CNC machines and Control Programming

History of CNC

1949-US Air Force asks MIT to develop a "numerically controlled" machine.

1952-Prototype NC machine demonstrated (punched tape input)

1980-CNC machines (computer used to link directly to controller)

1990-DNC: external computer “drip feeds” control programmer to machine tool controller

Advantages of CNC

- Easier to program;

- Easy storage of existing programs;

- Easy to change a program

- Avoids human errors

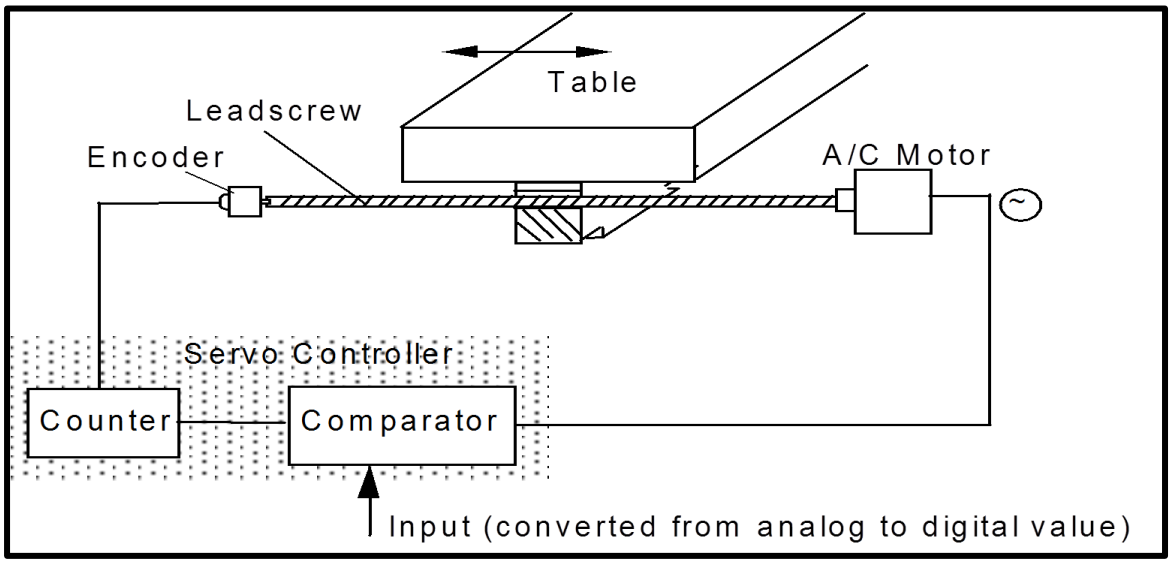
- NC machines are safer to operate

- Complex geometry is produced as cheaply as simple ones

- Usually generates closer tolerances than manual machines

NC machines

Motion control is done by: servo-controlled motors



CNC terminology

BLU: basic length unit ➔

smallest programmable move of each axis.

Controller: (Machine Control Unit, MCU) ➔

Electronic and computerized interface between operator and m/c

Controller components:

- Data Processing Unit (DPU)
  - Input device [RS-232 port/ Tape Reader/ Punched Tape Reader]
  - Data Reading Circuits and Parity Checking Circuits
  - Decoders to distribute data to the axes controllers.

2. Control-Loops Unit (CLU)

- Interpolator to supply machine-motion commands between data points
- Position control loop hardware for each axis of motion

Types of CNC machines

- *Based on Motion Type:*

  Point-to-Point or Continuous path

- *Based on Control Loops:*

  Open loop or Closed loop

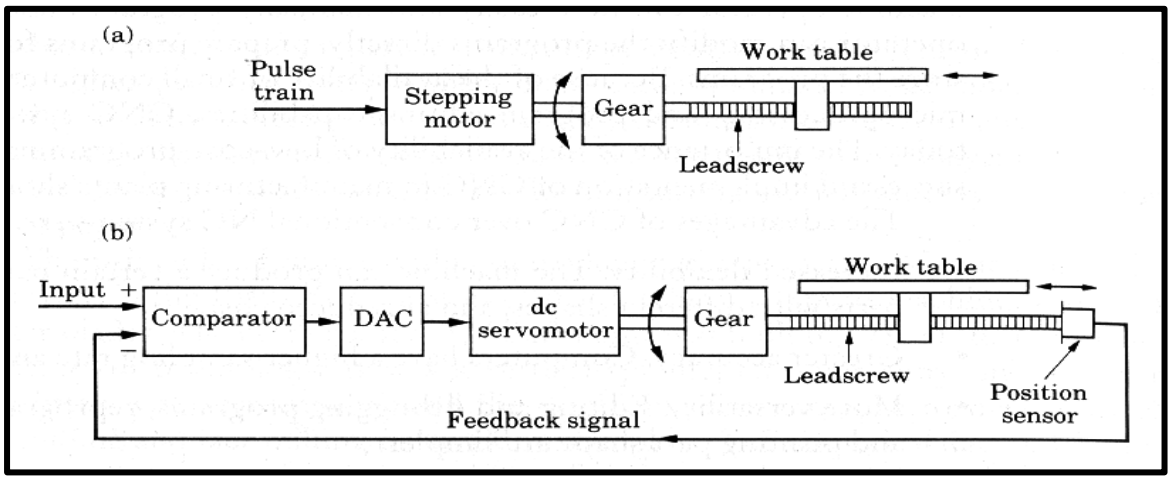
- *Based on Power Supply:*

  Electric or Hydraulic or Pneumatic

- *Based on Positioning System*

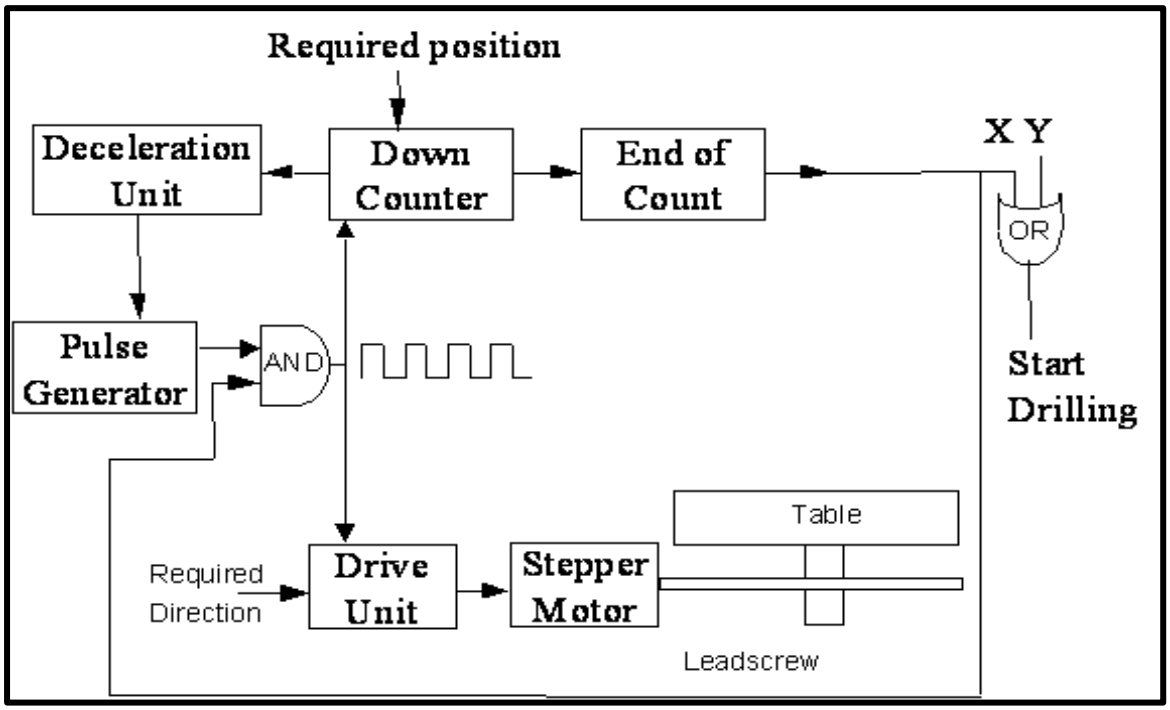
  Incremental or Absolute

Open Loop vs. Closed Loop controls

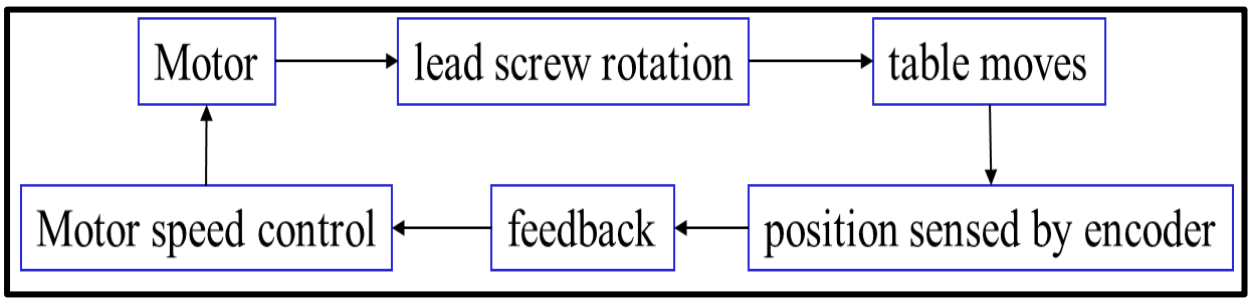


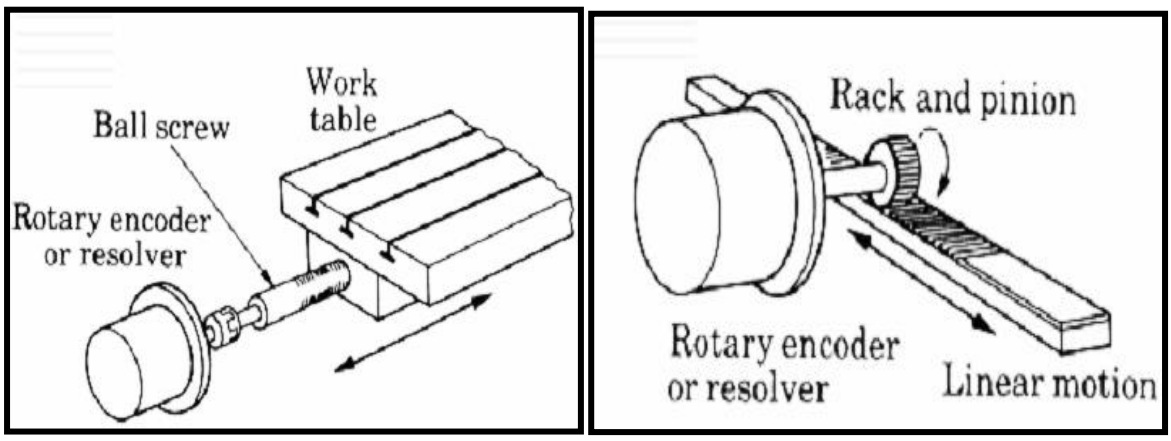
Open loop control of a Point-to-Point NC drilling machine

NOTE: this machine uses stepper motor control



Components





Two types of encoder configurations

Motion Control and feedback

Encoder outputs: electrical pulses (e.g. 500 pulses per revolution)

Rotation of the motor → linear motion of the table: by the **leadscrew**

The **pitch** of the leadscrew: horizontal distance between successive threads

One thread in a screw → single start screw: Dist moved in 1 rev = pitch

Two threads in screw → **double start screw**: Dist moved in 1 rev = 2* pitch

Example 1

A Stepping motor of 20 steps per revolution moves a machine table through a leadscrew of 0.2 mm pitch.

(a) What is the BLU of the system ?

(b) If the motor receives 2000 pulses per minute, what is the linear velocity in inch/min ?

Example 2

A DC servo-motor is coupled to a leadscrew (pitch 5mm) of a machine table. A digital encoder, which emits 500 pulses per revolution, is mounted on the leadscrew. If the motor rotates at 600 rpm, find

(a) The linear velocity of the table

(b) The BLU of the machine

(c) The frequency of pulses emitted by the encoder.

Manual NC programming

Part program: A computer program to specify

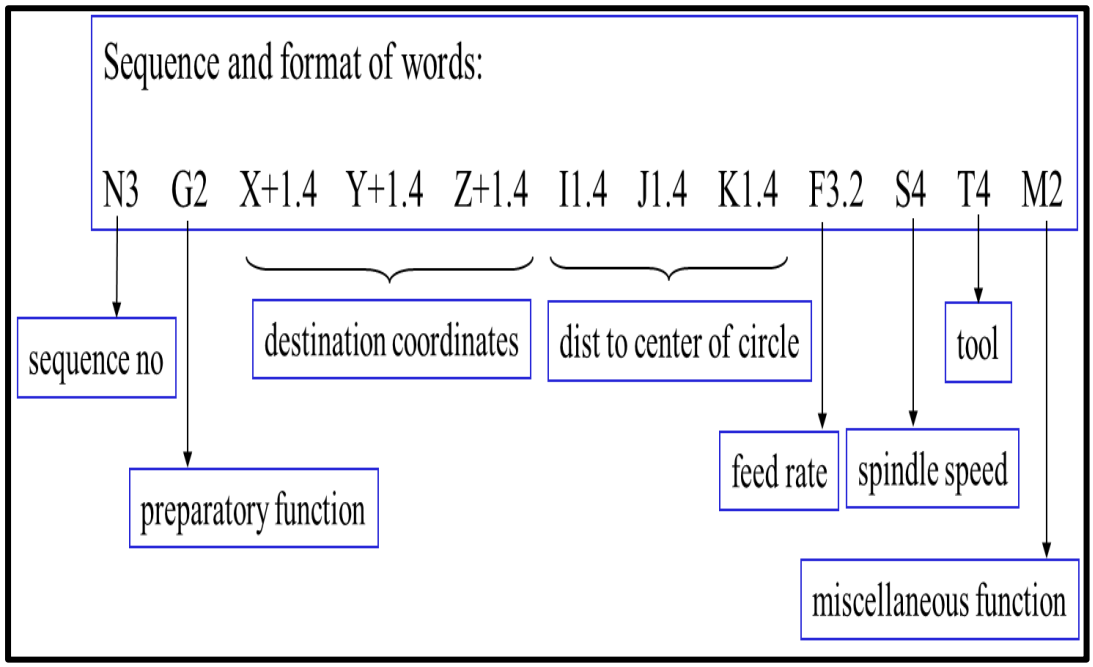
- Which tool should be loaded on the machine spindle;
- What are the cutting conditions (speed, feed, coolant ON/OFF etc)
- The start point and end point of a motion segment
- how to move the tool with respect to the machine.

History of CNC

The RS274-D is a **word address format**

Each line of program == 1 **block**

Each block is composed of several instructions, or (words)



Appendix I

RS274-D format: Alphabets and their meanings.

ALPHABET	ADDRESS FOR
A	Angular rotary table dimension around X axis
B	Angular rotary table dimension around Y axis
C	Angular rotary table dimension around Z axis
D	Angular dimension around special axis/ 3rd feed function/function for tool compensation
E	Angular dimension around special axis/2nd feed function/function for tool compensation
F	feed rate function
G	Preparatory function
I	Interpolation parameter for thread lead parallel to X axis
J	Interpolation parameter for thread lead parallel to Y axis
K	Interpolation parameter for thread lead parallel to Z axis
M	Miscellaneous function
N	Sequence number
O	Sequence number for secondary head (for dual machines, e.g Mill-Turn machine.)
P	Third rapid traverse dimension
Q	Second rapid traverse dimension
R	First rapid traverse dimension/radius for constant surface speed calculations
S	Spindle speed
T	Tool number function
U	Rotary table velocity Secondary motion dimension parallel to X axis
V	Rotary table velocity Secondary motion dimension parallel to Y axis
W	Rotary table velocity Secondary motion dimension parallel to Z axis
X	Primary X motion dimension
Y	Primary Y motion dimension
Z	Primary Z motion dimension
[EB]	This is the last character on each block, the End-of-Block character (usually the return, or newline character).

Appendix II
RS274-D: Useful Preparatory Functions

G00	Point to Point rapid positioning move	
G01	Linear Interpolation	Move in straight line at constant velocity
G02	Circular Interpolation, Arc CW (for 2D arcs in XY, XZ, or YZ planes)	Clockwise motion of tool with respect to workpiece, when viewing the plane of motion in -ve direction of the perpendicular axis
G03	Circular Interpolation, Arc CCW (for 2D arcs in XY, XZ, or YZ planes)	Counter-Clockwise motion of tool wrt w/p, when viewing the plane of motion in -ve direction of the perpendicular axis
G04	Dwell	a timed delay of programmed duration.
G06	Parabolic Interpolation	Programmed motion along a parabola; velocity of the axes is varied by the controller to maintain the feedrate as specified.
G08	Acceleration	Controlled velocity increase to programmed rate, starting immediately.
G09	Deceleration	Controlled velocity decrease to programmed rate.
G13-16	Axis Selection	
G17	XY plane selection for contouring	Used to identify plane for functions like circular interpolation, cutter compensation offset etc.
G18	XZ plane selection for contouring	
G19	YZ plane selection for contouring	
G28	Returning to zero position	
G33	Thread cutting, Constant lead	For machines equipped with thread cutting
G34	Thread cutting, Increasing lead	The lead increases at a constant rate (linear)
G35	Thread cutting, Decreasing lead	Decreases at constant rate (linear)
G40	Cutter compensation cancel, Offset cancel	
G41	Cutter compensation, Left	Cutter on left side of work surface, when viewing from cutter in the direction of relative cutter motion with displacement normal to the cutter path to adjust for the difference between actual and programmed cutter radii or diameters
G42	Cutter compensation, Right	As above..
G43	Cutter offset, inside corner	Displacement normal to cutter path to adjust for the difference between actual and programmed cutter radii or diameters. Cutter on inside corner.
G44	Cutter offset, outside corner	As above
G50-59	Reserved for adaptive control	
G70	programming units in inches	Will get cancelled by use of G71, M02, or M30
G71	programming units in metric	Will get cancelled by use of G70, M02, or M30
G72	3D Circular interpolation, CW	A mode where the cutter moves along a circular arc on the surface of a sphere. Velocities required to maintain feedrate are generated by the controller.
G73	3D Circular interpolation, CCW	
G74	Cancel multi-quadrant circular interpolation	
G75	Multi-quadrant circular interpolation	
G80	Cancel fixed cycle (Repeat of the previous block)	
G82	Circle operation	
G83	Drilling operation	
G84	Square or rectangular operatio operation	

G85-89 Fixed cycles, Number 1, 2, .., 9

G90	Absolute dimension inputs	Input data is in absolute coordinates
G91	Incremental dimension inputs	Input data is in form of incremental form, with respect to current position

G92 Preload registers- set current tool position (affects only the block in which it appears.)

G93 Inverse Time Feedrate (V/D)
G94 Inches/mm per minute feedrate [Inches used if G70 was used earlier, mm if G71]
G95 Inches/mm per spindle revolution feedrate
G96 Constant surface speed, feet/meters per minute
G97 Revolutions per minute (spindle speed)

Appendix III
RS274-D: Useful Miscellaneous Functions

M00	Program temporary stop	used in the last block of a program
M01	Optional (planned) stop	
M02	End of program	stops coolant, spindle, feedrate; resets the control/machine
M03	Spindle CW	will advance a right handed screw into workpiece.
M04	Spindle CCW	
M05	Spindle stop	
M06	Tool change	
M07	Coolant No. 2 ON	Mist coolant
M08	Coolant No. 1 ON	Flood coolant
M09	Coolant stop	
M10	Clamp (vacuum start)	
M11	Unclamp(vacuum stop)	
M12	Synchronization code	
M13	Spindle CW and Coolant ON	
M14	Spindle CCW and Coolant ON	
M15	Motion +	
M16	Motion -	
M19	Oriented spindle stop	
M25	Rapid traverse to home position	
M30	End of data	
M31	Interlock bypass	
M39	Chuck	
M40	Chuck	

M41-46 Gear changes, if assigned; otherwise unused.

M47 Return to program start
M48 Cancel M49
M49 Bypass override

M58 Cancel M59
M59 Bypass CSS updating a function which holds RPM constant at its value.

M90-98 reserved for user-defined controls

M99 Restart part program from the begining