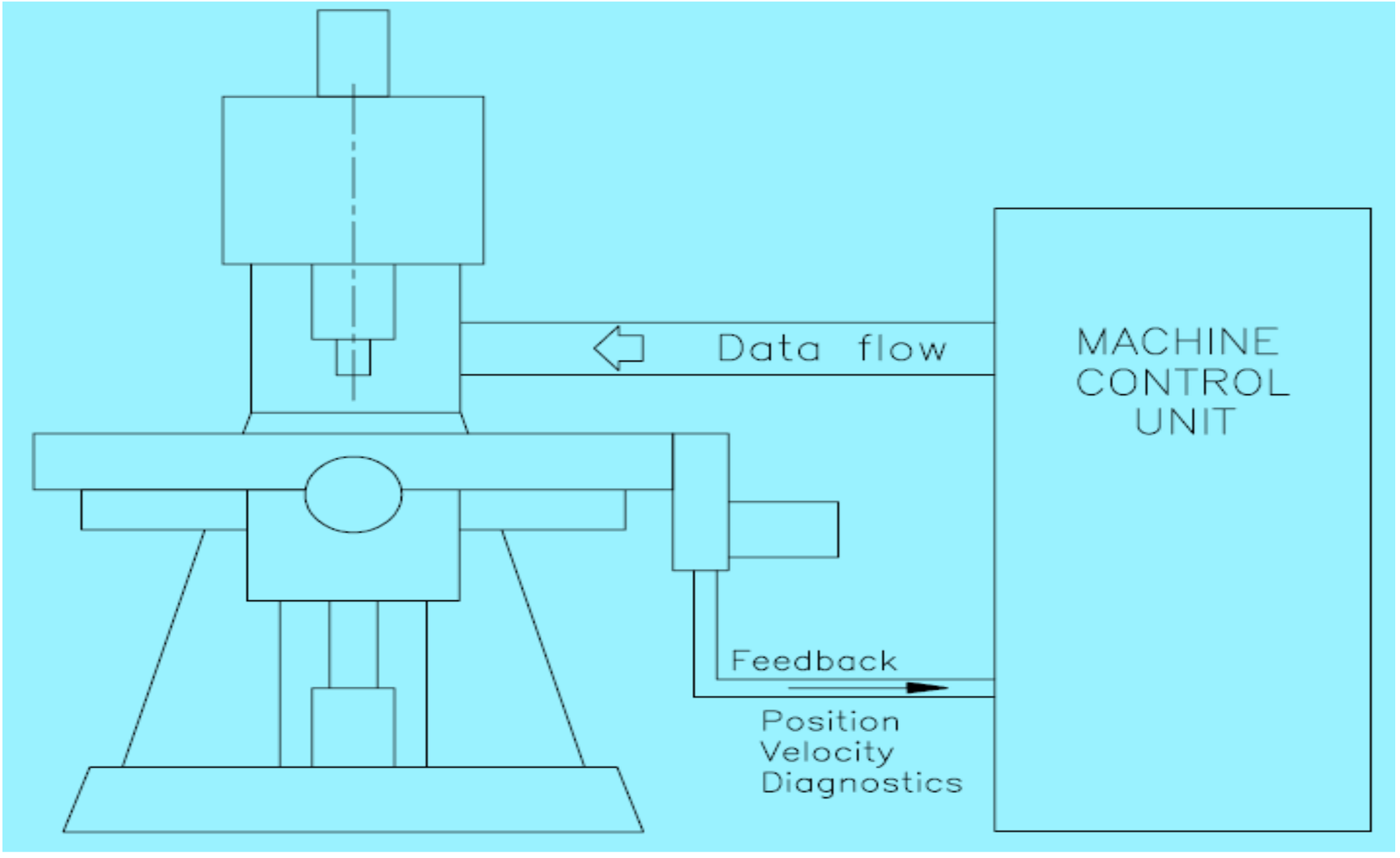
Computer Control in Machine Tools

Computer Numeric Control

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



Computer Numerical Control (CNC) Machine

Advantages and Disadvantages of CNC

Advantages:

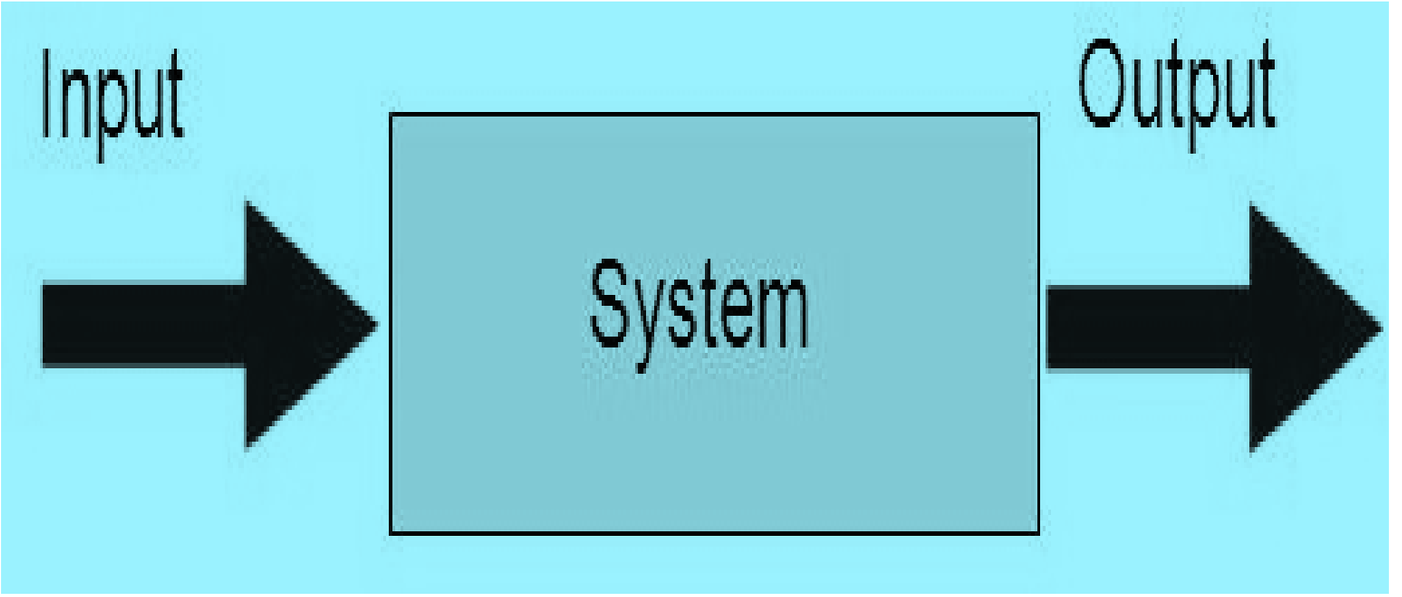
- High Repeatability and Precision e.g. Aircraft parts.
- Volume of production is very high.
- Complex contours/surfaces can be easily machined.
- Flexibility in job change, automatic tool settings, less scrap.
- More safe, higher productivity, better quality.
- Less paper work, faster prototype production, reduction in lead times.

Disadvantages:

- Costly setup, skilled operators.
- Computer programming knowledge required.
- Maintenance is difficult.

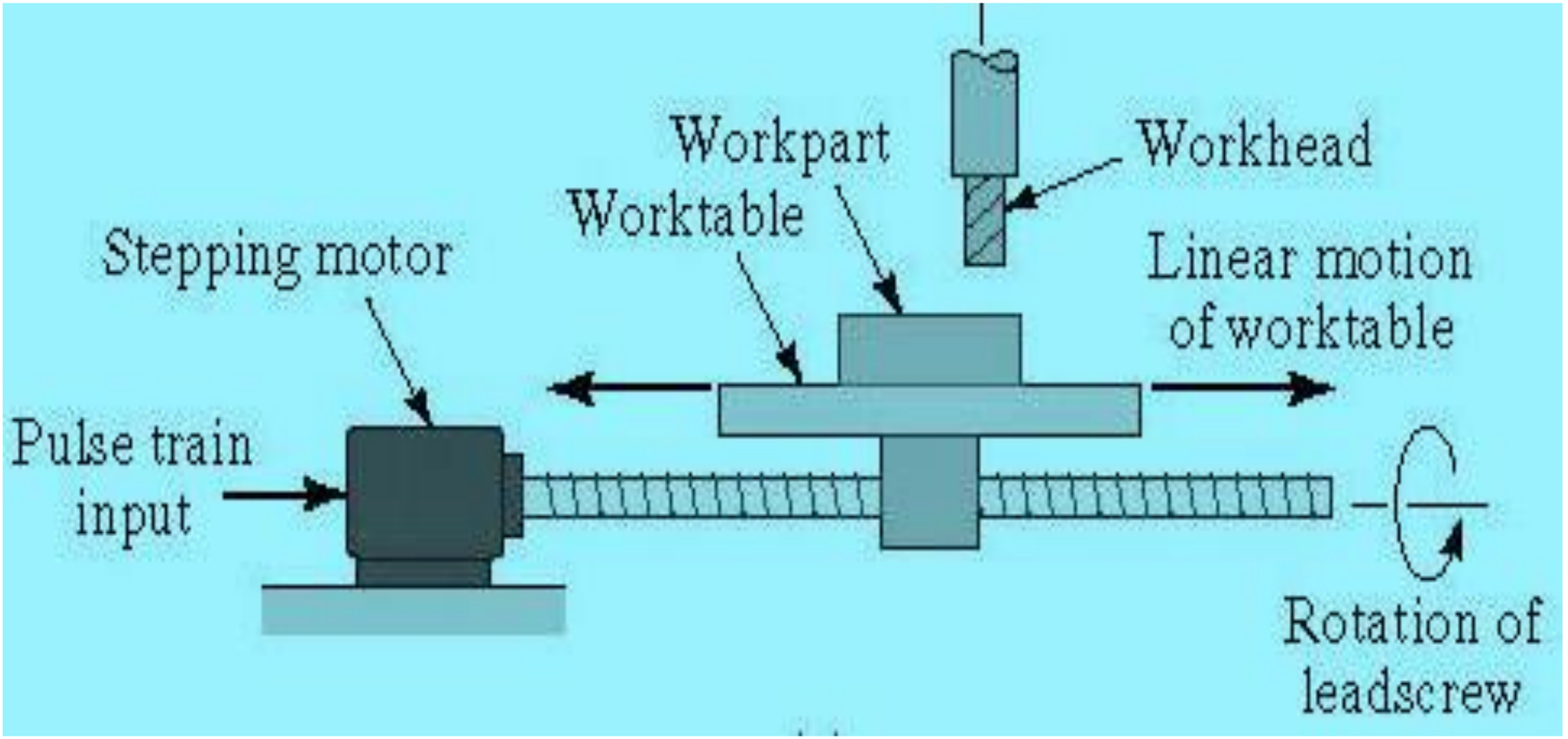
Open Loop Systems

Open loop systems have no access to the real time data about the performance of the system and therefore no immediate corrective action can be taken in case of system disturbance.



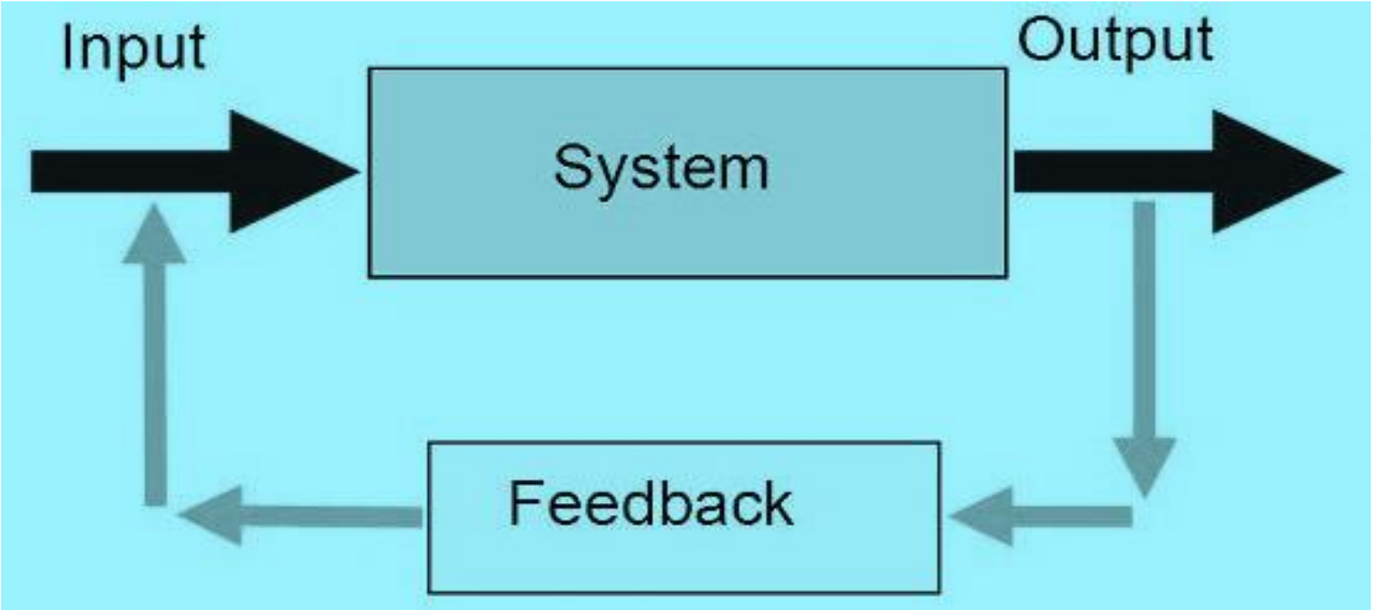
Block Diagram of an Open Loop System.

Open loop system



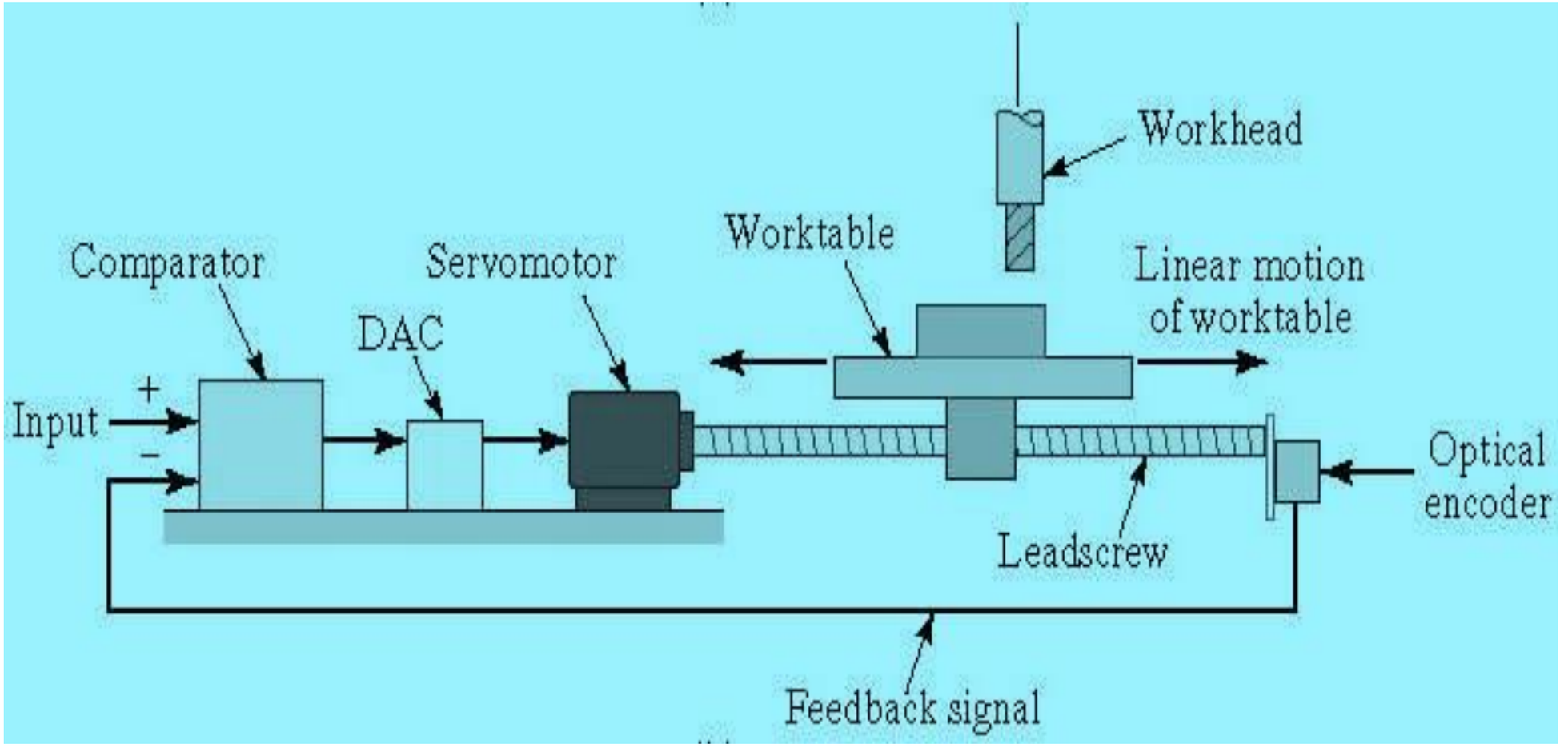
Close Loop Systems

In a close loop system, feed back devices closely monitor the output and any disturbance will be corrected in the first instance. Therefore high system accuracy is achievable.



Block Diagram of a Close Loop System

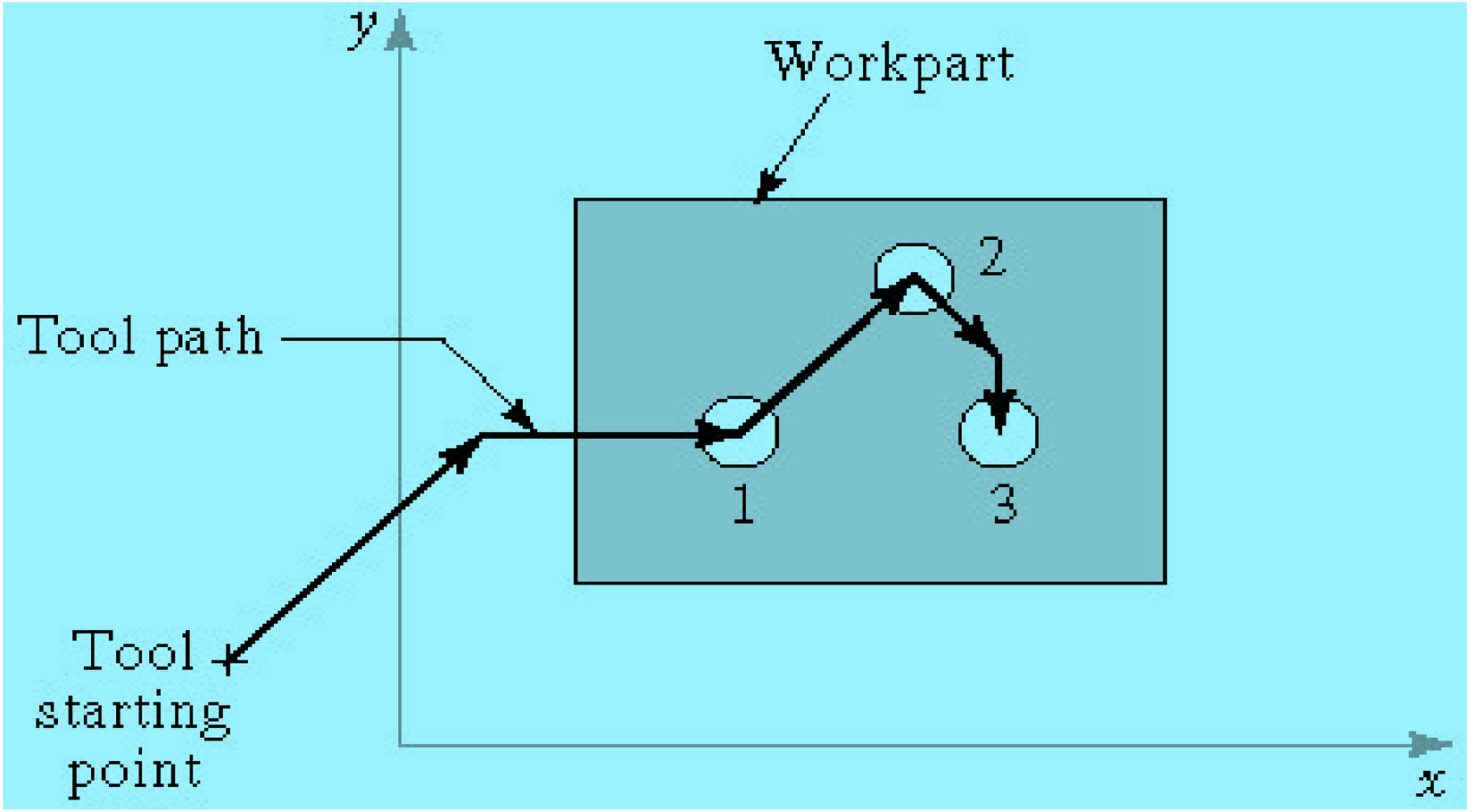
Close loop system



Motion Control Systems

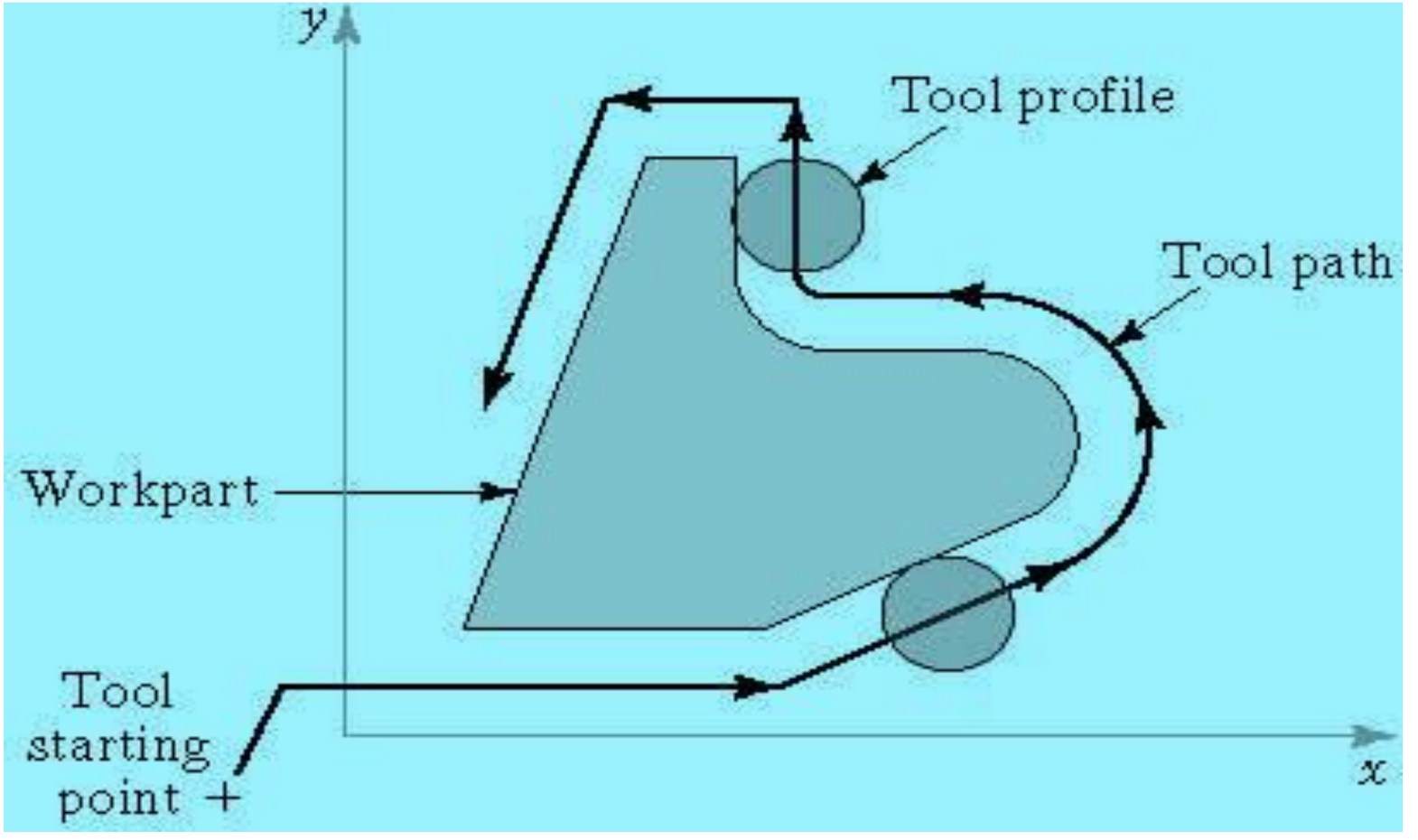
1. Point-To-Point Control in CNC Drilling of Three Holes in Flat Plate

- System moves to a location and performs an operation at that location (e.g., drilling)
- Also applicable in robotics



2. Continuous Path Control in CNC Profile Milling of Part Outline

- Also called contouring systems in machining
- System performs an operation during movement (e.g., milling and turning)



Elements of a CNC System

- Input Device
- Central Processing Unit/ Machine Control Unit
- Machine Tool
- Driving System
- Feedback Devices
- Display Unit

Input Devices

- Floppy Disk Drive
- USB Flash Drive
- Serial Communication
- Ethernet communication
- Conversational Programming

Central Processing Unit/ Machine Control Unit

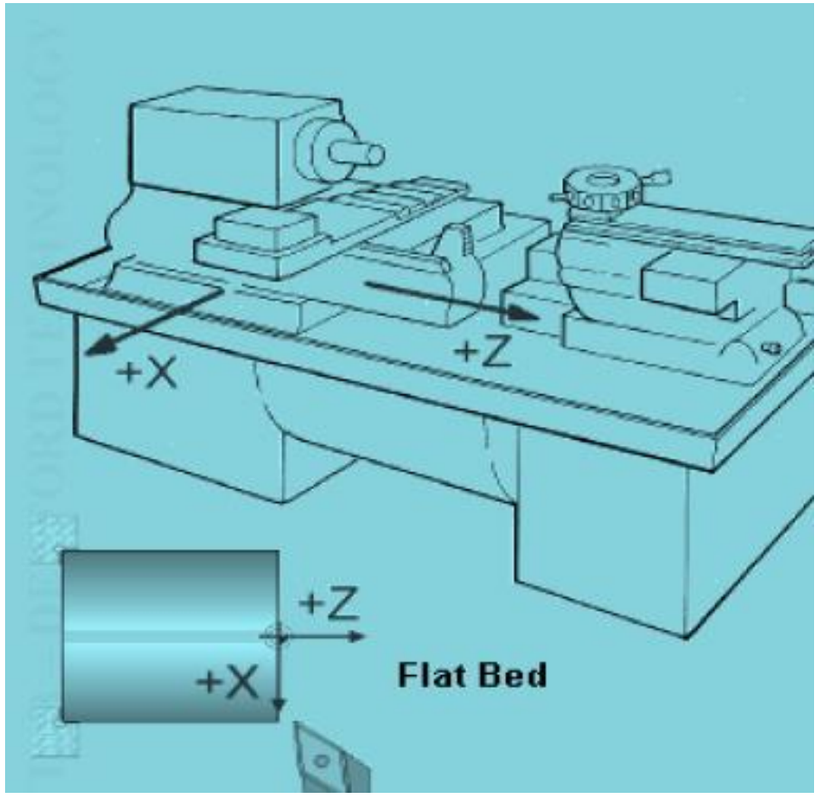
- The CPU is the heart of a CNC system.
- It accepts the information stored in the memory as part program.

- This data is decoded and transformed into specific position control and velocity signals.

- It also oversees the movement of the control axis or spindle and whenever this does not match with the programmed values, a corrective action as taken.

Machine Tool

- Most are made from high speed steel (HSS), tungsten carbide or ceramics.
- Tools are designed to direct waste away from the material.
- Some tools need coolant such as oil to protect the tool and work.



Driving System

- The requirement is that the driving system has to response accurately according to the programmed instructions.
- The motor is coupled either directly or through a gear box to the machine lead screw to moves the machine slide or the spindle.

Three types of electrical motors are commonly used:

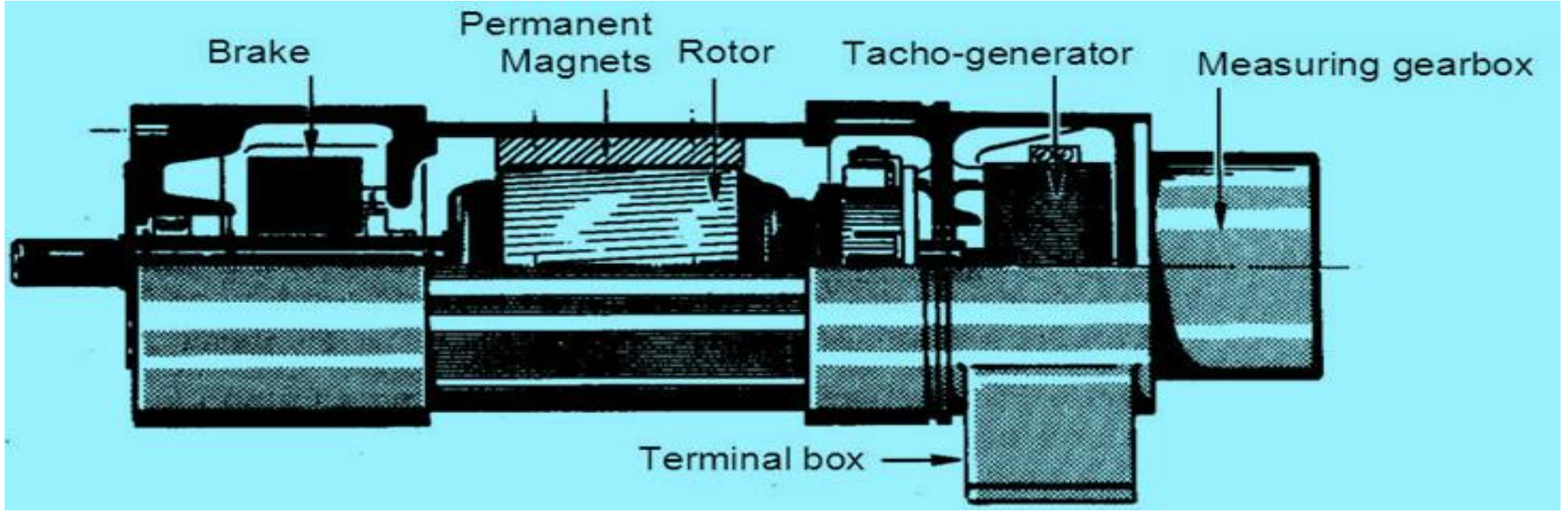
1. DC Servo motor
2. AC Servo motor
3. Stepping motor as explained ahead.

1. DC Servo Motor

- The principle of operation is based on the rotation of an armature winding in a permanently energized magnetic field.

- The armature winding is connected to a commutator, which is a cylinder of insulated copper segments mounted on the shaft.

- DC current is passed to the commutator through carbon brushes, which are connected to the machine terminals.



D1. DC Servo Motor Continues

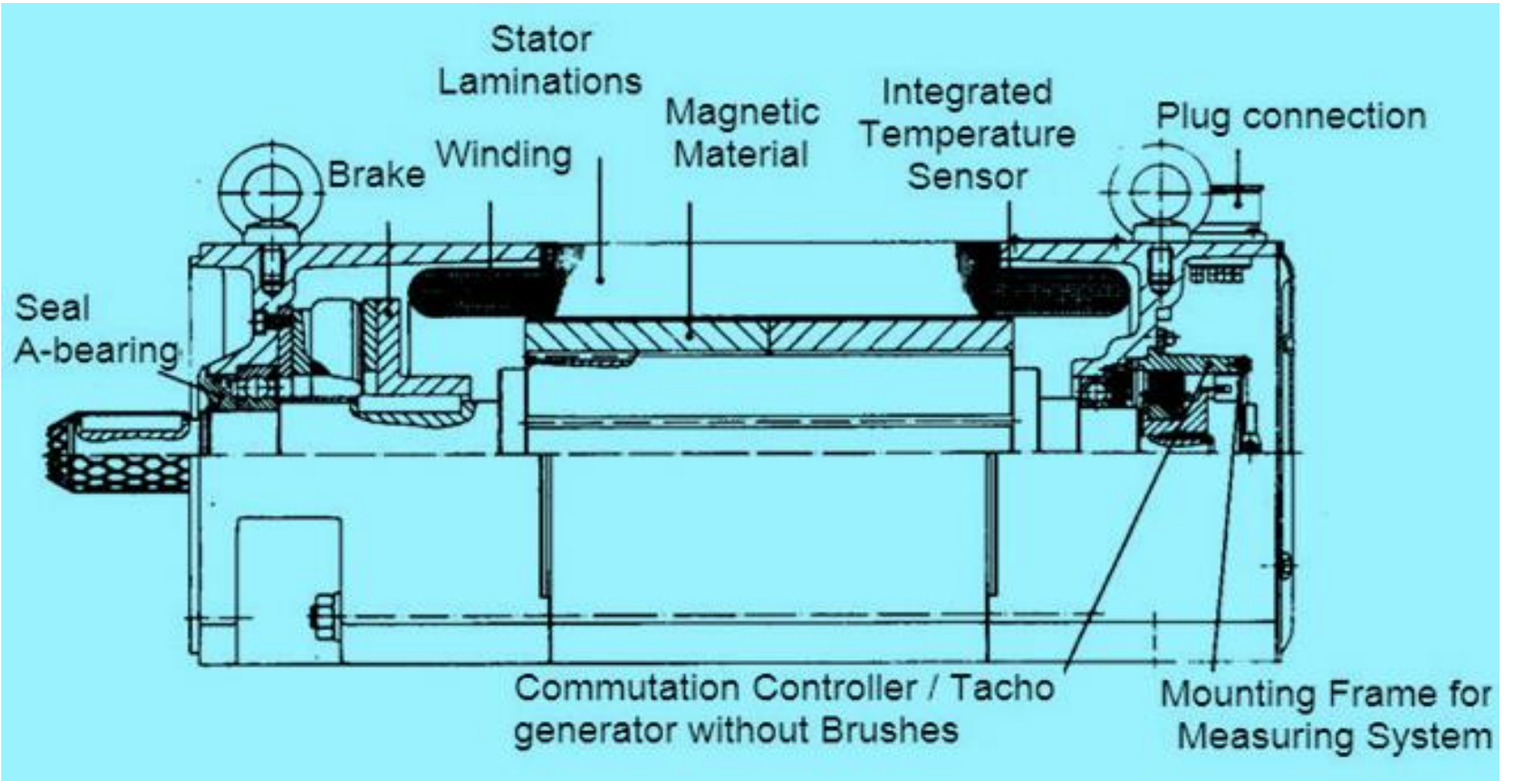
- The change of the motor speed is by varying the armature voltage and the control of motor torque is achieved by controlling the motor's armature current.

- In order to achieve the necessary dynamic behavior it is operated in a closed loop system equipped with sensors to obtain the velocity and position feedback signals.

2. AC Servo Motor

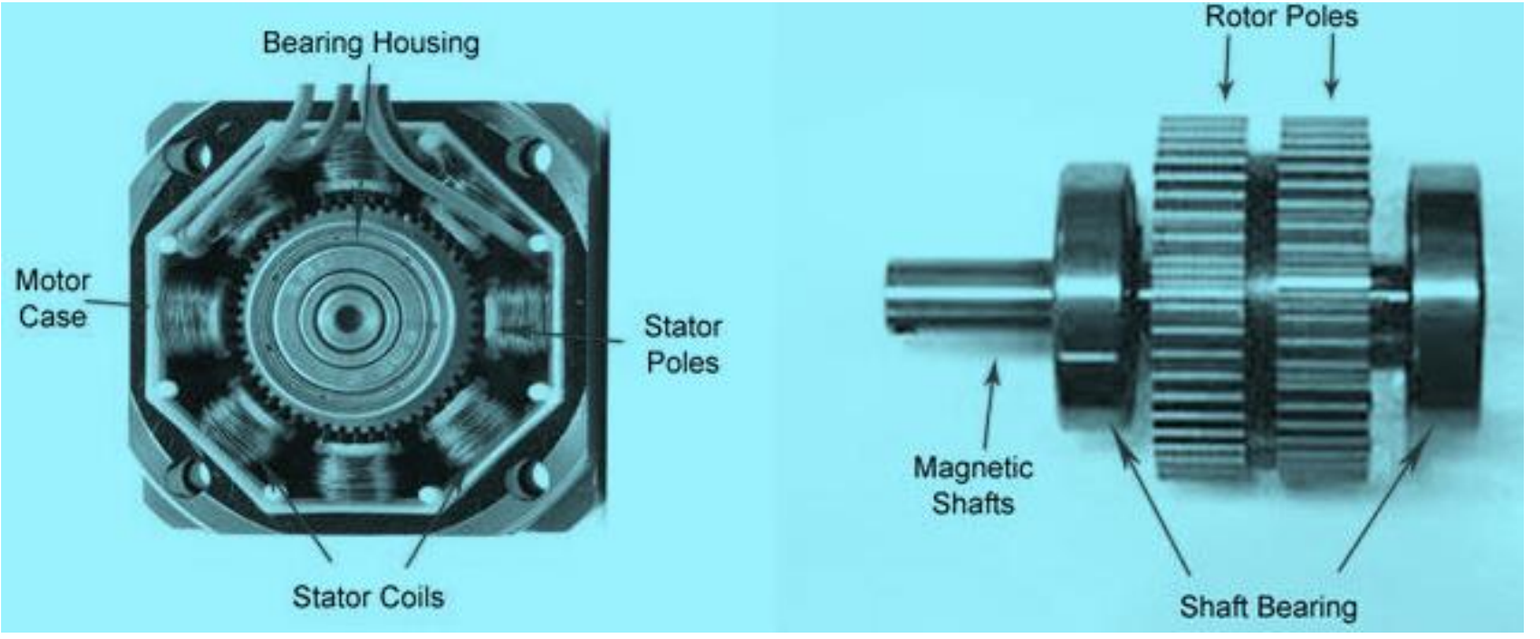
- In an AC servomotor, the rotor is a permanent magnet while the stator is equipped with 3-phase windings.

- The speed and position of the motor is notified by the encoder, which can be incremental or absolute.



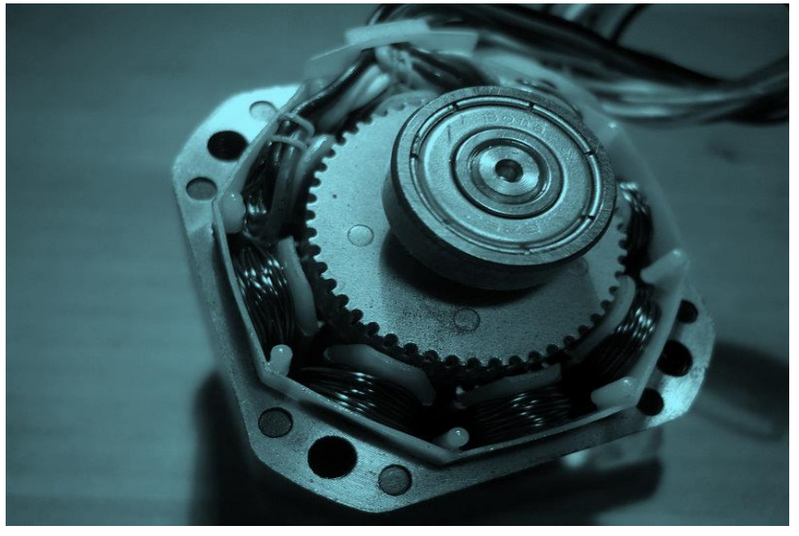
3. Stepping Motor

- The stepper motor is known by its property to convert a train of input pulses (typically square wave pulses) into a precisely defined increment in the shaft position.
- Each pulse moves the shaft through a fixed angle.
- Multiple "toothed" electromagnets arranged around a central gear-shaped piece of iron.
- The electromagnets are energized by an external driver circuit or a micro controller. In that way, the motor can be turned by a precise angle.



What does Stepper means?

- To make the motor shaft turn, first, one electromagnet is given power, which magnetically attracts the gear's teeth.
- When the gear's teeth are aligned to the first electromagnet, they are slightly offset from the next electromagnet.
- This means that when the next electromagnet is turned on and the first is turned off, the gear rotates slightly to align with the next one.
- From there the process is repeated. Each of those rotations is called a "step", with an integer number of steps making a full rotation.



- However, stepping motors are not commonly used in machine tools due to the following drawbacks:
- slow speed,
- low torque,
- low resolution
- easy to slip in case of overload.

Interpolation Methods

1.Linear interpolation

Straight line between two points in space

2. Circular interpolation

Circular arc defined by starting point, end point, centre or radius, and direction.

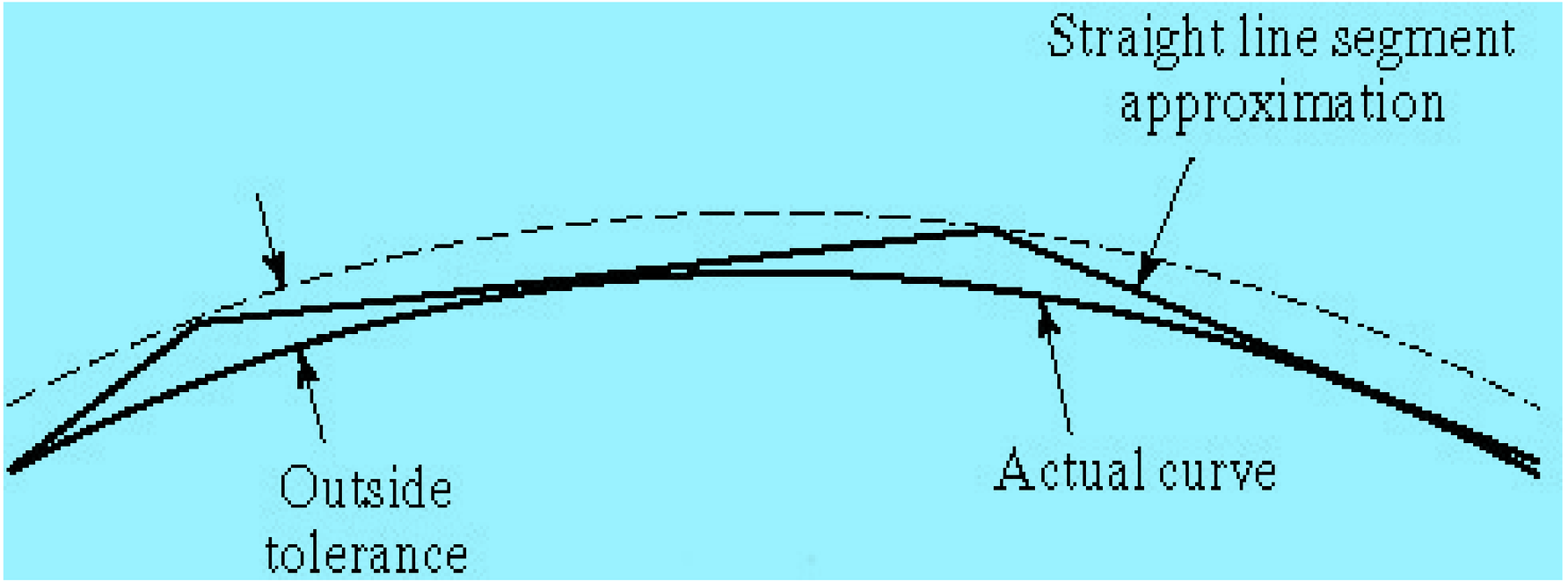
3. Helical interpolation

Circular plus linear motion

4. Parabolic and cubic interpolation

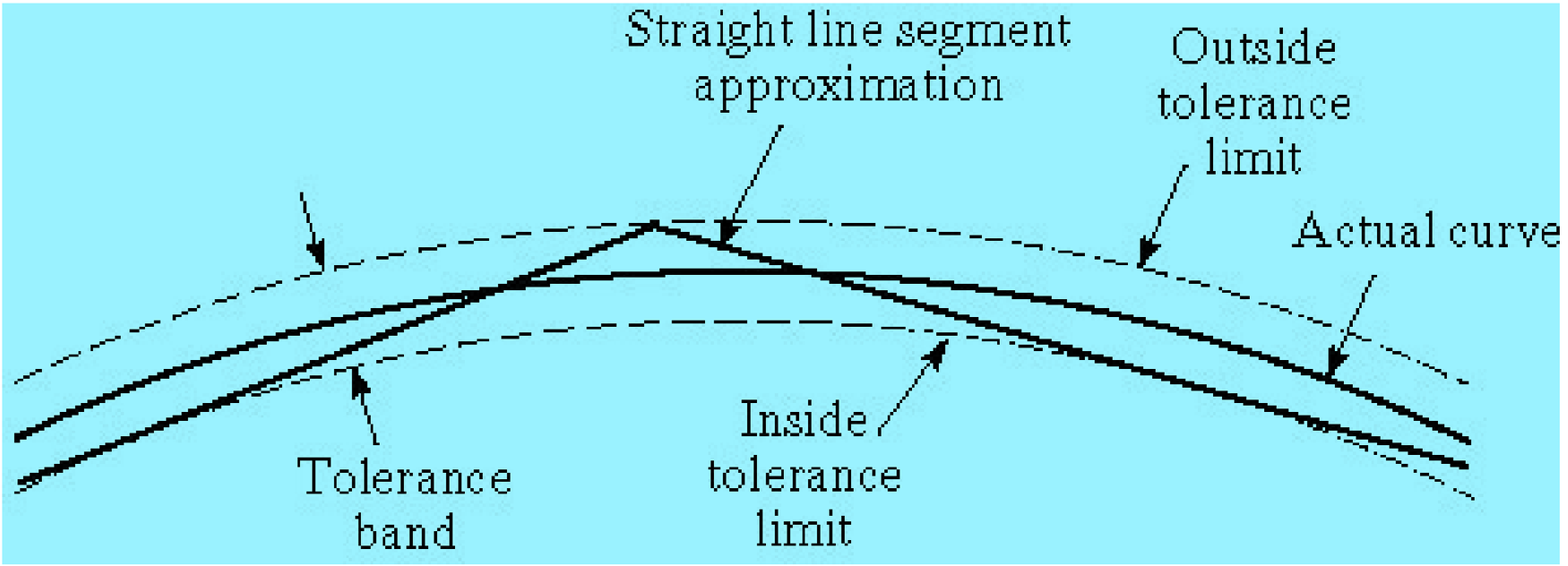
Free form curves using higher order equations

Circular Interpolation



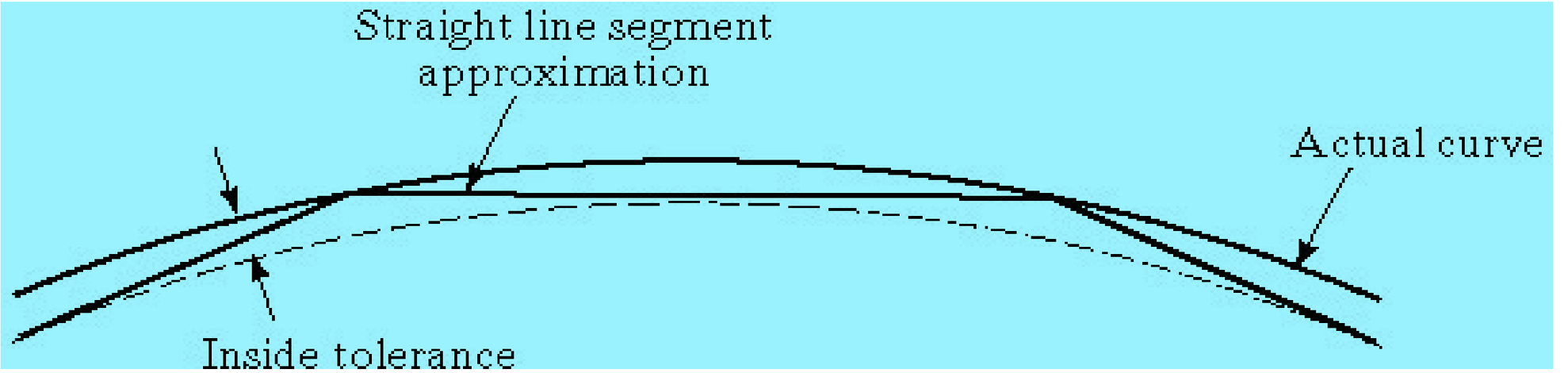
Approximation of a curved path in NC by a series of straight line segments, where tolerance is defined on only the outside of the nominal curve.

Circular Interpolation



Approximation of a curved path in NC by a series of straight line segments, where tolerance is defined on both the inside and outside of the nominal curve.

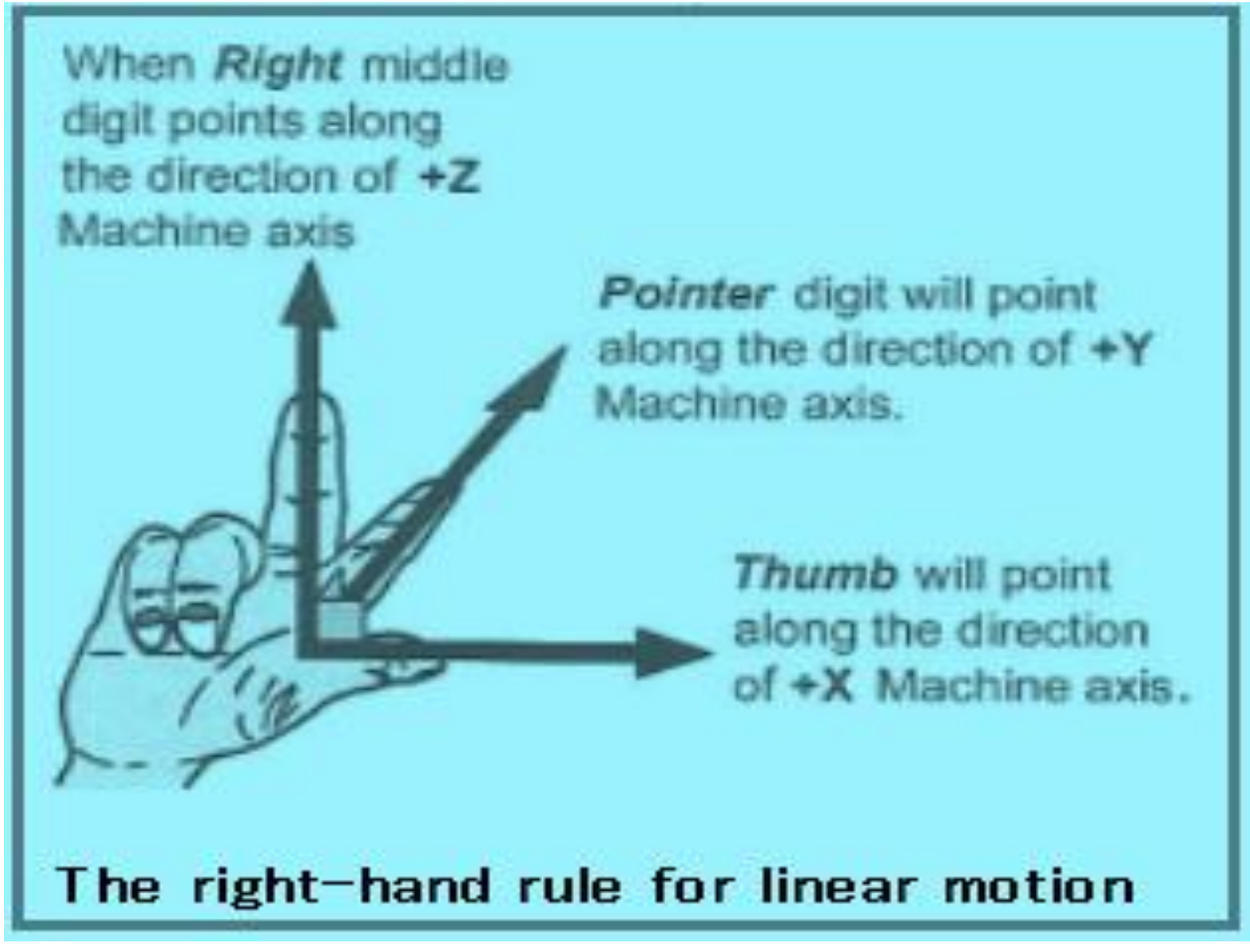
Circular Interpolation



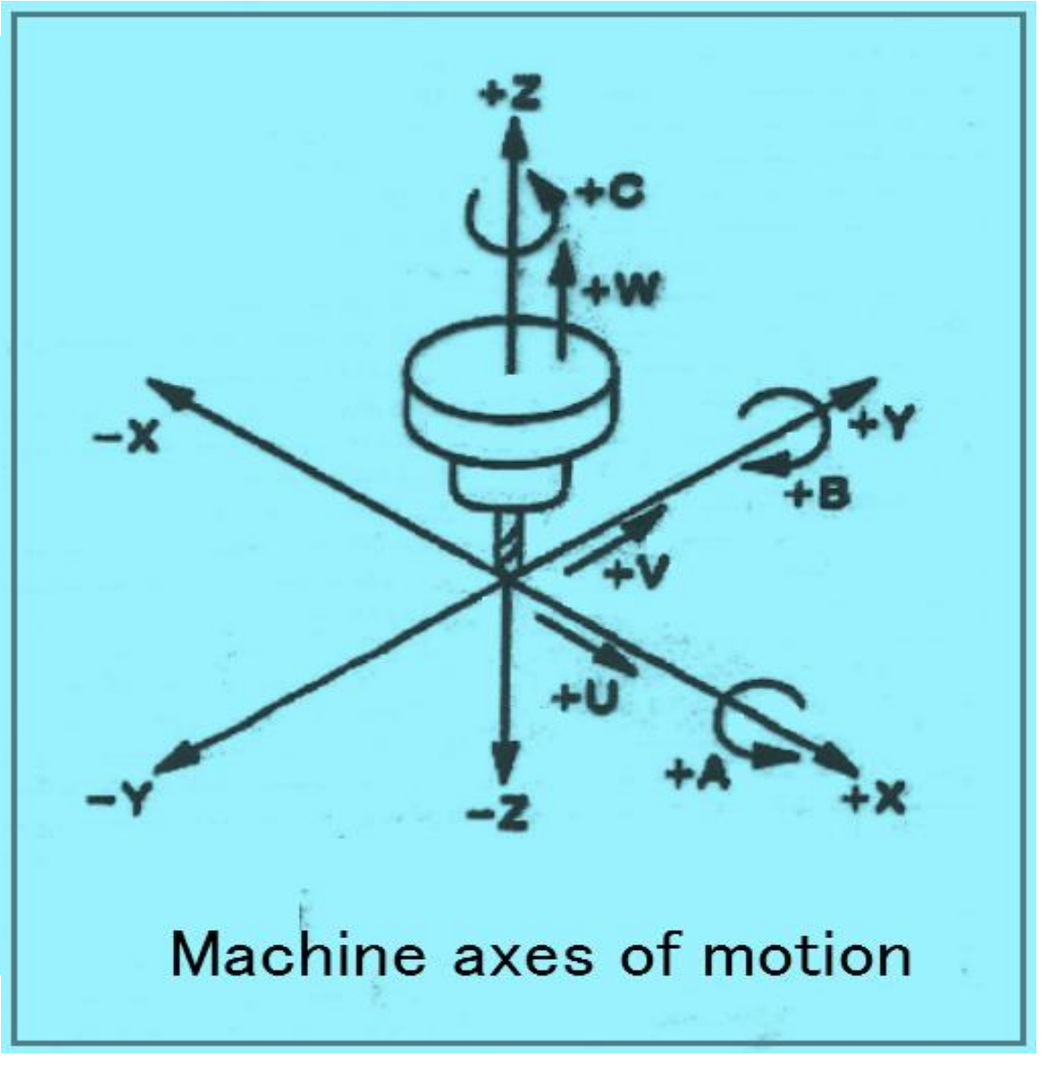
Approximation of a curved path in NC by a series of straight line segments, where tolerance is defined on only the inside of the nominal curve.

Machine axes

Machine axes are established according to the industry standard report EIA RS - 267A



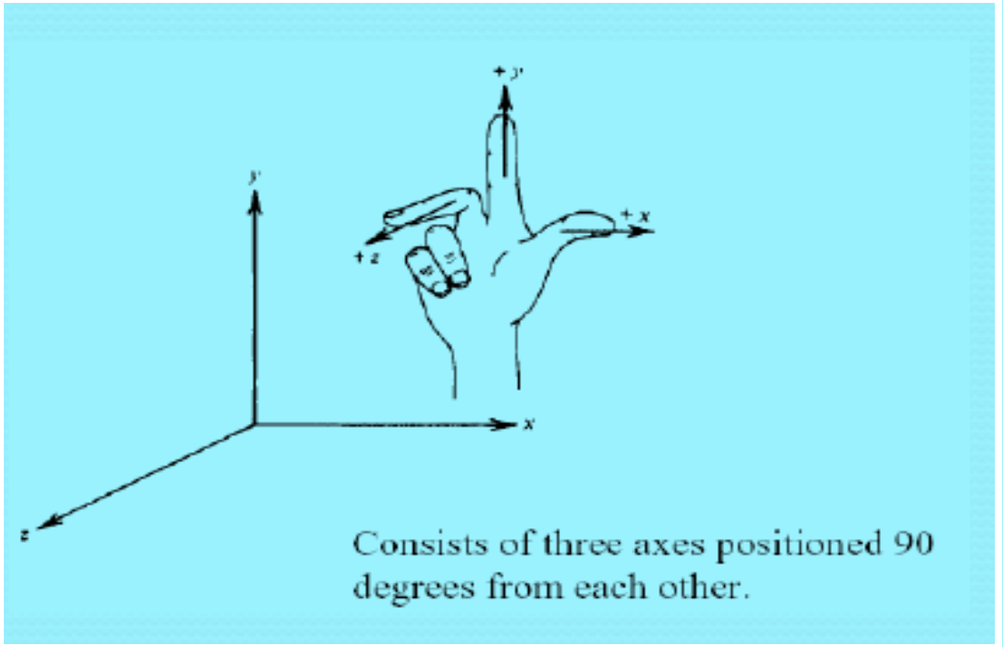
The right-hand rule for linear motion



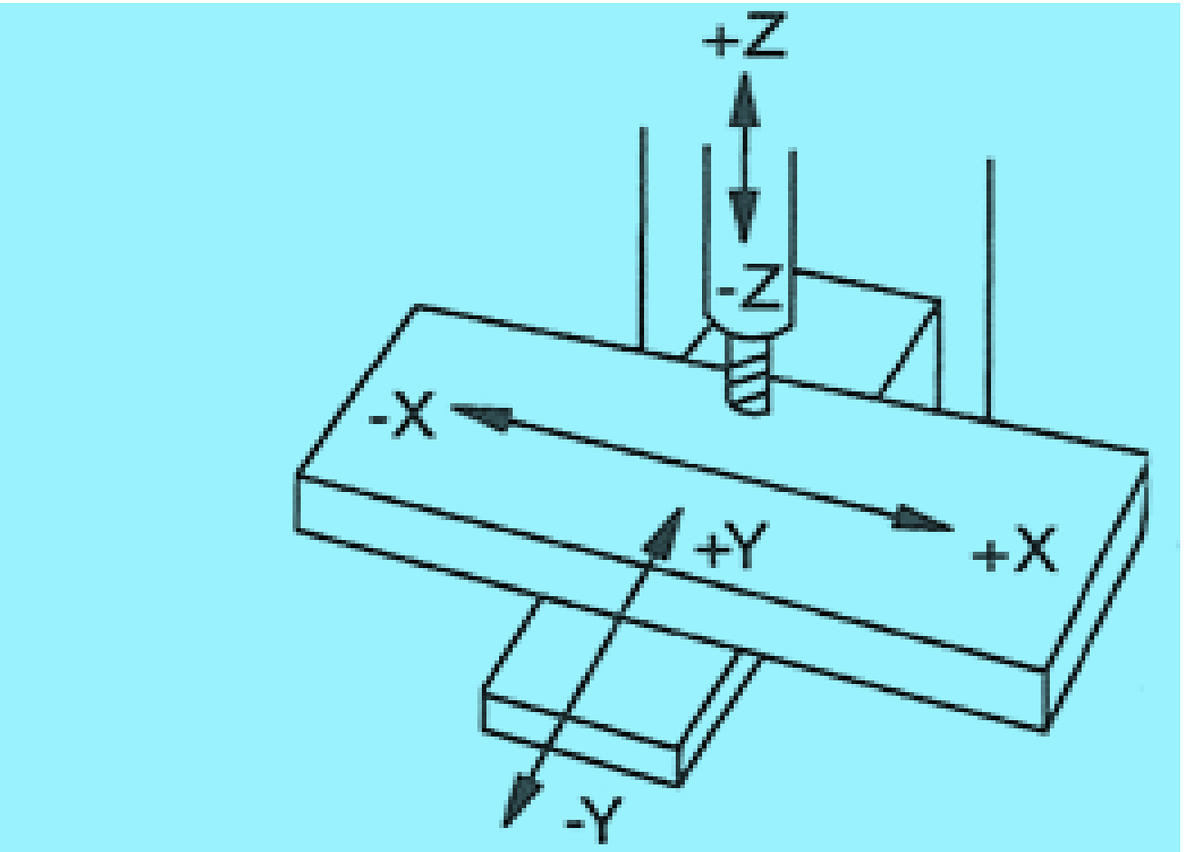
Machine axes of motion

Axes configuration

- X axes moves from right to left as you face the machine
- Y axes move toward and away from you
- The Z axes is the spindle movement up and down spindle .
- A move toward work is Z(-Z)
- A move away from work is Z(+ Z)

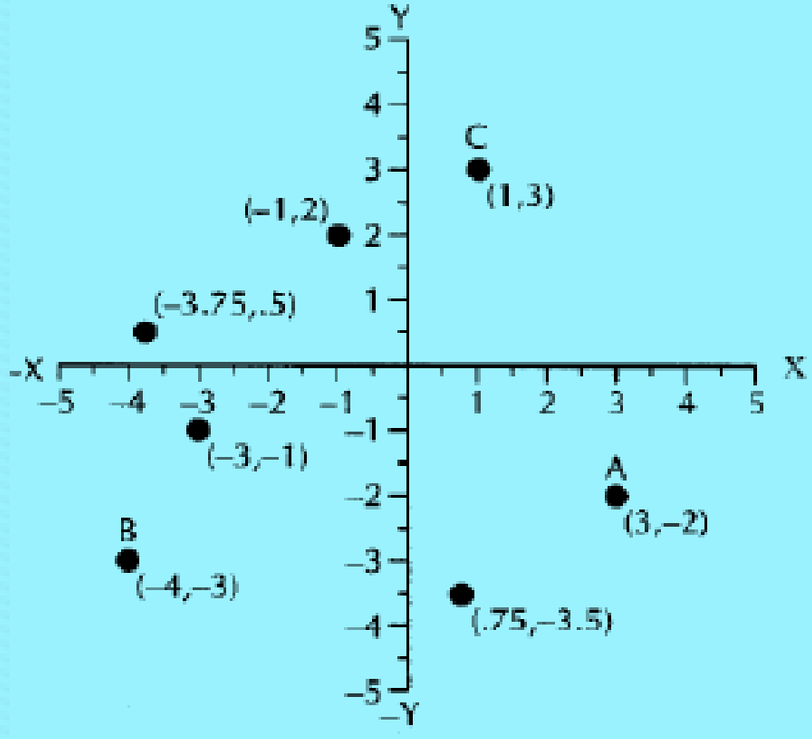


Consists of three axes positioned 90 degrees from each other.

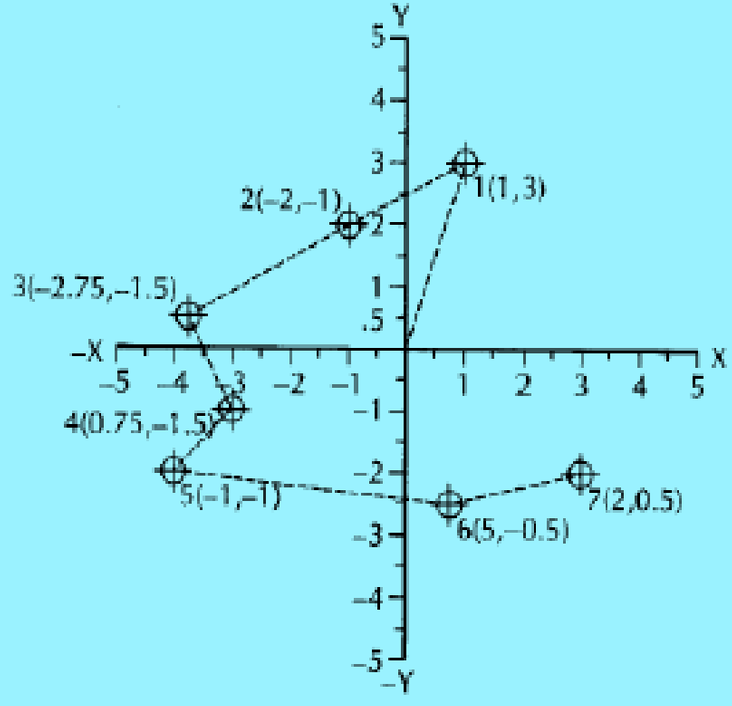


Typical milling machine configuration illustrating the X, Y, and Z axes.

Dimensioning Systems



Absolute Coordinate System



Incremental Coordinate System

CNC Programming

- Programming consists of a series of instructions in form of letter codes

Preparatory Codes:

- G codes- Initial machining setup and establishing operating conditions
- N codes- specify program line number to executed by the MCU

- Axis Codes: X,Y,Z - Used to specify motion of the slide along X, Y, Z direction
- Feed and Speed Codes: F and S- Specify feed and spindle speed
- Tool codes: T – specify tool number

Miscellaneous codes – M codes For coolant control and other activities

Programming Key Letters

O - Program number (Used for program identification)

N - Sequence number (Used for line identification)

G - Preparatory function

X - X axis designation

Y - Y axis designation

Z - Z axis designation

R - Radius designation

F – Feed rate designation

S - Spindle speed designation

H - Tool length offset designation

D - Tool radius offset designation

T - Tool Designation

M - Miscellaneous function

Table of Important G Codes

G codes are instructions describing machine tool movement

G00 Rapid Transverse

G01 Linear Interpolation

G02 Circular Interpolation, CW

G03 Circular Interpolation, CCW

G17 XY Plane, G18 XZ Plane,G19 YZ Plane

G20/G70 Inch units

G21/G71 Metric Units

G40 Cutter compensation cancel

G41 Cutter compensation left

G42 Cutter compensation right

G43 Tool length compensation (plus)

G44 Tool length compensation (minus)

G49 Tool length compensation cancel

G80 Cancel canned cycles

G81 Drilling cycle

G82 Counter boring cycle

G83 Deep hole drilling cycle

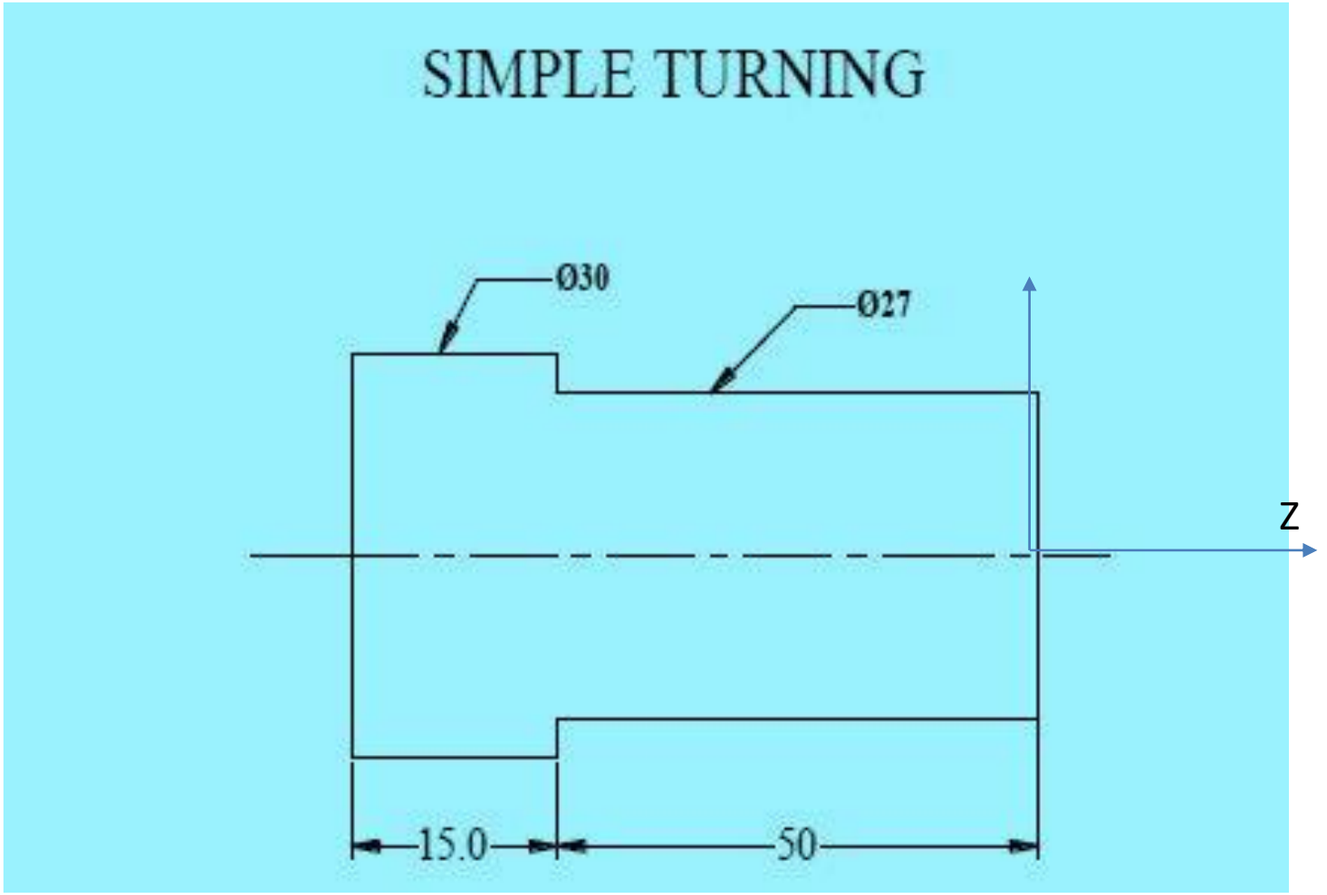
G90 Absolute positioning

G91 Incremental positioning

Table of Important M codes

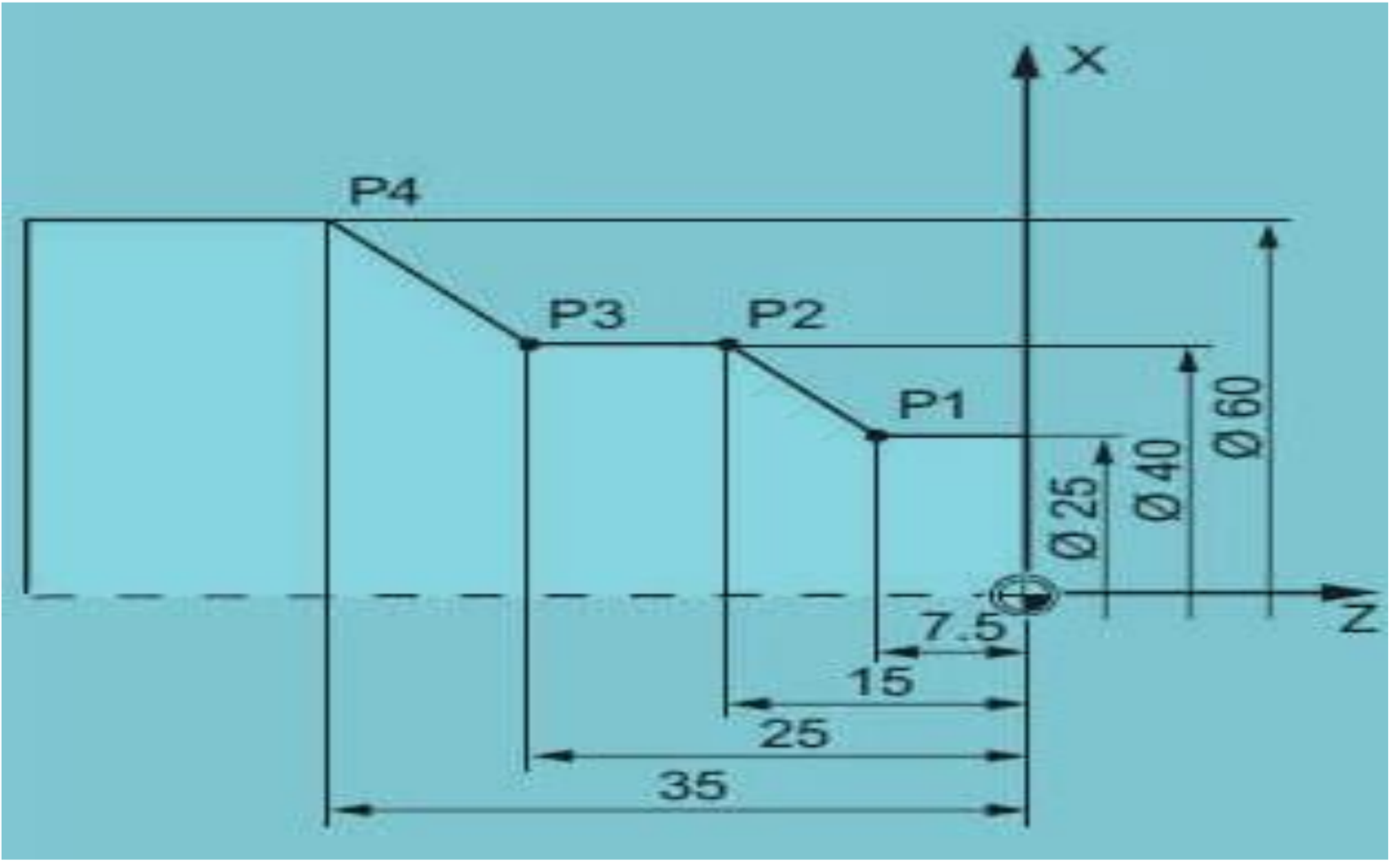
M Codes are instructions describing miscellaneous functions like calling the tool, spindle rotation, coolant on/off etc.,

M00	Program Stop
M01	Optional Stop
M02	Program End
M03	Spindle Forward
M04	Spindle Reverse
M05	Spindle Stop
M06	Automatic Tool change
M08	Coolant On
M09	Coolant Off
M10	Vice / Chuck Open
M11	Vice / Chuck Close
M30	Program Stop & Rewind
M38	Door Open
M39	Door Close
M98	Sub program Call
M99	Subprogram Exit




```
G00 X30 Z1
G00 X29 Z1
G01 X29 Z-50 F50
G01 X30 Z-50
G00  X30 Z1
G00 X28 Z1
G01 X28 Z-50
G01 X30 Z-50
G00 X30 Z1
G00 X 27 Z1
G01 X27 Z-50
G01 X30 Z-50
G00 X30 Z1
G28 U0 W0
M05
M30
```

Part Program



T0101
G97 S500 M03
G01 X25 G95 F0.3
G01 Z-7.5
G01 X40 Z-15
G01 Z-25
G01 X60 Z-35
G40 G00 X200 Z100

Reference: http://home.iitk.ac.in/~jrkumar

THANK YOU