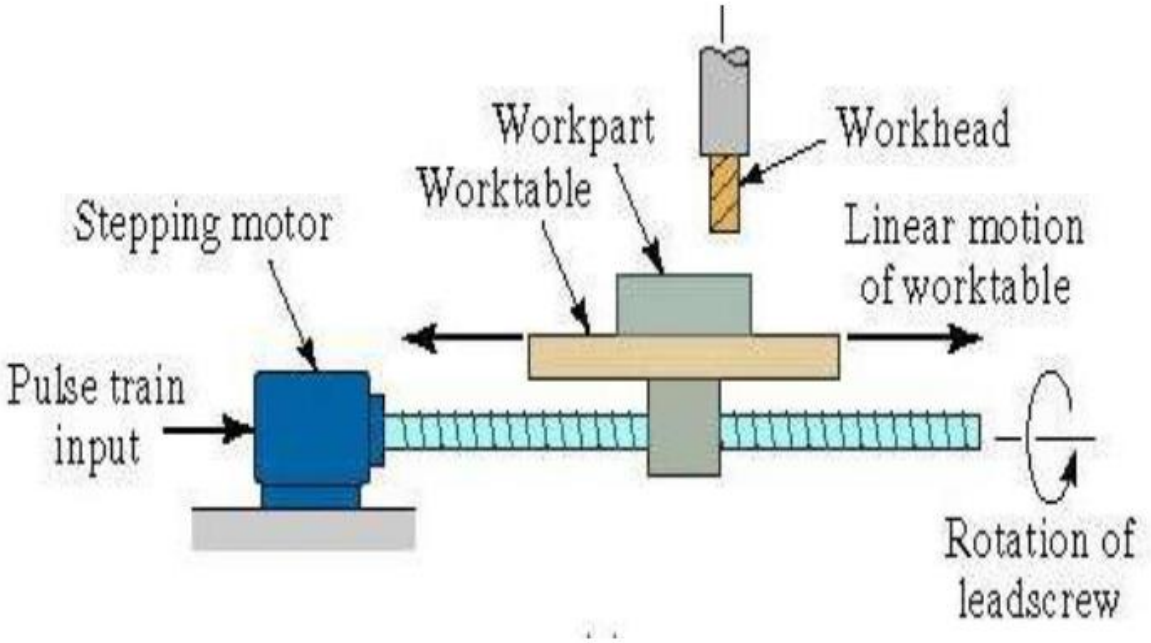
- Open loop system
- Closed loop system

Open Loop Systems

The term open-loop means that there is no feedback, and in open loop systems the motion controller produces outputs depending only on its set points, without feedback information about the effect that the output produces on the motion axes.



Block Diagram of an Open Loop System.

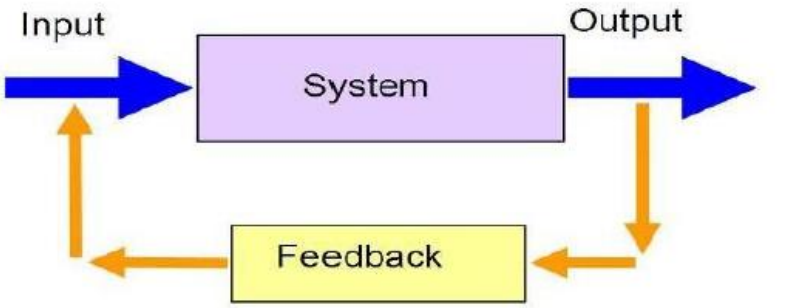


Open Loop Control System

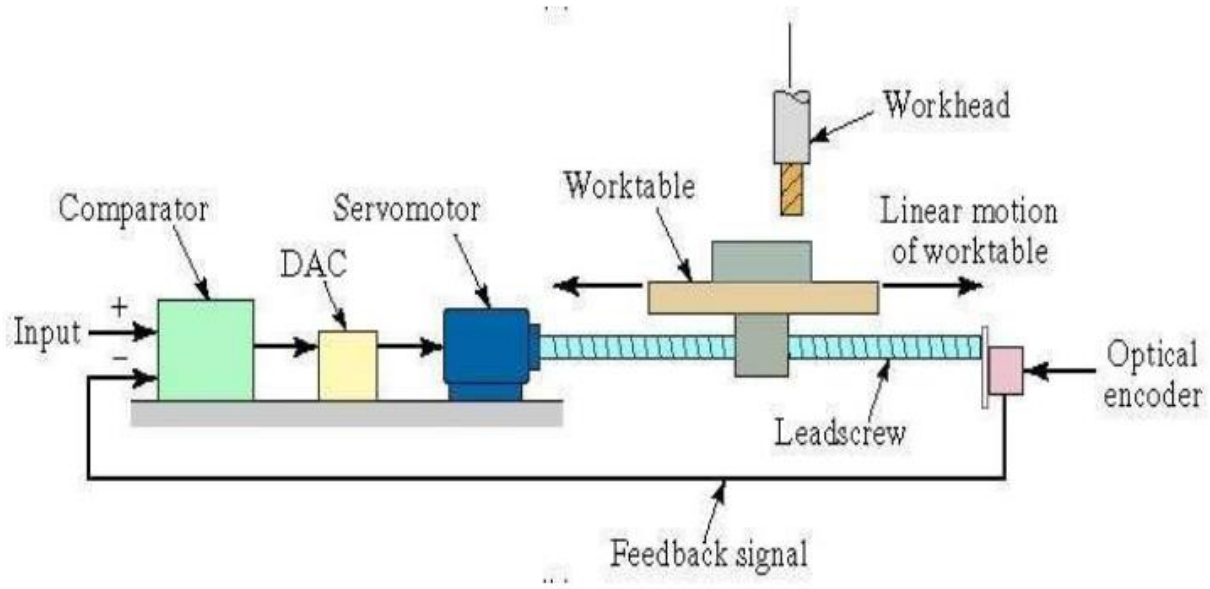
Closed-loop control

As described in the module on controllers, continuously senses the actual position and velocity of the axis, using digital sensors such as encoders or

analog sensors such resolvers and tacho-generators and compares them with the set points. In this case the servo motor and its drive system, to achieve motion.



Block Diagram of a Close Loop System



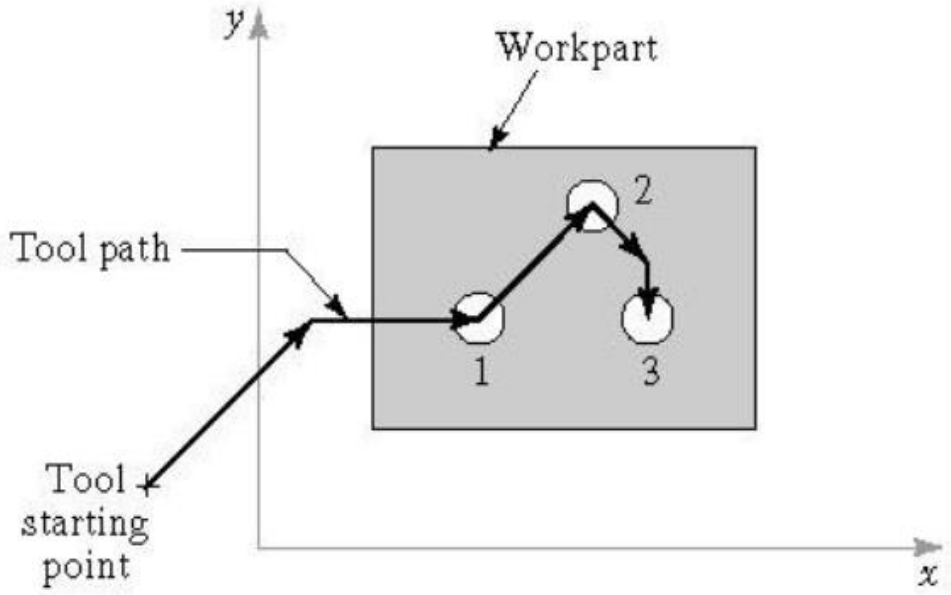
Closed loop Control System

Based on Motion Type:

- Point-to-Point and
- Continuous path

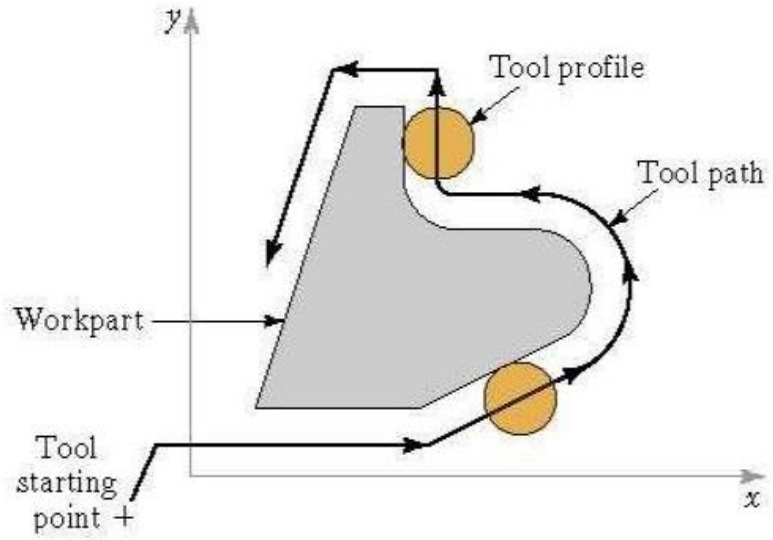
Point-to-Point Systems

- It is used in some CNC machines such as drilling, boring and tapping machines etc.
- The control equipment for use with them are known as point-to-point control equipment.
- Feed rates need not to be programmed.
- In these machine tools, each axis is driven separately.
- It also applicable in robotics



Continuous Path or Contouring Systems

- It is used in CNC machine tools such as milling machines.
- These machines require simultaneous control of axes.
- Contouring machines can also be used as point-to-point machines, but it will be uneconomical to use them unless the work piece also requires having a contouring operation to be performed on it.
- System performs an operation during movement (e.g., milling and turning)



Based on Positioning System :

- Absolute Positioning
- Incremental Positioning

Absolute Positioning

An absolute movement moves to a coordinate based on your zero point. An absolute NC system is one in which all position coordinates are referred to one fixed origin called the zero point.

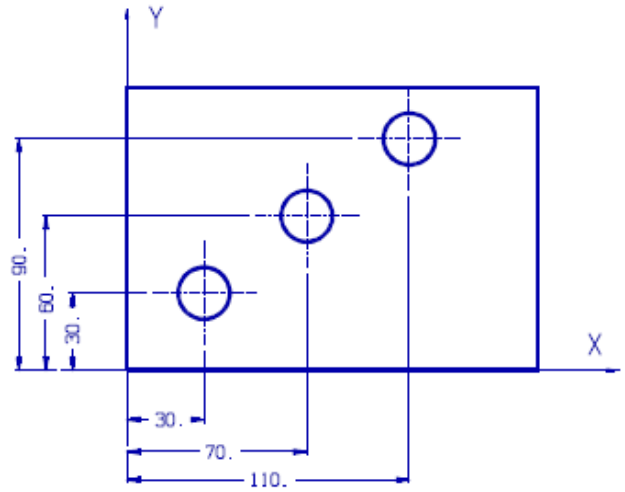


Fig.2-3 Absolute System

Incremental Positioning

An **incremental** movement moves **a distance** based on your **current position**. An incremental movement does not take your part zero point into consideration. In an incremental system the movements in each Part program block are expressed as the displacements along each coordinate axes with reference to the final position achieved at the end of executing the previous program block.

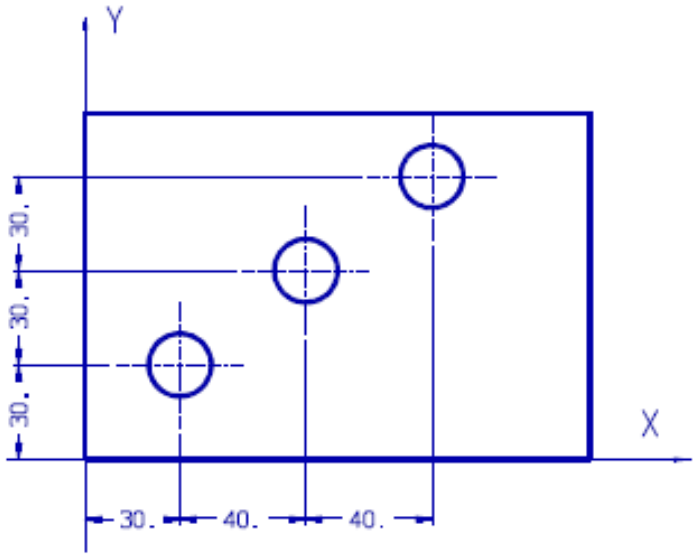
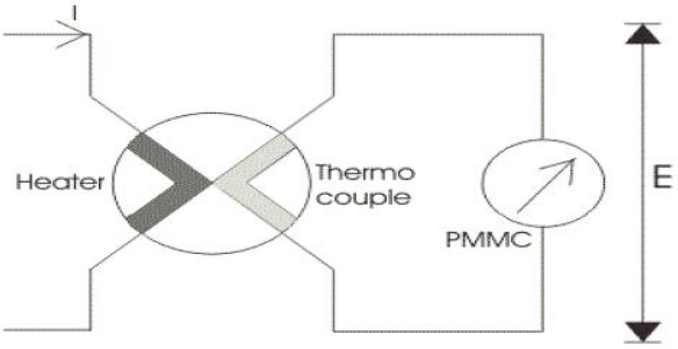


Fig.2-2 Incremental System

3.12 EXTRA TOPICS-APPLICATIONS OF TRANSDUCERS

Thermocouples

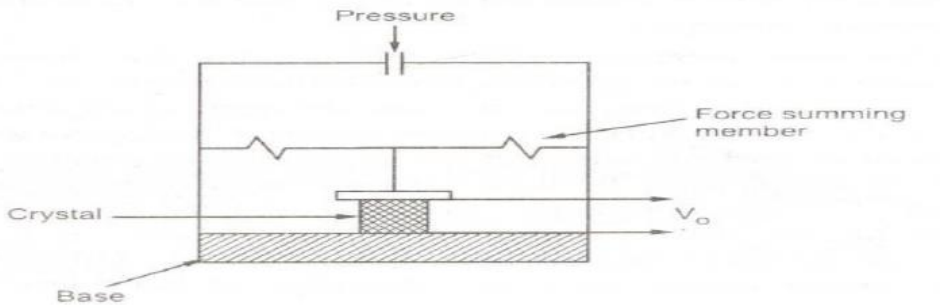
Basically thermocouple consists of two different metals which are placed in contact with each other as shown in the diagram.



First part is called the heater element because when the current will flow through this, a heat is produced and thus the temperature will increased at the junction. At this junction an emf is produced which is approximately proportional to the temperature difference of hot and cold junctions.

The emf produced is a DC voltage which is directly proportional to root mean square value of electric current. A permanent magnet moving coil instrument is connected with the second part to read the current passing through the heater.

Piezoelectric transducer:

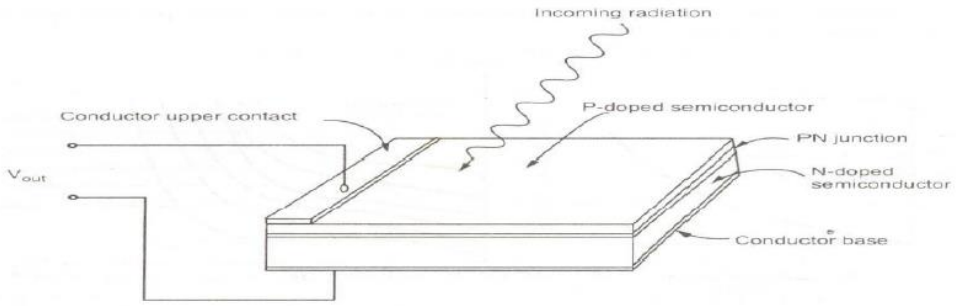


A piezoelectric quartz crystal is hexagonal prism shaped crystal, which has pyramids Jt both ends. This is shown in the Fig. (a). The marking of co-ordinate axes are fixed for such crystals. The axis passing through the end points of pyramids is called optic axis or z axis. The axis passing through corners is called electrical axis or x axis while the aXIs passing through midpoints of opposite sides is called mechanical axis or y axis.

Photovoltaic cell:

Fig shows structure of photovoltaic cell. It shows that cell is actually a PN-junction diode with appropriately doped semiconductors. When photons strike on the thin p-doped upper layer, they are absorbed by the electrons in the n-layer; which causes formation of conduction electrons and holes. These conduction electrons and holes are separated by depletion region potential of the

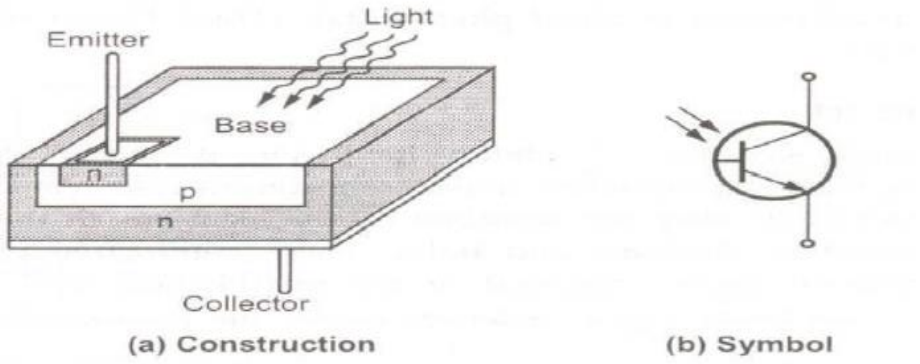
pn junction. When il load is connected across the cell, the depletion region potential causes the photocurrent to flow through the load N



Phototransistor:

The photo transistor has a light sensitive collector to base junction. A lens is used in a transistor package to expose base to an incident light. When no light is incident, small leakage current flows from collector to emitter called IeEO, due to small thermal generation. This is very small current, of the order of nA. This is called a dark current. When the base is exposed to the light, the base current is produced which is proportional to the light intensity. Such photo induced base current is denoted as I)...The resulting collector current is given by, The structure of a phototransistor is shown in the Fig. (a) while the symbol is shown in the Fig.

$$I_C \approx h_{fe} I_\lambda$$



To generate more base current proportional to the light, larger physical area of the base is exposed to the light. The fig .shows the graph of base current

against· the radiation flux density measured in mW/ cm2. The Fig. (b) shows the collector characteristics of a phototransistor. As light intensity increases, the base current increases exponentially. Similarly the collector current also increases corresponding to the increase in the light intensity. A phototransistor can be either a two lead or a three lead device. In a three lead device, the base lead is brought out so that it can be used as a conventional BJT with or without the light sensitivity feature. In a two lead device, the base is not electrically available and the device use is totally light dependent.