

Computer Numerical Control
CNC



Numerical Control

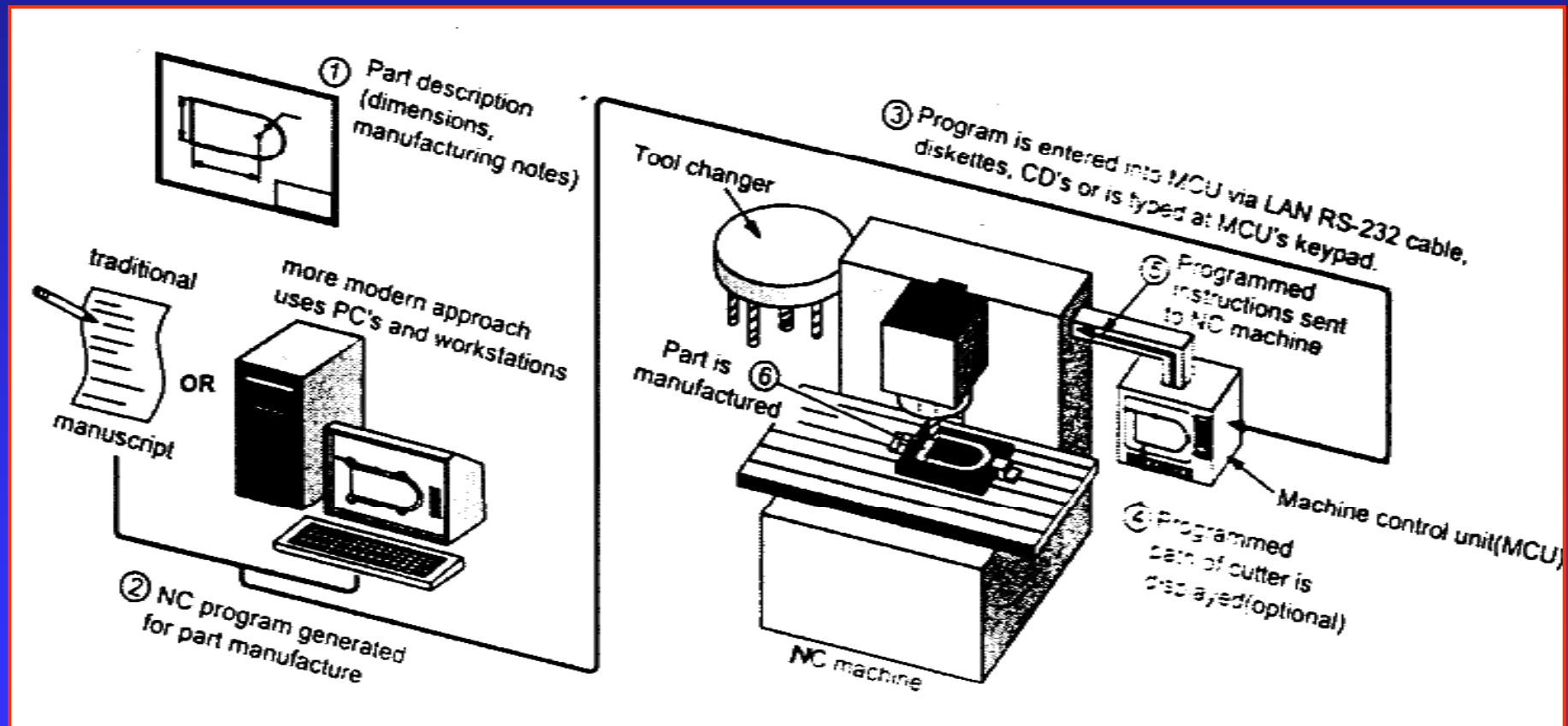
- Numerical control is a method of automatically operating a manufacturing machine based on a code of letters, numbers, and special characters.
- The numerical data required to produce a part is provided to a machine in the form of a program, called *part program or CNC program*.
- The program is translated into the appropriate electrical signals for input to motors that run the machine.

Numerical Control - History

- The concept is credited to John Parson (1947). Using punched cards he was able to control the position of a machine in an attempt to machine helicopter blade.
- US Air Force teamed up with MIT to develop a programmable milling machine (1949).
- In 1952, a three-axis Cincinnati Hydrotel milling machine was demonstrated. The term *Numerical Control* (NC) originated. The machine had an electromechanical controller and used punched cards.
- A new class of machines called machining centers and turning centers that could perform multiple machining processes was developed.
- Modern NC machine has a computer on board, *Computer Numerical Control* (CNC). They can run unattended at over 20,000 rpm (spindler speed) with a feed rate of over 600 ipm and an accuracy of .0001

Computer Numerical Control (CNC)

A CNC machine is an NC machine with the added feature of an on-board computer.



Hardware Configuration of NC Machine

Machine Control Unit (MCU)

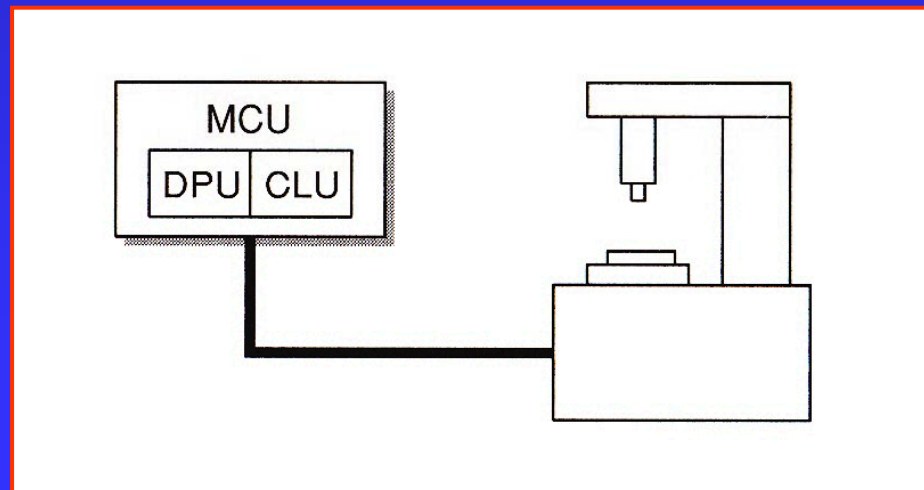
the brain of the NC machine.

The Data Processing Unit (DPU)

reads the part program.

The Control Loop Unit (CLU)

controls the machine tool operation.



HAAS CNC Machines



CNC Machines

Machining Centers, equipped with automatic tool changers, are capable of changing 90 or more tools. Can perform milling, drilling, tapping, boring... on many faces.



CNC Machines

Turning Centers are capable of executing many different types of lathe cutting operations simultaneously on a rotating part.



CNC Controllers

The NC controller is the brain of the NC system, it controls all functions of the machine.

- Motion control deals with the tool position, orientation and speed.
- Auxiliary control deals with spindle rpm, tool change, fixture clamping and coolant.

Many different types of controllers are available in the market (GE, Fanuc, Allen-Bradley, Okuma, Bendix, ...).

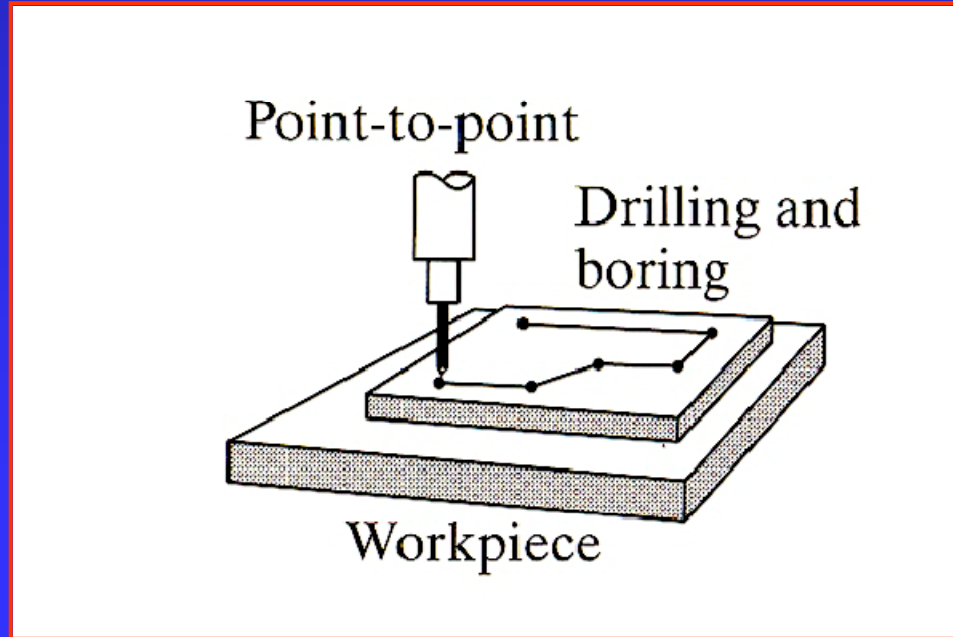
There are two basic types of control systems:

point-to-point and continuous path.

Point-to-Point Tool Movements

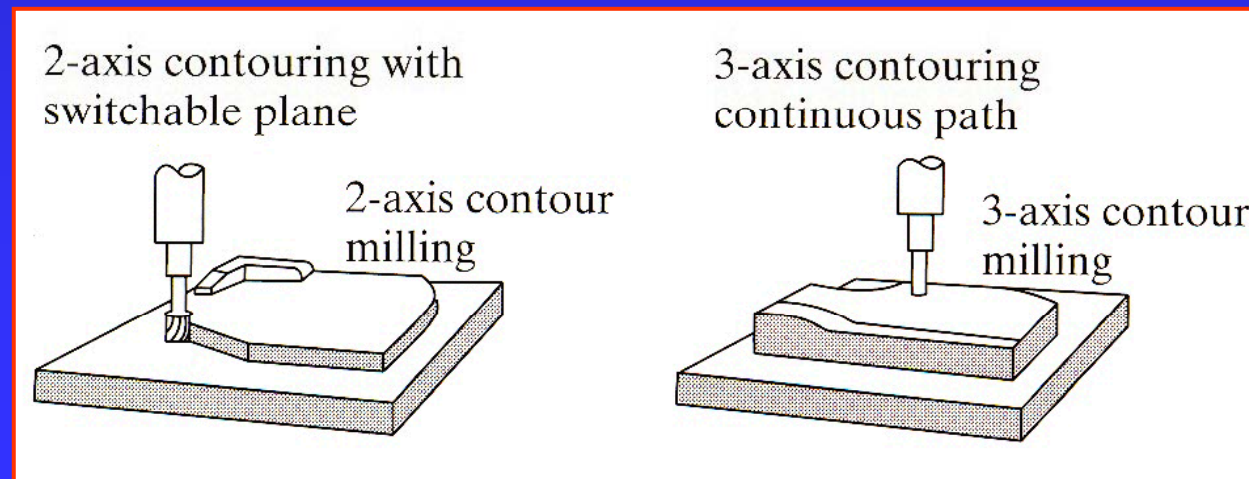
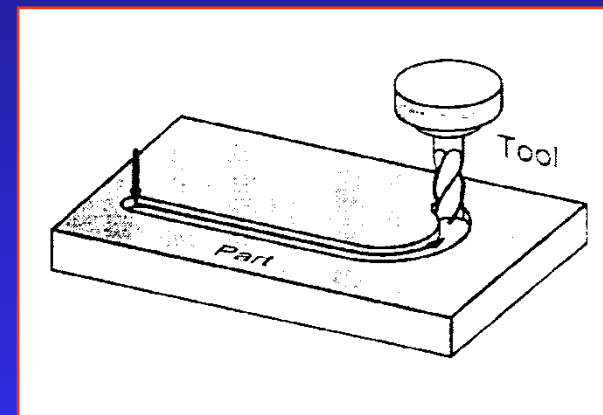
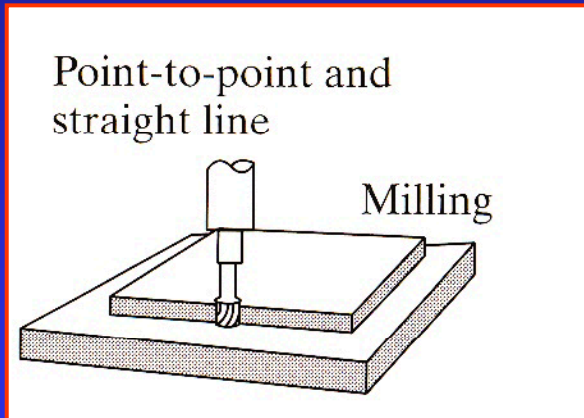
Point-to-point control systems cause the tool to move to a point on the part and execute an operation at that point only. The tool is not in continuous contact with the part while it is moving.

Drilling, reaming, punching, boring and tapping are examples of point-to-point operations.



Continuous-Path Tool Movements

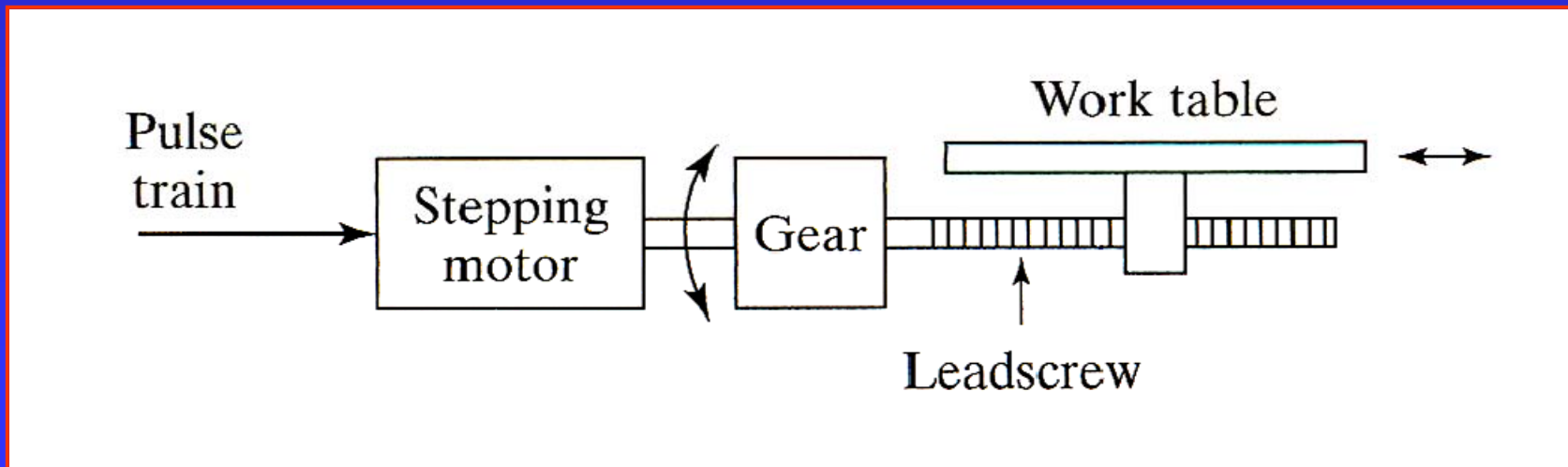
Continuous-path controllers cause the tool to maintain continuous contact with the part as the tool cuts a contour shape. These operations include milling along any lines at any angle, milling arcs and lathe turning.



Loop Systems for Controlling Tool Movement

Open Loop System

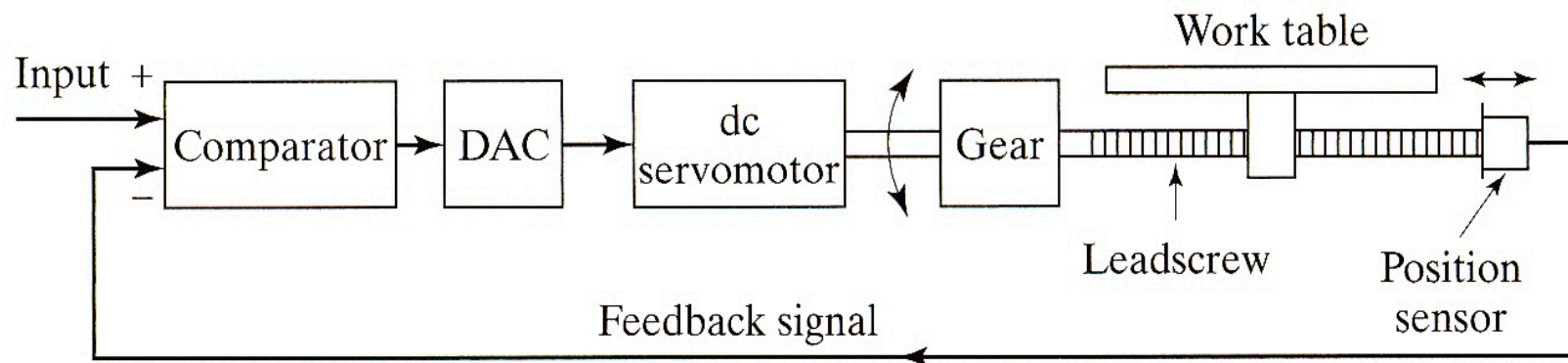
Uses stepping motor to create movement. Motors rotate a fixed amount for each pulse received from the MCU. The motor sends a signal back indicating that the movement is completed. No feedback to check how close the actual machine movement comes to the exact movement programmed.



Loop Systems for Controlling Tool Movement

Closed Loop System

AC, DC, and hydraulic servo-motors are used. The speed of these motors are variable and controlled by the amount of current or fluid. The motors are connect to the spindle and the table. A position sensor continuously monitors the movement and sends back a signal to Comparator to make adjustments.



Flow of Computer-Aided CNC Processing

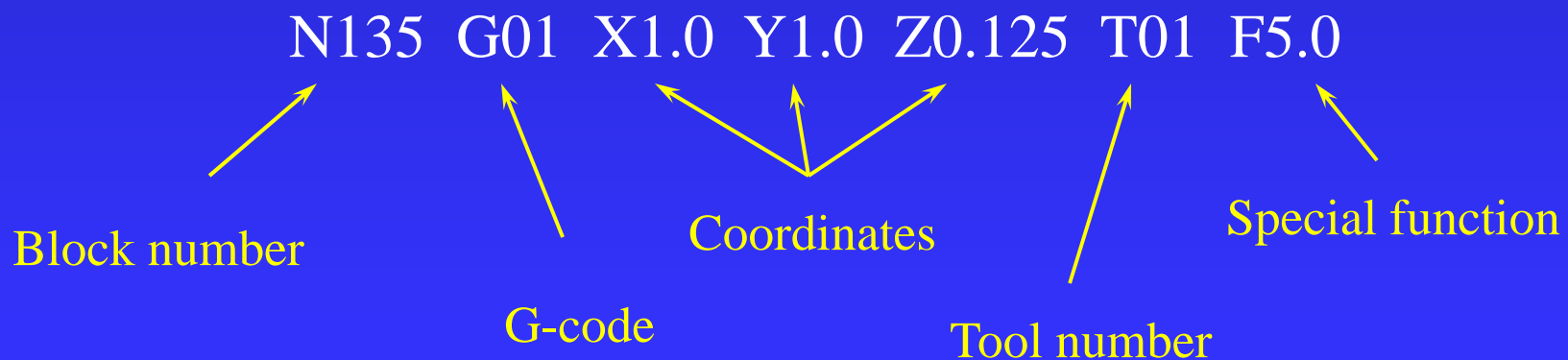
- Develop or obtain the 3D geometric model of the part, using CAD.
- Decide which machining operations and cutter-path directions are required (computer assisted).
- Choose the tooling required (computer assisted).
- Run CAM software to generate the CNC part program.
- Verify and edit program.
- Download the part program to the appropriate machine.
- Verify the program on the actual machine and edit if necessary.
- Run the program and produce the part.

Basic Concept of Part Programming

Part programming contains geometric data about the part and motion information to move the cutting tool with respect to the work piece.

Basically, the machine receives instructions as a sequence of blocks containing commands to set machine parameters; speed, feed and other relevant information.

A block is equivalent to a line of codes in a part program.



Basic Concept of Part Programming

Preparatory command (G code)

The G codes prepare the MCU for a given operation, typically involving a cutter motion.

- G00 rapid motion, point-to-point positioning
- G01 linear interpolation (generating a sloped or straight cut)
- G06 parabolic interpolation (produces a segment of a parabola)
- G17 XY plane selection
- G20 circular interpolation
- G28 automatic return to reference point
- G33 thread cutting

Basic Concept of Part Programming

Miscellaneous commands (M code)

M00 program stop

M03 start spindle rotation (cw)

M06 tool change

M07 turn coolant on

Feed commands (F code)

Used to specify the cutter feed rates in inch per minute.

Speed commands (S code)

Used to specify the spindle speed in rpm.

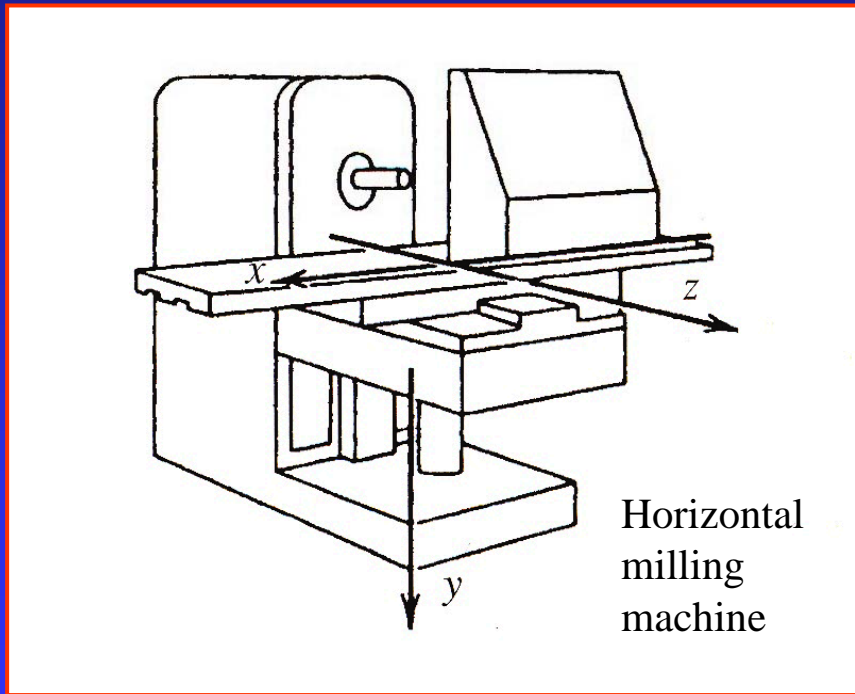
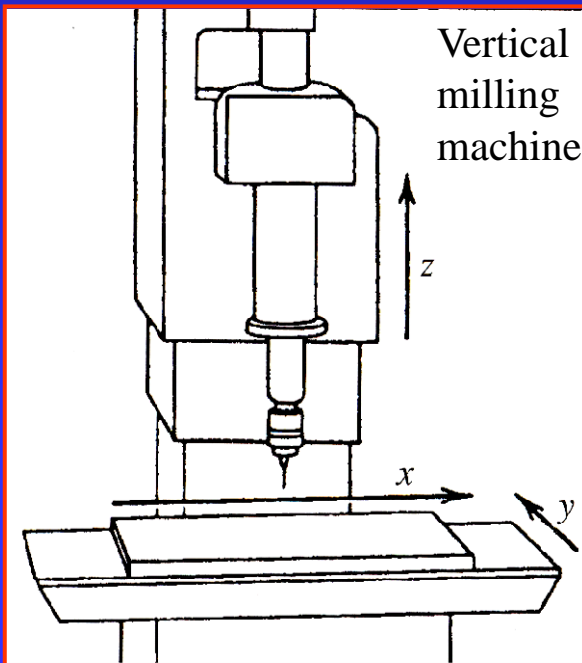
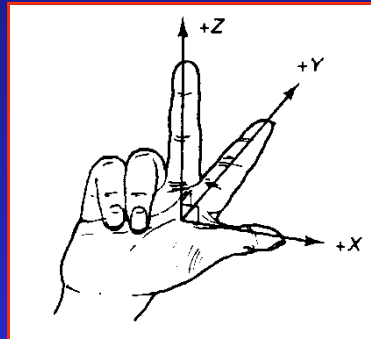
Tool commands (T code)

Specifies which tool to be used, machines with automatic tool changer.

CNC Machine Axes of Motion

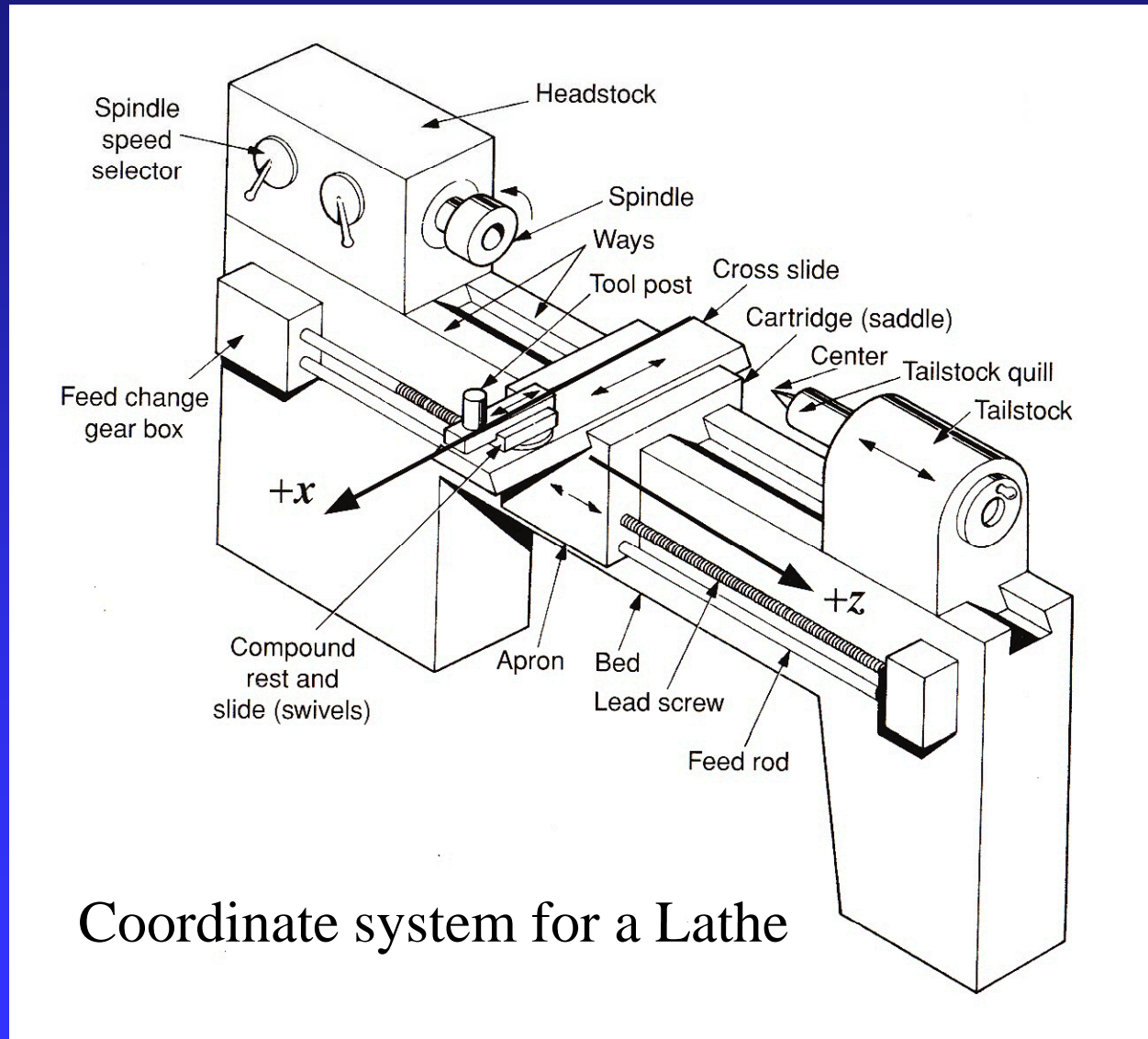
The coordinate system used for the tool path must be identical to the coordinate system used by the CNC machine. The standards for machine axes are established according to the industry standard report EIA RS-267A.

Right hand rule



CNC machines milling machines can perform simultaneous linear motion along the three axis and are called **three-axes machines**.

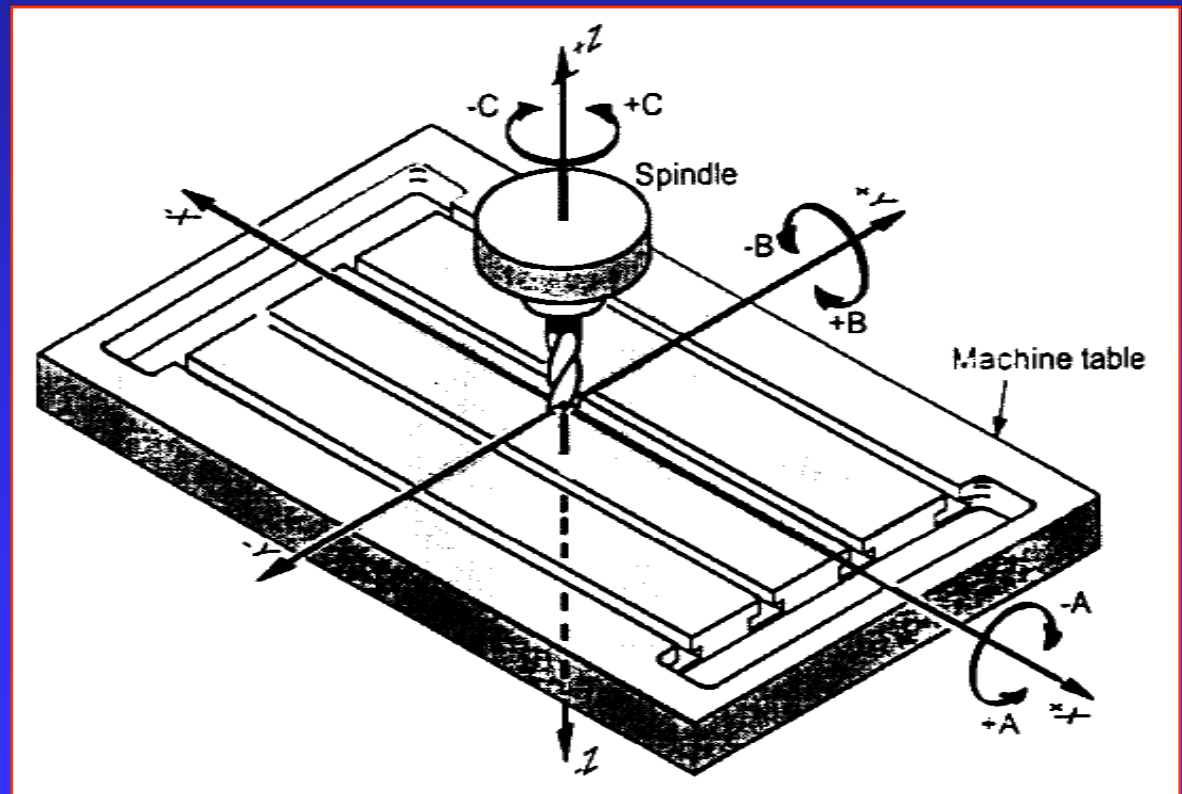
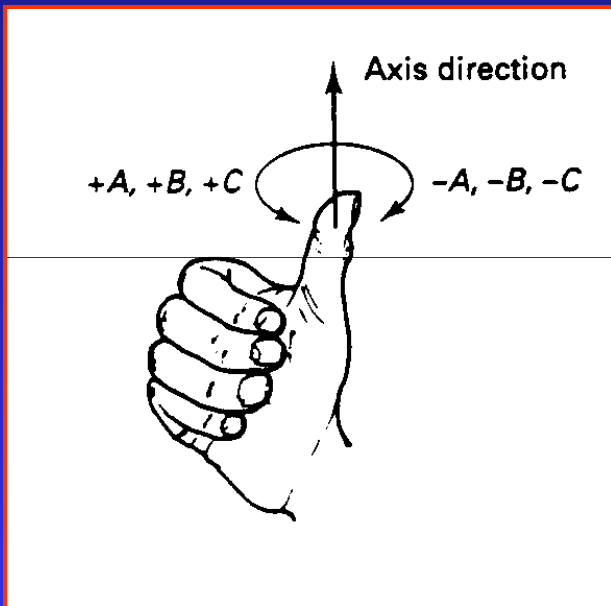
CNC Machine Axes of Motion



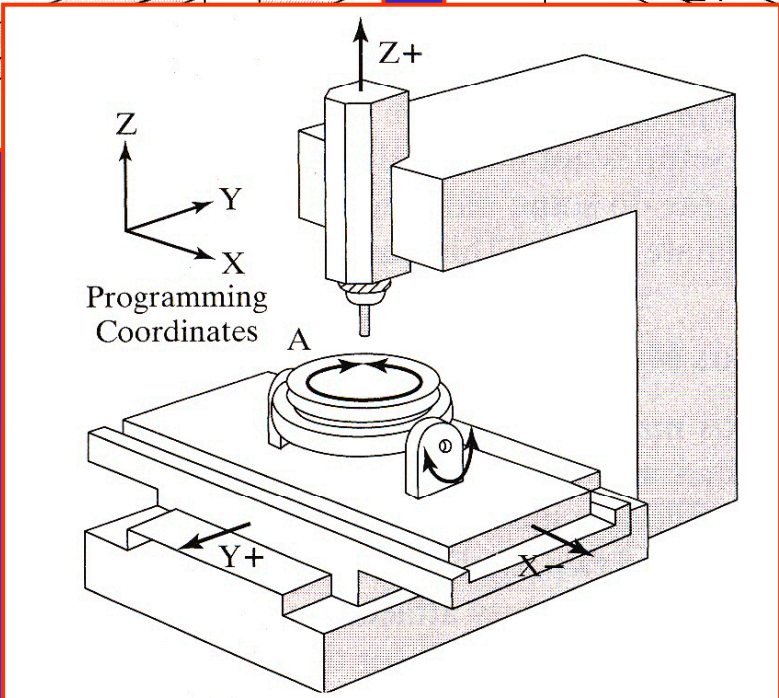
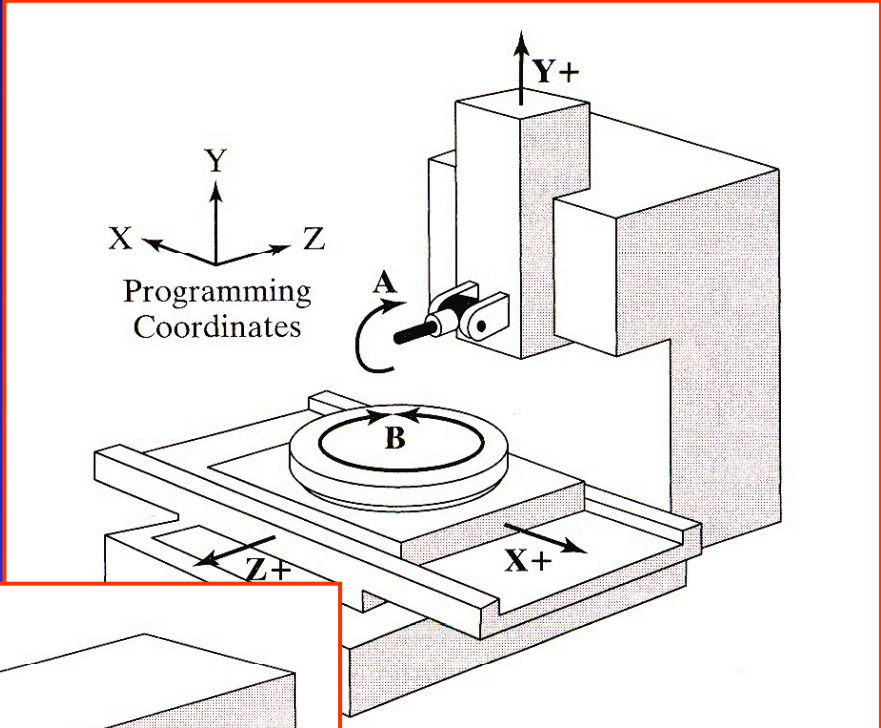
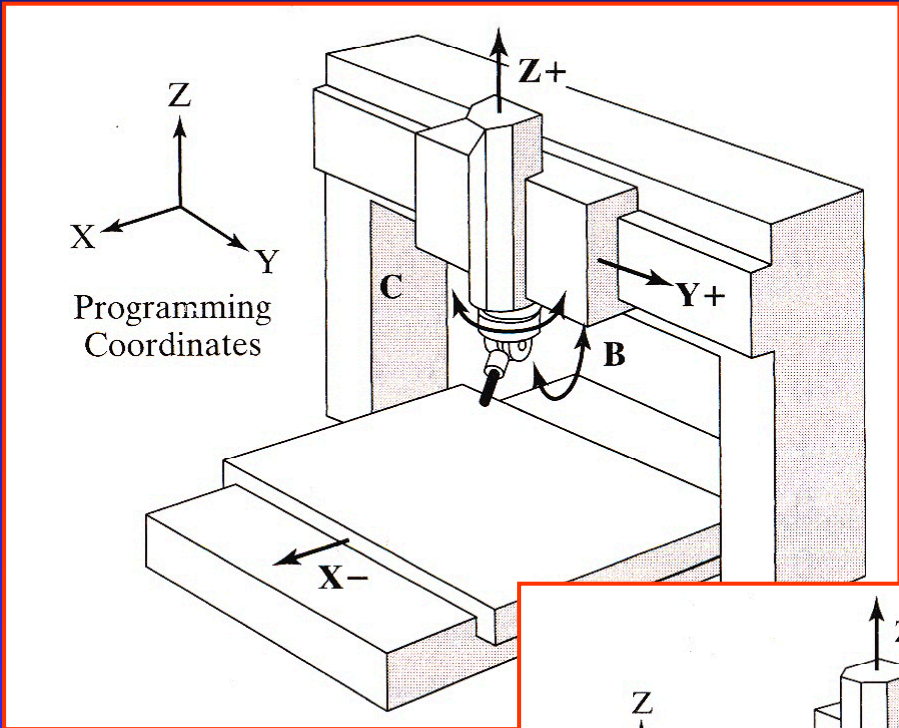
Coordinate system for a Lathe

CNC Machine Axes of Motion

More complex CNC machines have the capability of executing additional rotary motions (4th and 5th axes).



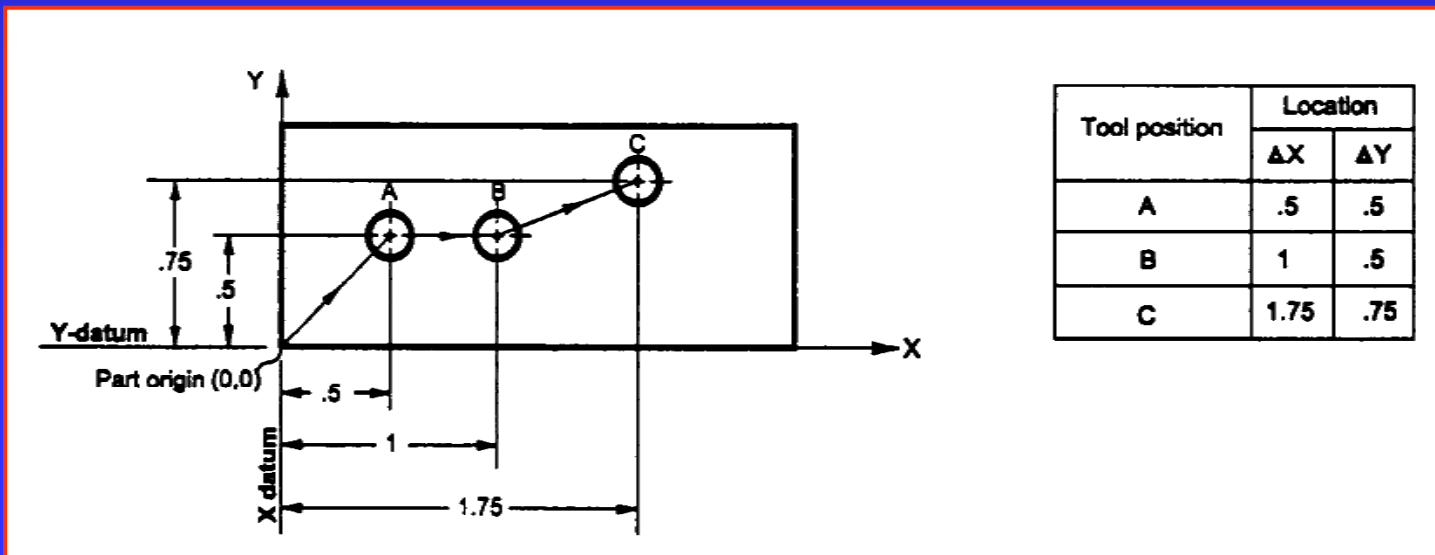
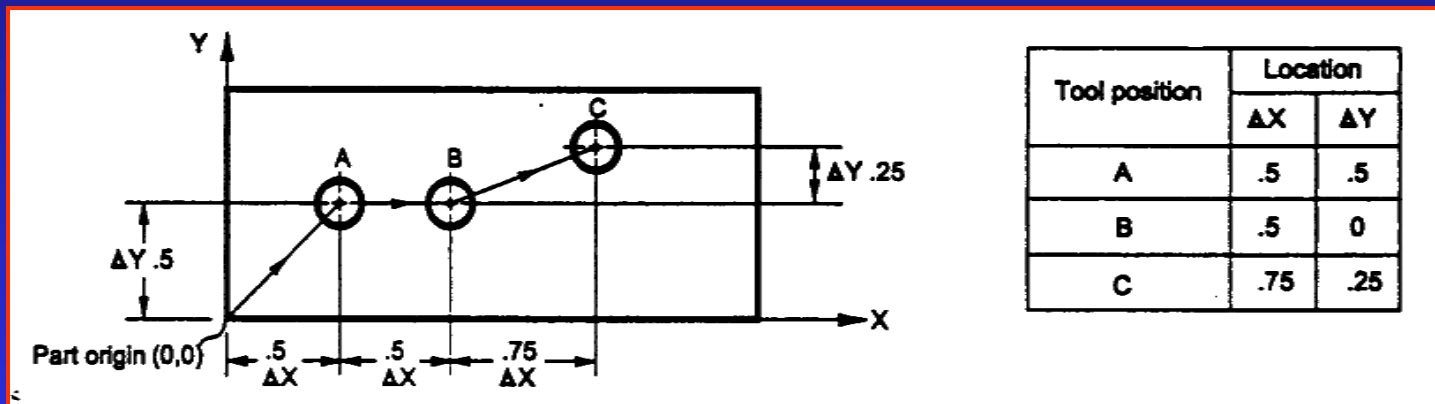
CNC Machine Axes of Motion



Five-axis
machine
configurations

CNC Machine Tool Positioning Modes

Within a given machine axes coordinate system, CNC can be programmed to locate tool positions in the following modes; incremental, absolute, or mixed.



Example of a part program

N001 G91 (incremental)

N002 G71 (metric)

Loading tool

Rapid motion

Tool change

N003 G00 X0.0 Y0.0 Z40.0 T01 M06

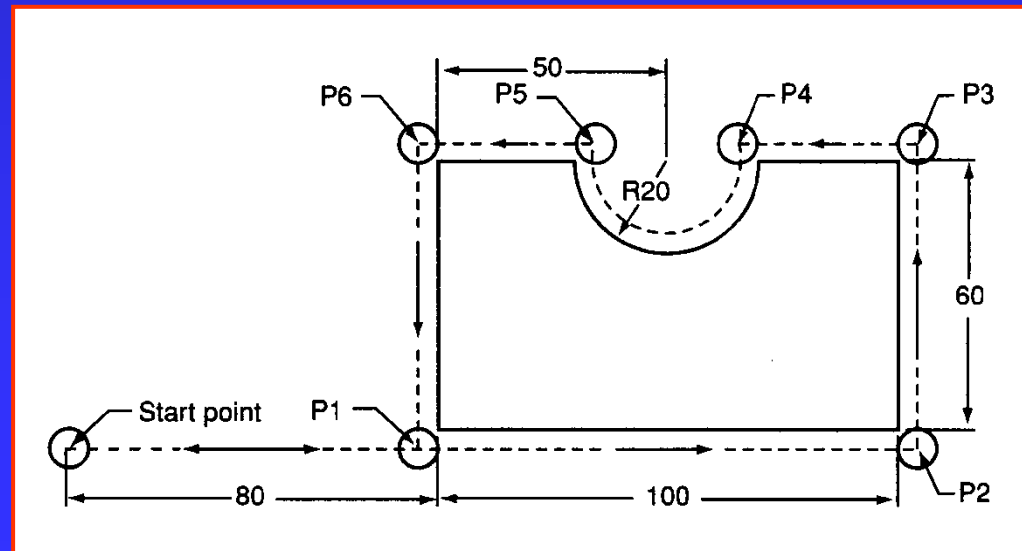
Positioning tool at P₁

Start spindle

Start coolant

N004 G01 X75.0 Y0.0 Z-40.0 F350 M03 M08

Linear interpolation



Example of a part program

Moving tool from P_1 to P_3 through P_2

N005 G01 X110

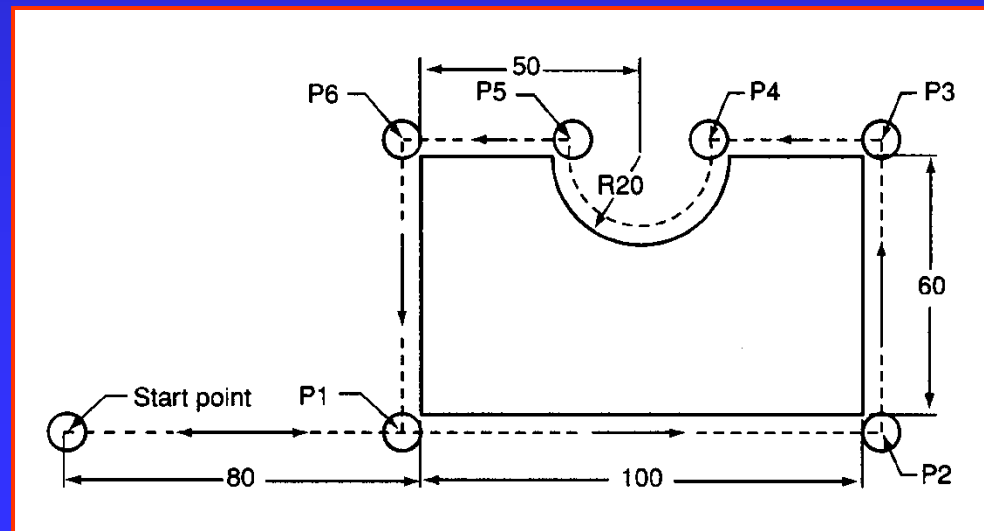
N006 G01 Y70.0

*Moving tool from P_3 to P_4 along a straight line
and from P_4 to P_5 clockwise along circular arc.*

N007 G01 X-40.86

N008 G02 X-28.28 Y0.0 I-14.14 J-5.0

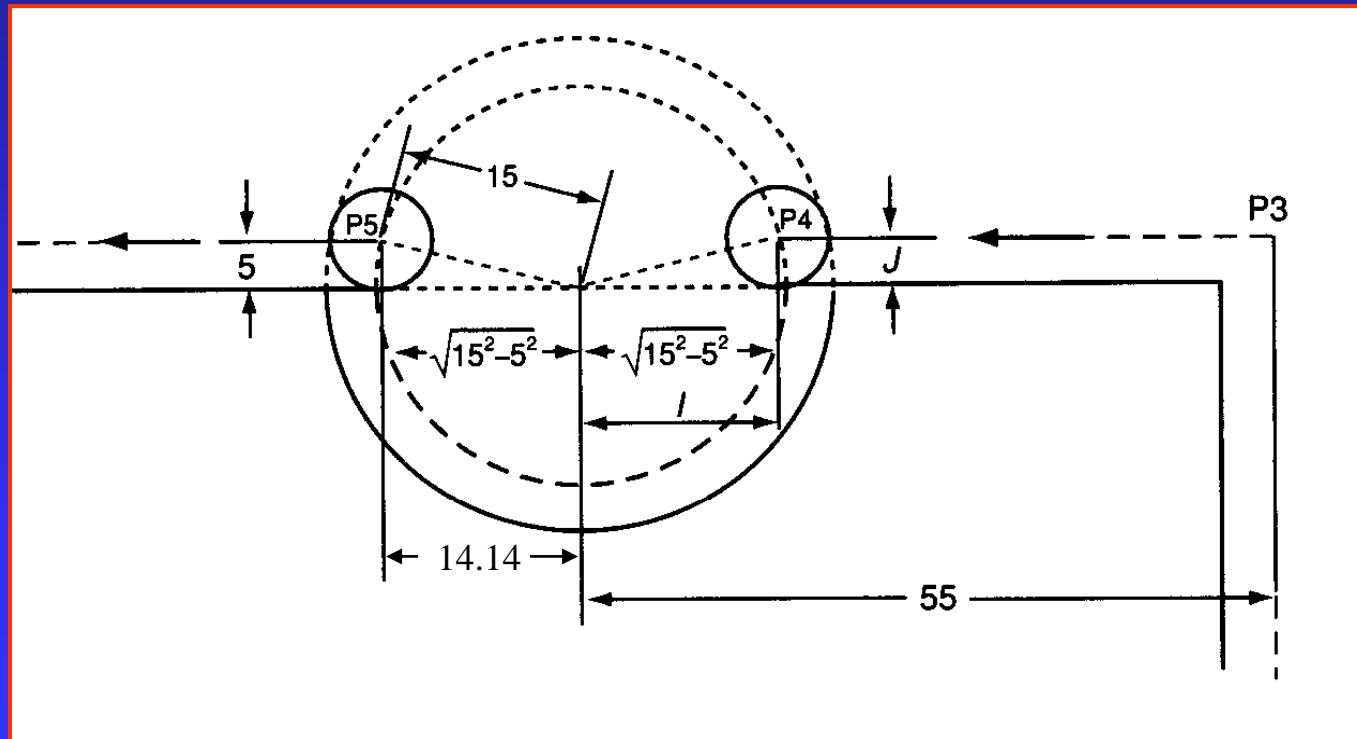
Tool dia.=10 mm



Example of a part program

X and Y specify the end point of the arc (P5) with respect to the start point (P4).

I and J specify the center of the arc with respect to the start point.



N008 G02 X-28.28 Y0.0 I-14.14 J-5.0

Computer-Assisted Part Programming

Automatically Programmed Tools (ATP) language is the most comprehensive and widely used program. The language is based on common words and easy to use mathematical notations

- Identify the part geometry, cutter motions, speeds, feeds, and cutter parameter.
- Code the above information using ATP.
- Compile to produce the list of cutter movements and machine control information (Cutter Location data file, CL).
- Use post-processor to generate machine control data for a particular machine. This is the same as NC blocks.

Part Programming from CAD Database “Integrated CAD/CAM Systems”

- In an integrated CAD/CAM system, the geometry and tool motions are derived automatically from the CAD database by the NC program (Pro/E, Unigraphics,)
- No need for manual programming or using APT language.

Integrated CAD/CAM System

- CAD and Cam (Computer Aided Manufacturing) together create a link between product design and manufacturing.
- The CAD system is used to develop a geometric model of the part which is then used by the CAM system to generate part programs for CNC machine tools.
- Both CAD and CAM functions may be performed either by the same system or separate systems in different rooms or even countries.
- Extending the connection between CAD and CAM to its logical limits within a company yields the concept of the computer-integrated enterprise (CIE). In CIE all aspects of the enterprise is computer aided, from management and sales to product design and manufacturing.

CAD/CAM

- CAD/CAM systems allow for rapid development and modifying of designs and documentation.
- The 3D geometric model produced becomes a common element for engineering analysis (FEA), machining process planning (including CNC part programming, documentation (including engineering drawings), quality control, and so on.
- The coupling of CAD and CAM considerably shortens the time needed to bring a new product to market.
- Increased productivity is generally the justification for using CAD/CAM system.

Product Data Management System (PDM)

Product development cycle includes activities not only in design and manufacturing but also in analysis, quality assurance, packaging, shipping, and marketing.

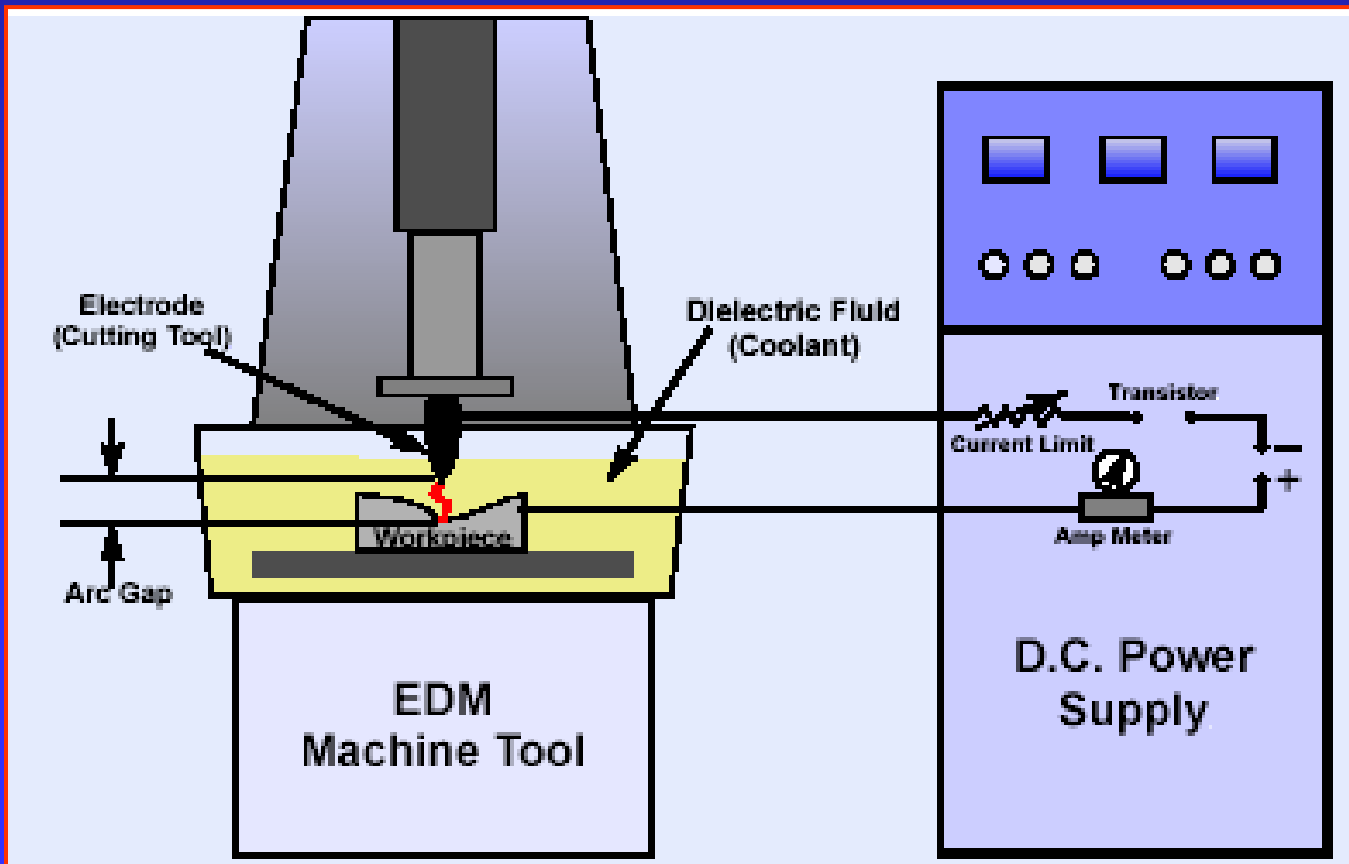
Software systems called product data management (PDM) are available to smooth data flow among all these activities.

Some available software; SDRC's Metaphase, Unigraphics's IMAN, Computer Vision's Optegra.

(web-enabled software).

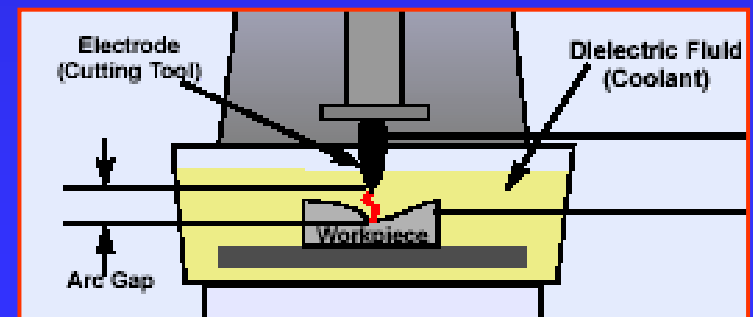
Electrical Discharge Machine - EDM

Die-sinking EDM systems, the electrode (cutting tool) and workpiece are held by the machine tool. The power supply controls the electrical discharges and movement of the electrode in relation to the workpiece. During operation the workpiece is submerged in a bath of dielectric fluid (electrically nonconducting). (Die-Sinking EDM is also called Sinker, Ram-Type, Conventional, Plunge or Vertical EDM)



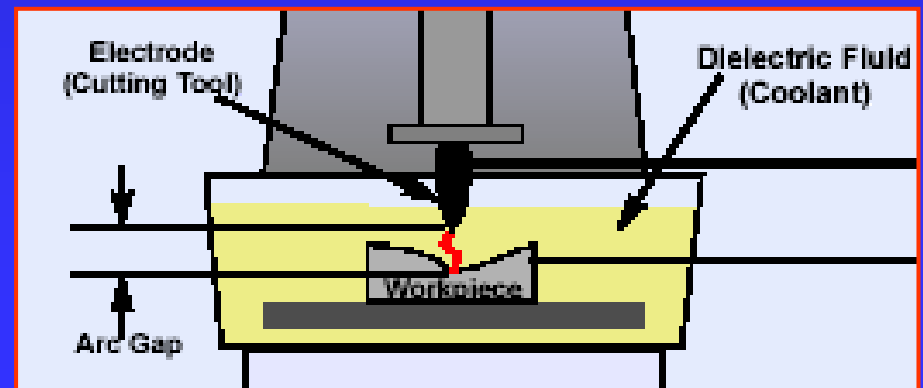
EDM – Die-Sinking (Plunge)

- During normal operation the electrode never touches the workpiece, but is separated by a small spark gap.
- The electrode (plunger) can be a complex shape, and can be moved in X, Y, and Z axes, as well as rotated, enabling more complex shapes with accuracy better than one mil.
- The spark discharges are pulsed on and off at a high frequency cycle and can repeat 250,000 times per second. Each discharge melts or vaporizes a small area of the workpiece surface.
- The amount of material removed from the workpiece with each pulse is directly proportional to the energy it contains.
- Plunge EDM is best used in tool and die manufacturing, or creating extremely accurate molds for injection-molding plastic parts.



EDM

- The dielectric fluid performs the following functions:
 - It acts as an insulator until sufficiently high potential is reached .
 - Acts as a coolant medium and reduces the extremely high temp. in the arc gap.
 - More importantly, the dielectric fluid is pumped through the arc gap to flush away the eroded particles between the workpiece and the electrode which is critical to high metal removal rates and good machining conditions.
- A relatively soft graphite or metallic electrode can easily machine hardened tool steels or tungsten carbide. One of the many attractive benefits of using the EDM process.



EDM

The EDM process can be used on any material that is an electrical conductor

The EDM process does not involve mechanical energy, therefore, materials with high hardness and strength can easily be machined.

Applications include producing die cavity for large components, deep small holes, complicated internal cavities

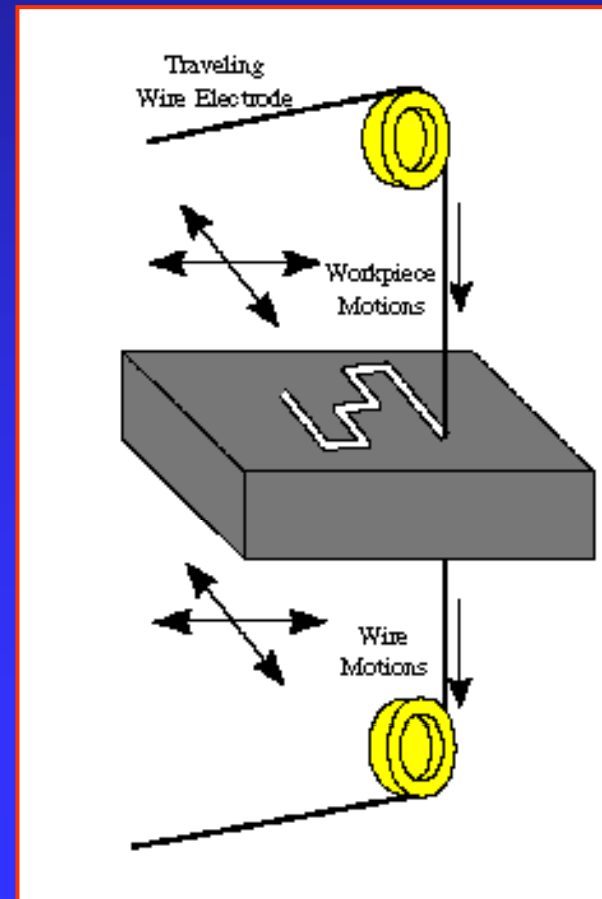
Dimensional accuracy of ± 0.0005 in is achievable.

Minimum wall thickness: .01 inch, over 5 inch span

Feature to feature positioning: .001

Wire EDM

Wire EDM machines utilize a very thin wire (.0008 to .012 in.) as an electrode. The wire is stretched between diamond guides and carbide that conduct current to the wire and cuts the part like a band saw. Material is removed by the erosion caused by a spark that moves horizontally with the wire.



EDM Examples



7075-T6 aluminum back plate latch, EDM cost is less than half the milling cost.

These simple, flat shapes, used in food processing, which usually would be stamped, were wire EDMed instead because they required a superior quality edge.



Intricately detailed automobile part

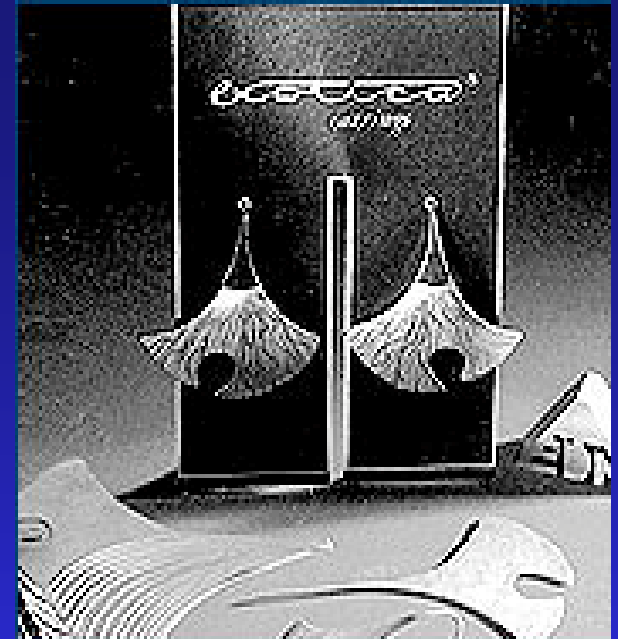


EDM Examples

To manufacture titanium earring shapes wire EDM proved the most cost effective when compared to stamping and laser cutting.



Turbine blades



Small parts made using EDM

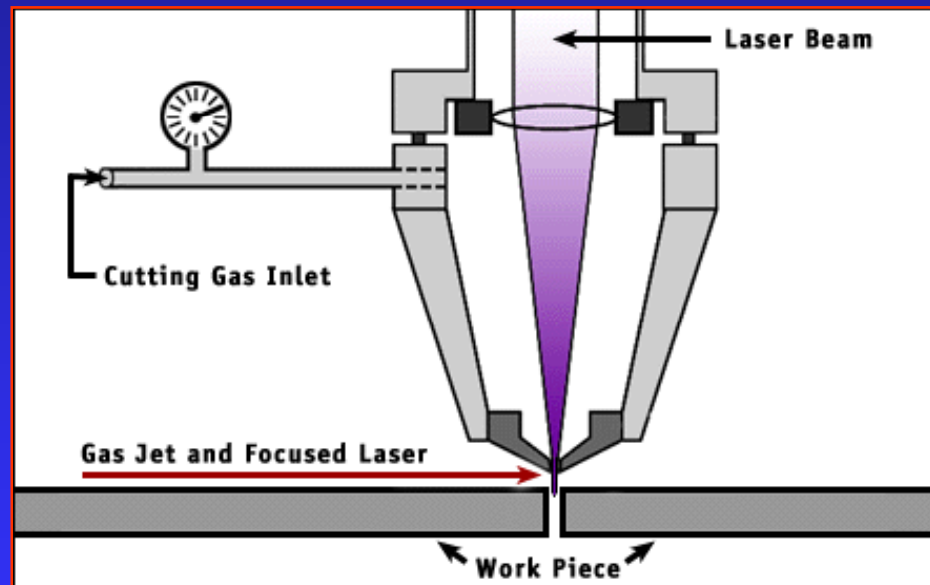
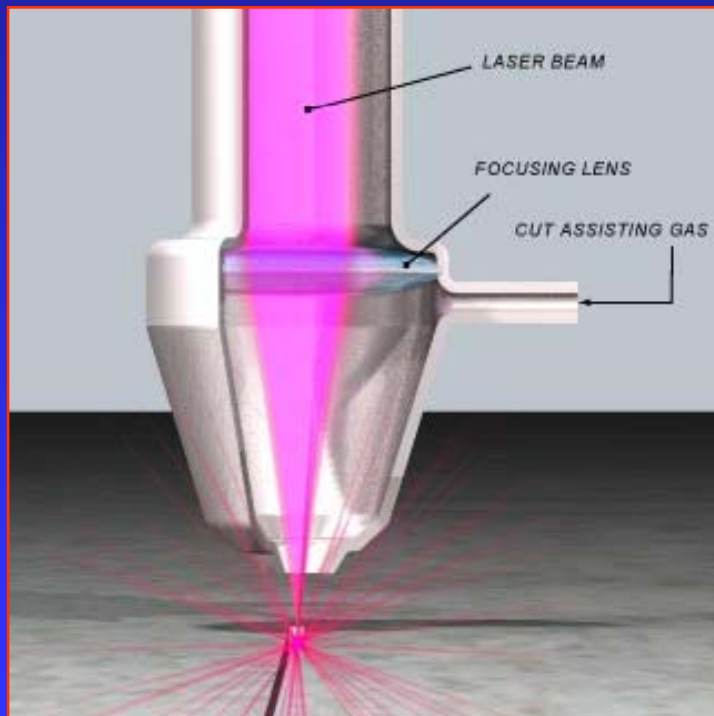
Small gear (with insect for scale) shows a capability of EDM micromachining.



CNC Machines

Laser Machining and Cutting

The machine utilizes an intense beam of focused laser light to cut the part. Material under the beam experiences a rapid rise in temp. and is vaporized. Laser cuts with a minimum of distortion, no mechanical cutting forces.



Gas is blown into the cut to clear away molten metals, or other materials in the cutting zone. In some cases, the gas jet can be chosen to react chemically with the workpiece to produce heat and accelerate the cutting speed

Laser machining and Cutting

- The first ever 'gas-assisted' laser cuts were done in 1967.
- Sheet metal cutting has since become, by far, the dominant industrial use of lasers in materials processing. Approximately 12 000 industrial laser cutting systems have been installed world-wide, with a total market value of some 4.5 billion US dollars. Over 60% of this equipment is installed in Japan.
- Today, laser cutting is used extensively for producing profiled flat plate and sheet, for diverse applications in the engineering industry sectors.
- Metals, ceramics, polymers and natural materials such as wood and rubber can all be cut using CO₂ lasers.

Laser machining and Cutting



MALOYA LASER INC.



MLI is capable of cutting up to .625" in steel and steel alloys .375" in stainless steel (& high temperature alloys, .250" in aluminum, and .125" brass. With automated loading and dual hydraulically alternating beds (sizes 78" x 157") there is no downtime on production runs. Minimum set time and virtually no tooling cost, MLI can be very cost effective in prototyping and production runs.

Laser machining and Cutting

Advantages

- Excellent control of the laser beam with a stable motion system achieves an extreme edge quality. Laser-cut parts have a condition of nearly zero edge deformation, or roll-off
- It is also faster than conventional tool-making techniques.
- Laser cutting has higher accuracy rates over other methods using heat generation, as well as water jet cutting.
- There is quicker turnaround for parts regardless of the complexity, because changes of the design of parts can be easily accommodated. Laser cutting also reduces wastage.

Laser machining and Cutting

Disadvantages

- The material being cut gets very hot, so in narrow areas, thermal expansion may be a problem.
- Distortion can be caused by oxygen, which is sometimes used as an assist gas, because it puts stress into the cut edge of some materials; this is typically a problem in dense patterns of holes.
- Lasers also require high energy, making them costly to run.
- Lasers are not very effective on metals such as aluminum and copper alloys due to their ability to reflect light as well as absorb and conduct heat. Neither are lasers appropriate to use on crystal, glass and other transparent materials.

Laser machining and Cutting



Laser drilling hole



Laser welding in automobile industry