Ch 7:Numerical Control

Learning Objectives:

By the end of the lecture the student should be able to:

- Explain what NC is
- Explain what CNC is
- Outline how CNC work (Control system, Controller…)
- Explain the fundamentals of motion control in CNC
- Perform basic NC programming

NOTE: Materials used to create this presentation were supplied from:

Lecture notes designed by 2008 Pearson Education Inc. Third Edition by Professor Mikell P. Groover

Lecture notes designed by Professor Darek Ceglarek, University of Wisconsin – Madison.

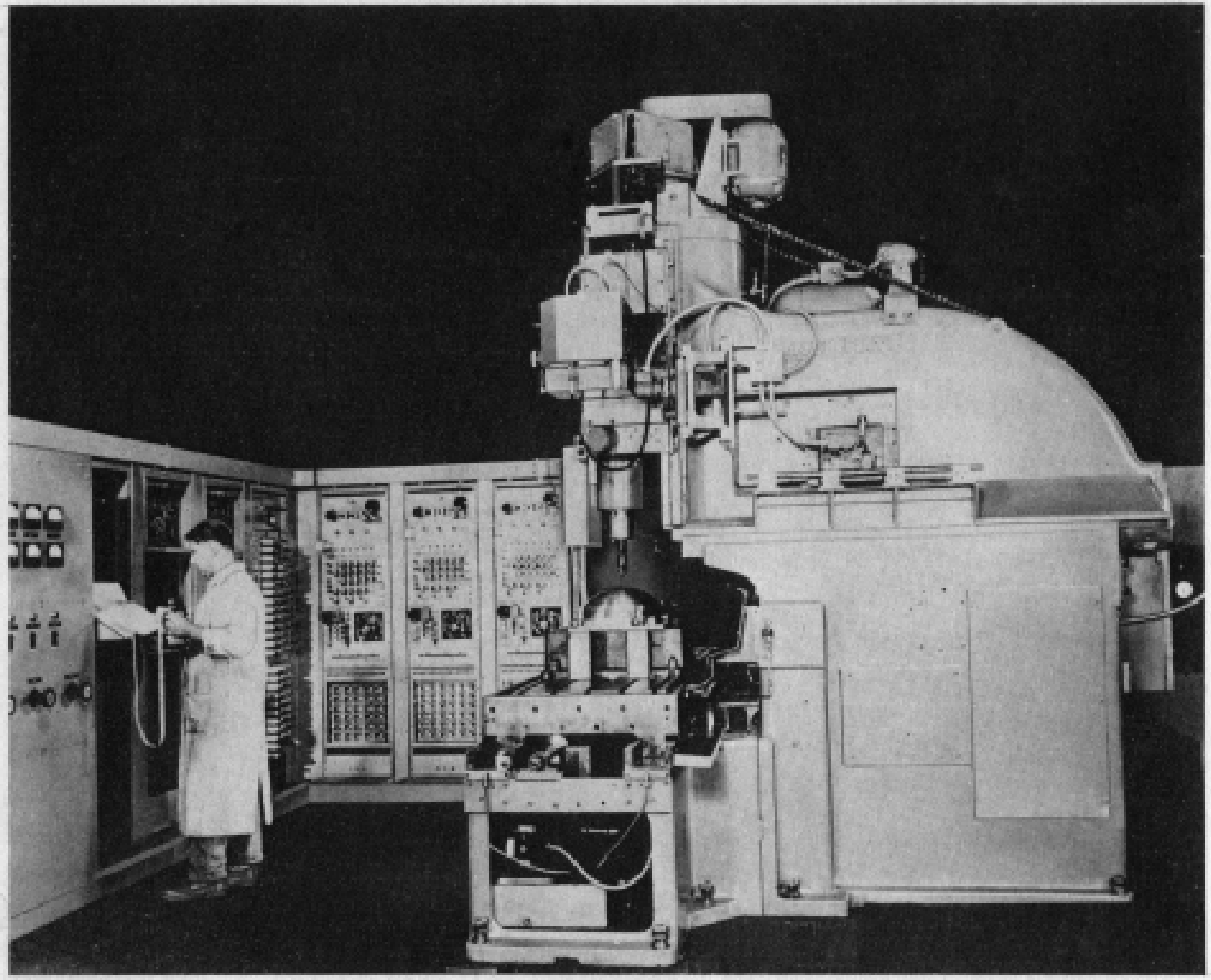
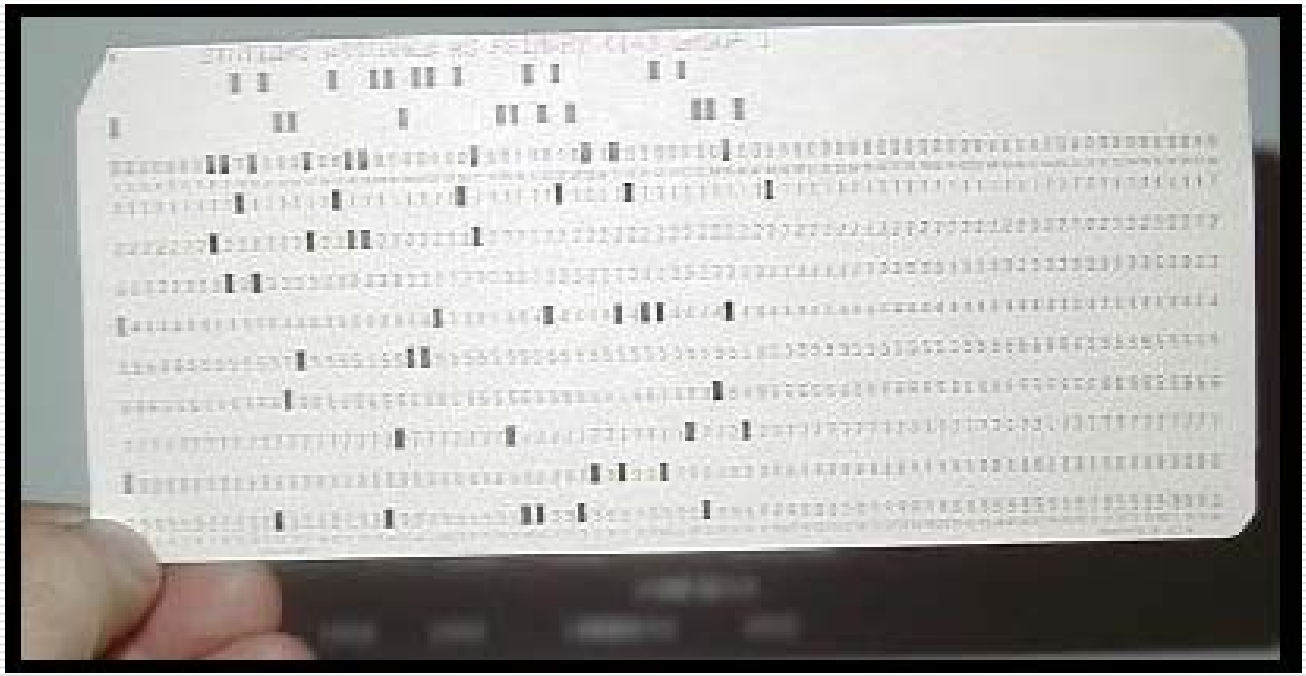
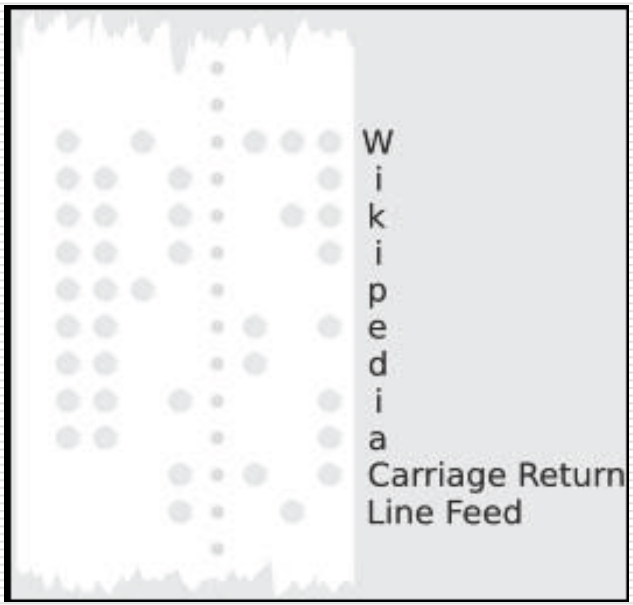
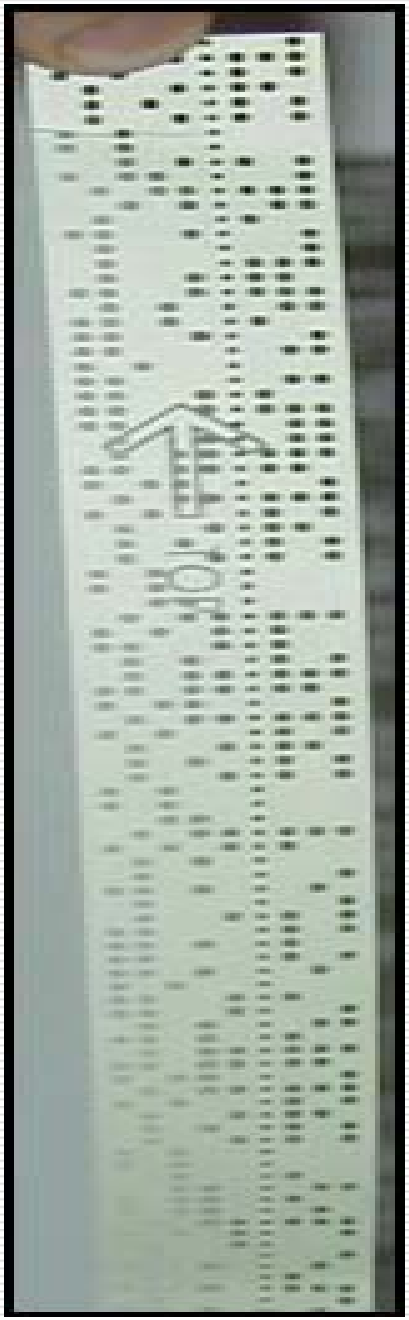


FIG. 1–8. Believed to be the first NC machine, the one shown above was successfully demonstrated at MIT in 1952.





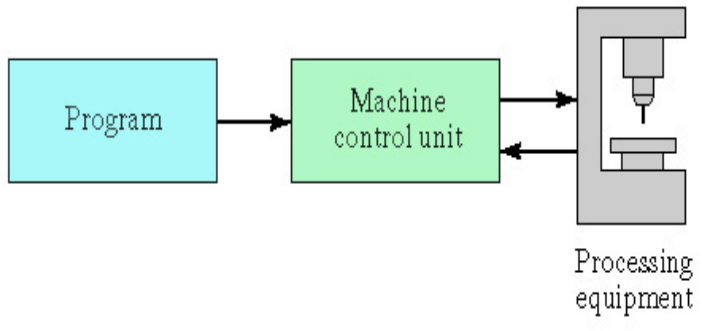


Source: Wikipedia

Numerical Control (NC): Definition

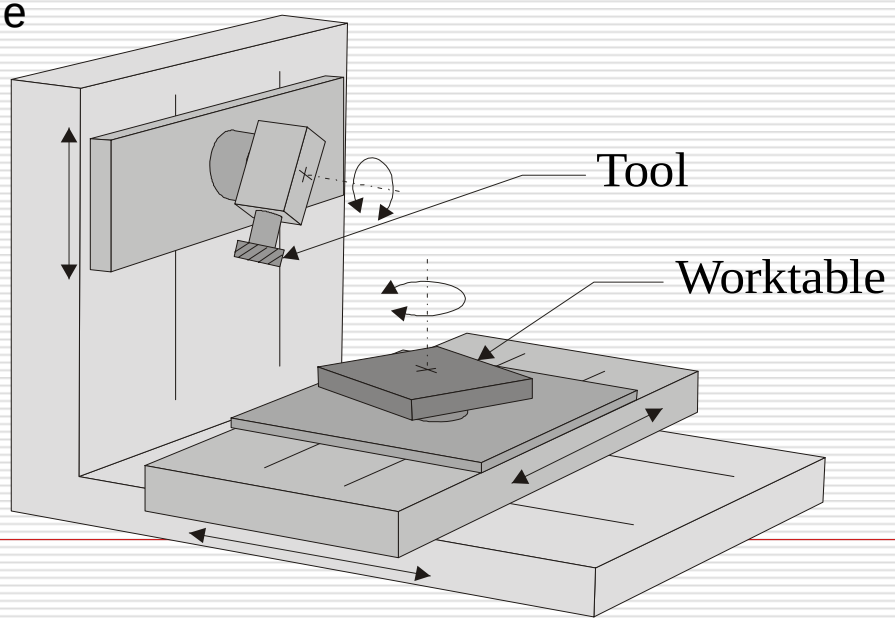
- Use of numbers, letters and other symbols to control the processing equipment - a form of programmable automation (to duplicate/replace human control of machine tools)

- Basic Components of NC:
  1. Program of instructions
     - Part program in machining
  2. Machine control unit
     - Controls the process
  3. Processing equipment
     - Performs the process



Machining using NC

- Machining refers to cutting operations that are based on the removal of material from a rough-shaped workpiece via turning, milling, drilling, etc:
- Example: Up to 5 motion axes may need to be controlled simultaneously.
- Each linear axis has a maximum travel distance. The combination of the maximum travel distances for all the axes determines a machine's work envelope

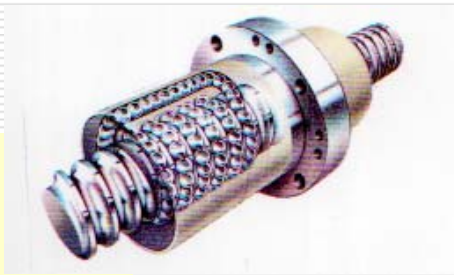


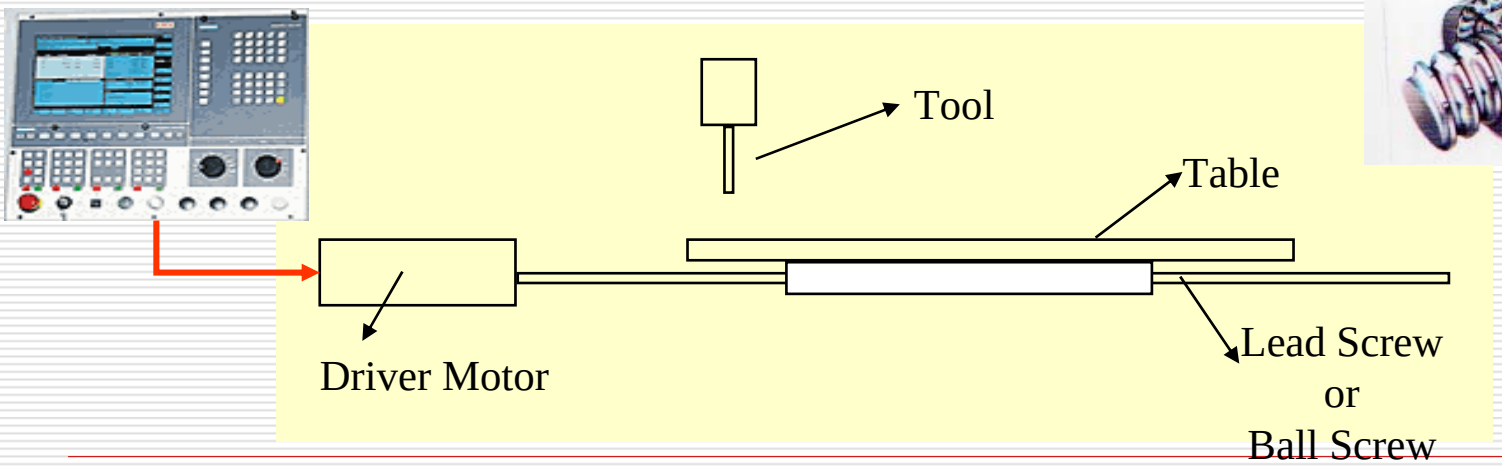
Computer Numerical Control (CNC)

- Computer Numerical Control (CNC) has one microcomputer at the machine tool to control the NC functions
- CNC machines thus provide a high level of:
  - Accuracy
  - Repeatability
  - Programming capability
- CNC advantages
  - Program entry only once, stored in memory to ↓ errors
  - Program can be edited at the machine site
  - Therefore - more flexible
  - Integrated with the manufacturing information system

How CNC Work?

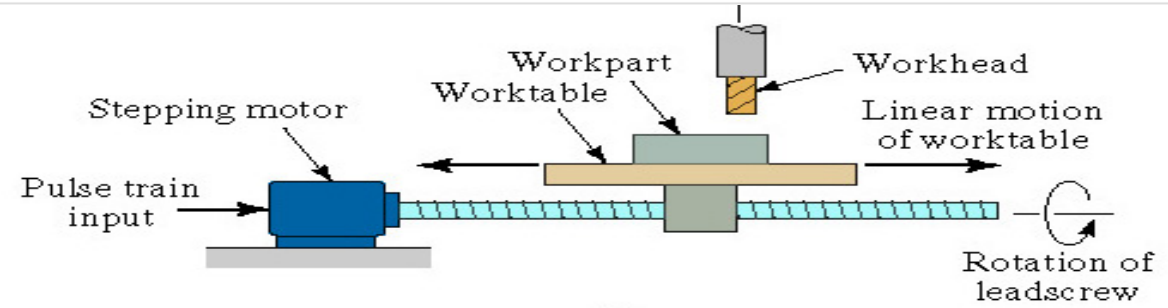
- Each CNC machine has a CNC controller which can be programmed to drive the machine through a series of motions
- Axis: Each direction of motion of a CNC machine is called an axis. It is simply a direction of motion under the influence of the CNC controller. It can either be linear or rotary.
- Ball (lead) screw transfer rotation to linear motion of the mechanical device. The drive motor is the link between the ball screw and the CNC control. The motor can be either a stepper motor or a servo motor.



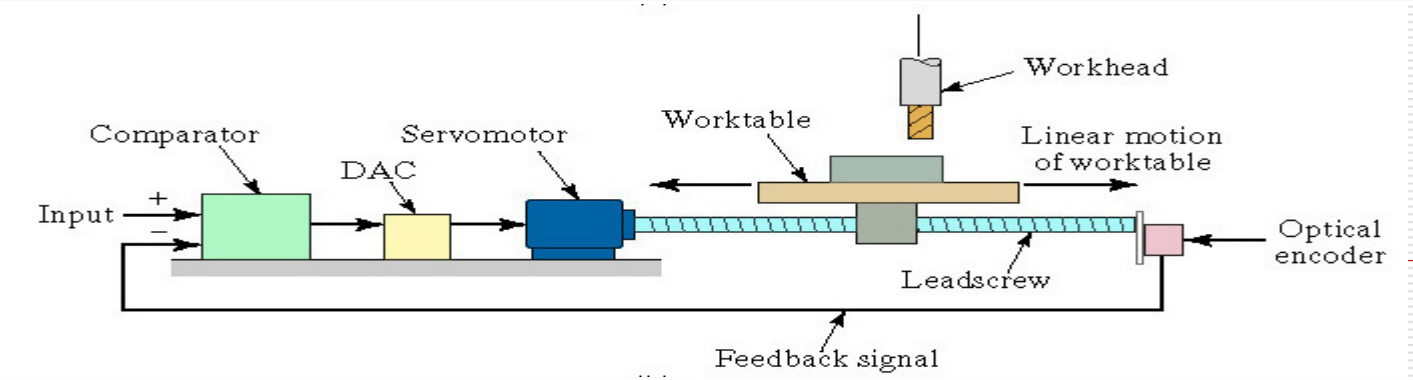


Control Systems

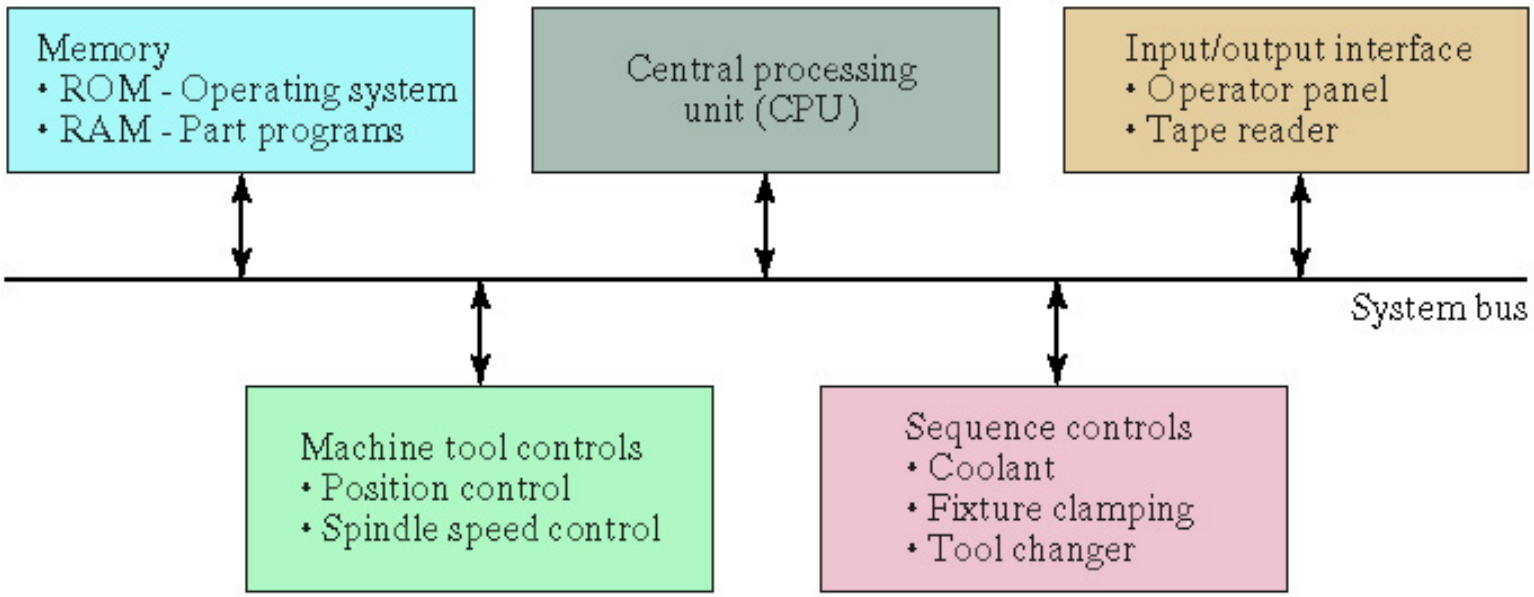
- Open-Loop Motion Control System
  - Operates without verifying that the actual position achieved in the move is the desired position



- Closed-Loop Motion Control System
  - Uses feedback measurements to confirm that the final position of the worktable is the location specified in the program



Basic Components of Controller



Motion Control Systems

Point-to-Point systems

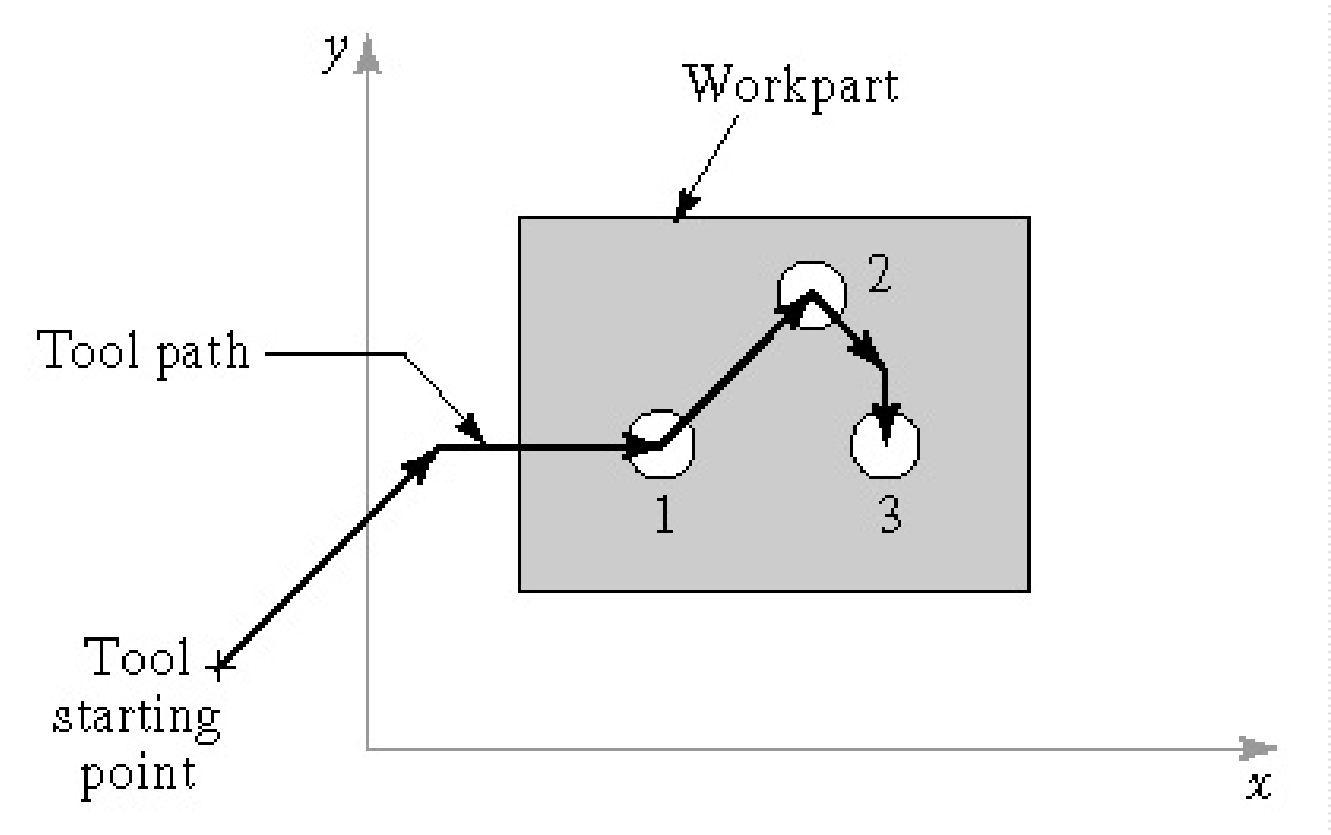
- Also called position systems
- System moves to a location and performs an operation at that location (e.g., drilling)
- Also applicable in robotics

Continuous path systems

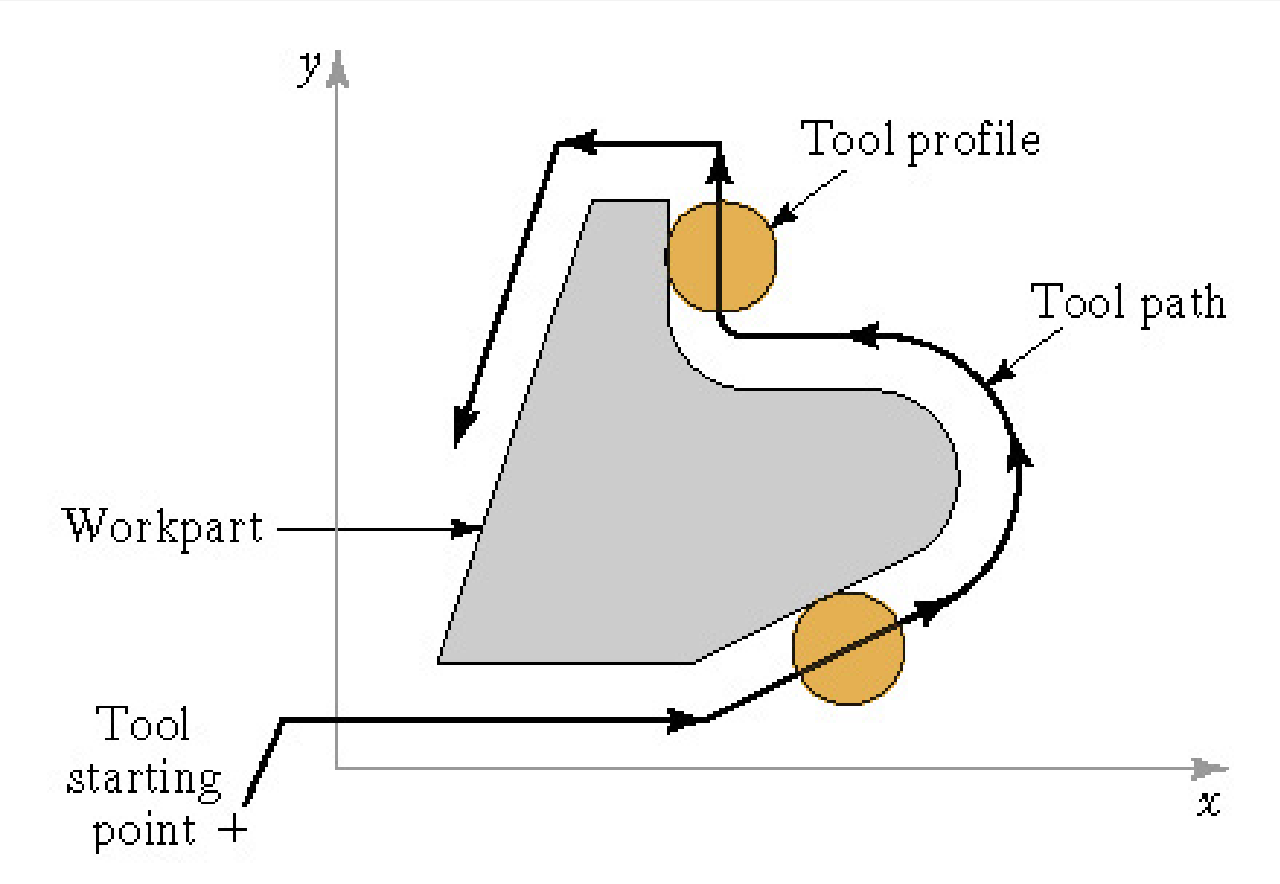
- Also called contouring systems in machining
- System performs an operation during movement (e.g., milling and turning)

Point-To-Point Control in NC

Example: Drilling of Three Holes in Flat Plate



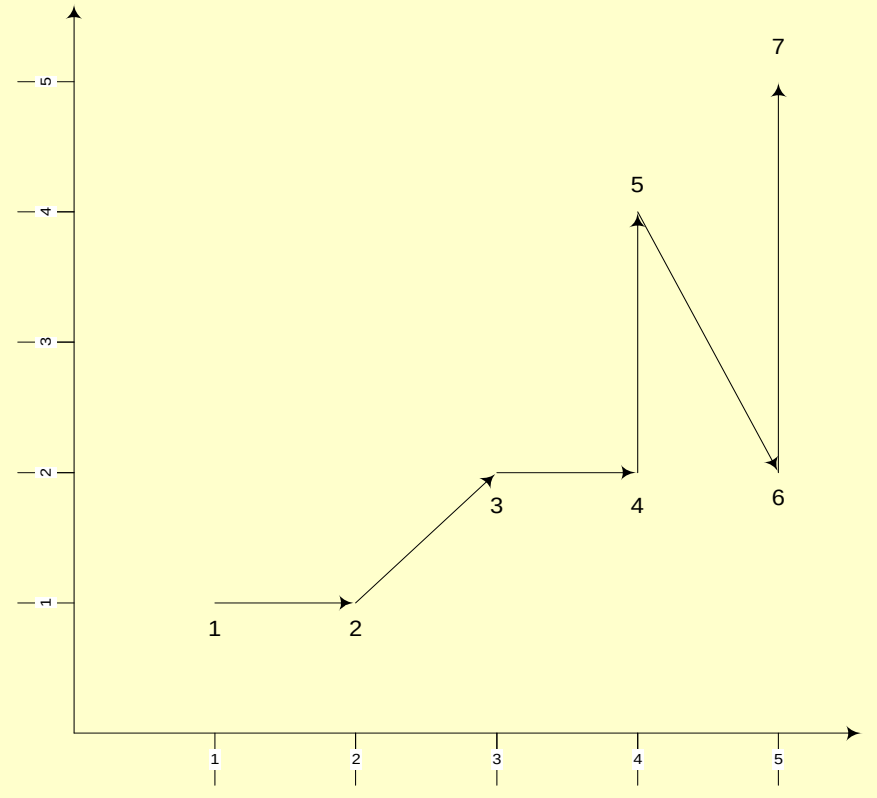
Continuous Path Control in NC
Example: Profile Milling of Part Outline



Absolute Vs. Incremental Mode

- Absolute Mode
  - the distances moved are relative to the program zero.
- Incremental Mode:
  - the distances moved are relative to the machine's current position.

Example

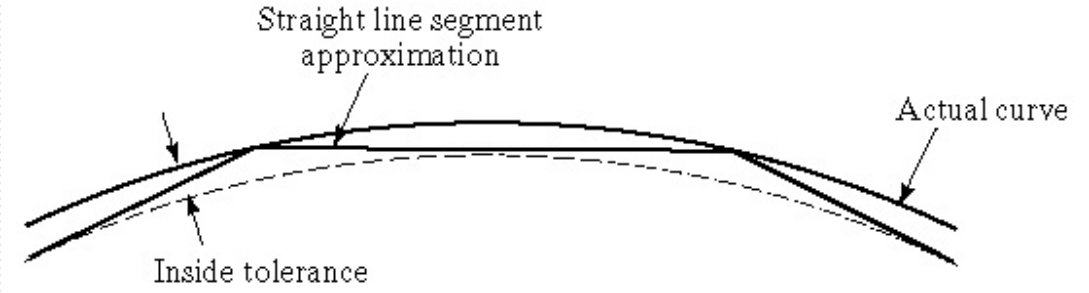


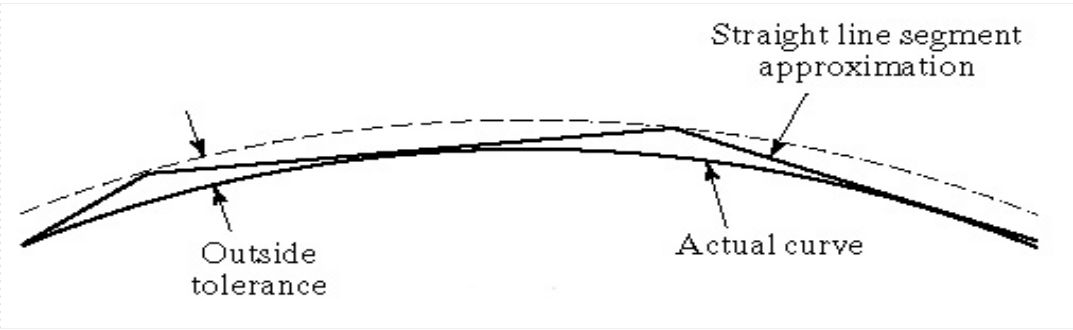
Point	Absolute Mode	Incremental Mode
1	X 1.0 Y 1.0	X 1.0 Y 1.0
2	X 2.0 Y 1.0	X 1.0 Y 0.0
3	X 3.0 Y 2.0	X 1.0 Y 1.0
4	X 4.0 Y 2.0	X 1.0 Y 0.0
5	X 4.0 Y 4.0	X 0.0 Y 2.0
6	X 5.0 Y 2.0	X 1.0 Y –2.0
7	X 5.0 Y 5.0	X 0.0 Y 3.0

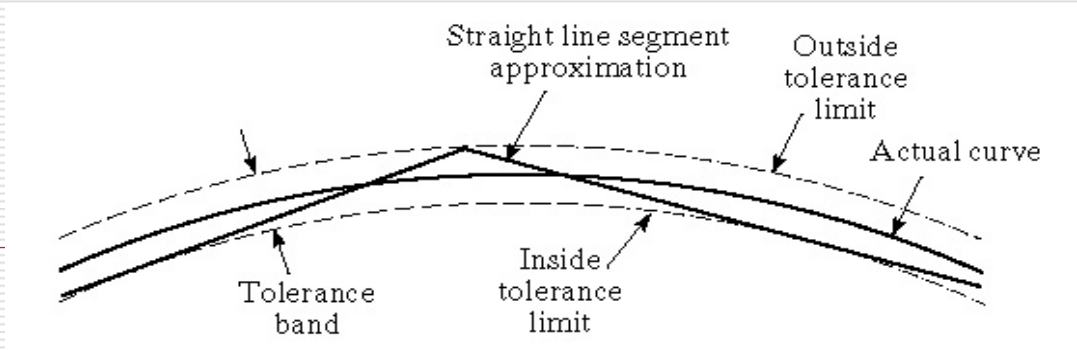
Motion Interpolation Methods

1. Linear interpolation
   - Straight line between two points in space
2. Circular interpolation
   - Circular arc defined by starting point, end point, center or radius, and direction
3. Helical interpolation
   - Circular plus linear motion
4. Parabolic and cubic interpolation
   - Free form curves using higher order equations

Circular Motion





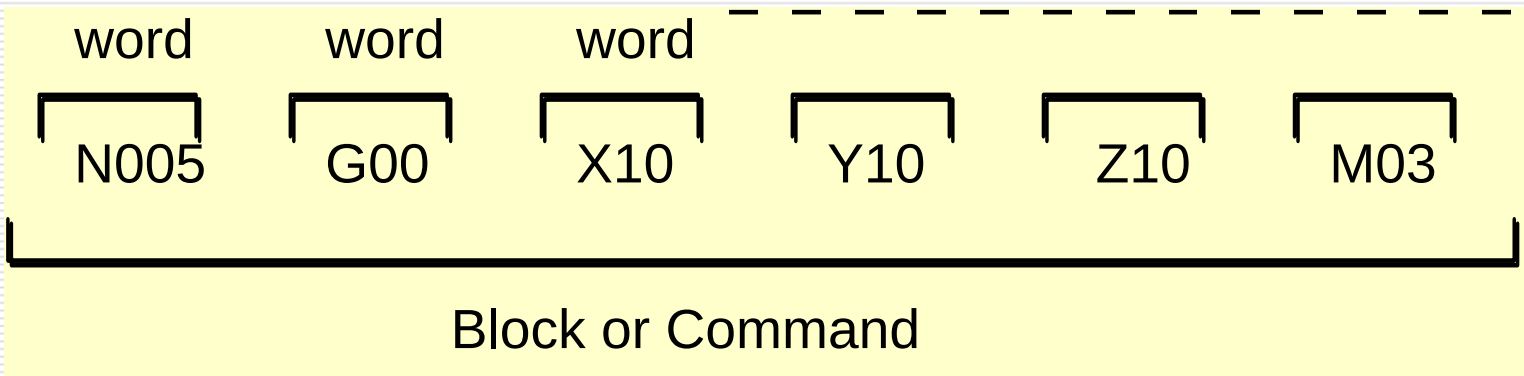


NC Part Programming

- Data for producing a part by NC machining
  - Part drawing (design) information
    - Dimension - length, width, height, radius, etc.
    - Segment shape to calculate tool path - linear, circular, parabolic, etc.
    - Diameter of holes to be drilled
  - Machining parameters
    - Depend on surface quality, required tolerances, type of work piece (material) and cutting tools, feed rates, spindle speeds, and auxiliary functions (on/off coolant)
  - Part programmer determined data
    - Cutting direction, change of tools, and sequence of operations (optimal - OR problem)

NC Programming Languages

- There does not exist a standard NC programming language
- Every CNC machine manufacturer has a special language for programming their machines.
- The closest to a standard language are G/M codes.
  - A G/M code CNC program is made up of a series of commands. Each command or block is made up of words
  - Each word is composed of a letter address (X,Y,Z,R, etc.) and a numerical value.



Components of a G/M Code Program

- Sequence number (N-words)
- Preparatory work (G-words)
  - Example: Instructions to the controller
    G00 Point-to-point operation (rapid speed)
- Coordinates (x-, y-, z-words)
- Feed rate (F-words)
  - Feed rate - in./min.
- Spindle speed (S-words)
  - RPM - rev./min.
- Tool selection (T-words)
- Tool length offset (H-words)
- Tool radius offset (D-words)
- Specifies Miscellaneous functions (M-words)

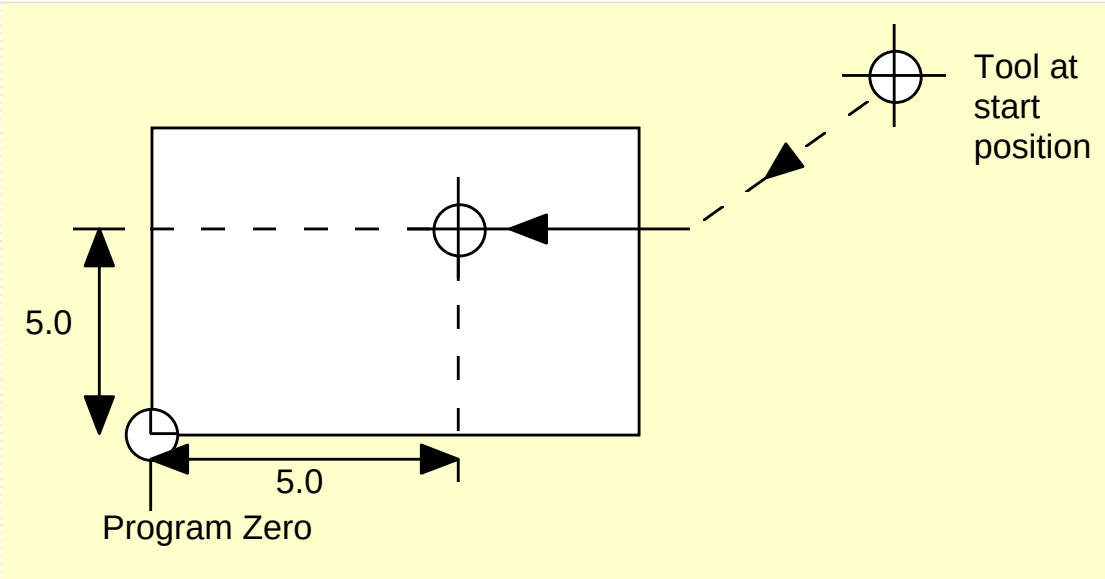
M- Words

- Miscellaneous function (M-words)

M00	Stop program
M03	Start spindle on CW direction
M04	Start spindle on CCW direction
M05	Stop spindle
M06	Tool change
M07	Turn coolant on (mist mode)
M08	Turn coolant on (flood mode)
M09	Turn coolant off
M30	End of program

Example 1

N015 G00 X5.0Y5.0



G-Words

- Instructions to the controller
  - G00 Point-to-point operation (rapid speed)
  - G01 Linear interpolation
  - G02 Circular interpolation - clockwise
  - G03 Circular interpolation - counterclockwise
  - G04 Dwell (wait) for programmed duration
  - G90 Absolute mode
  - G91 Incremental mode

Example 2

N0027 G01 X175.25 Y325.00 Z136.50 F125 S800 T1712 M03 M08

Statement Number 27 (N0027) a linear-interpolation motion (G01) to a position defined by (X175.25 Y325.00 Z136.50), with a feed rate of 125 mm/min (F125), and a spindle speed of 800 rpm (S800), using a tool Number 1712 (T1712), performing a CW turn of the spindle (M03), and having the coolant on (M08).

NC Part Programming

- Methods of NC Part Programming
  - Manual part programming
    - A punched tape is prepared directly from a part program manuscript
  - Computer assisted part programming
    - Much of the tedious computational work required in manual programming is performed by the computer
  - Manual data input (MDI)
    - NC program is entered directly into the MCU at the site of the processing machine
  - NC programming using CAD/CAM
    - an interactive graphics system equipped with NC programming software is used to facilitate the part programming task
  - Computer-automated part programming
    - extends the notion of automating certain portions of the NC part programming procedure to its logical conclusion

NC Programming Using CAD/CAM

- CAD/CAM system
  - A computer interactive graphics system equipped with software to accomplish certain functions in design and mfg.
- Geometry definition using CAD/CAM
  - Has the capability to create/modify and retrieve/store the part geometric model
  - No need to recreate the geometry of the part during the NC programming procedure
- Tool path generation using CAD/CAM
  - Has tool libraries to identify the available tools in tool crib
  - Tool offset calculations are done automatically
  - Graphic display for the tool path selection and generation