NC and CNC machines and Control Programming

Introduction to NC and CNC machines

CNC controls and RS274 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

Motivation and uses

To manufacture complex curved geometries in 2D or 3D was extremely expensive by mechanical means (which usually would require complex jigs to control the cutter motions)

Machining components with repeatable accuracy

Unmanned machining operations

Advantages of CNC

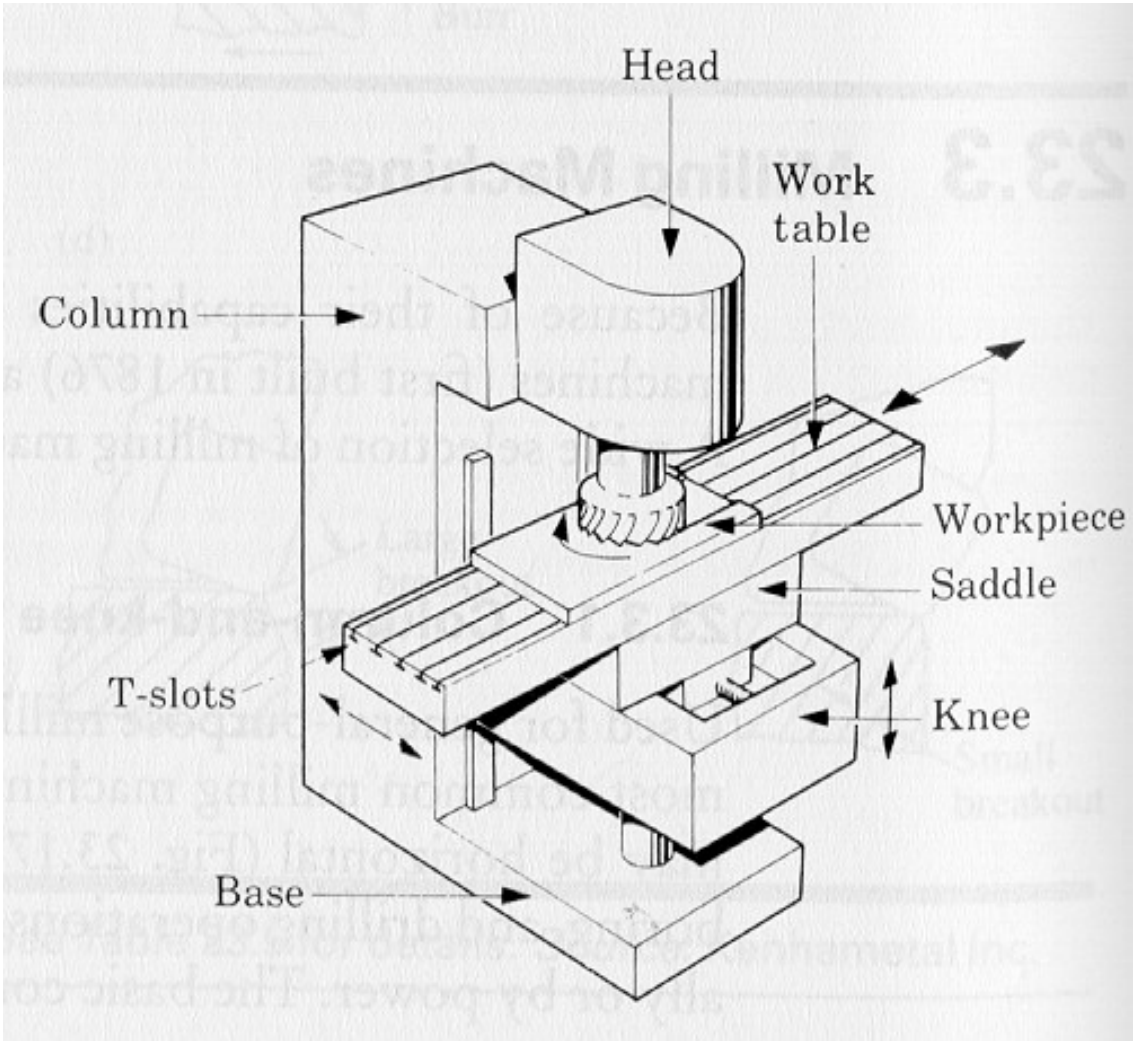
- Easier to program;
- Easy storage of existing programs;
- Easy to change a program
- Avoids human errors
- NC machines are safer to operate
- Complex geometry is produced as cheaply as simple ones
- Usually generates closer tolerances than manual machines

Conventional milling machines

Vertical milling machine

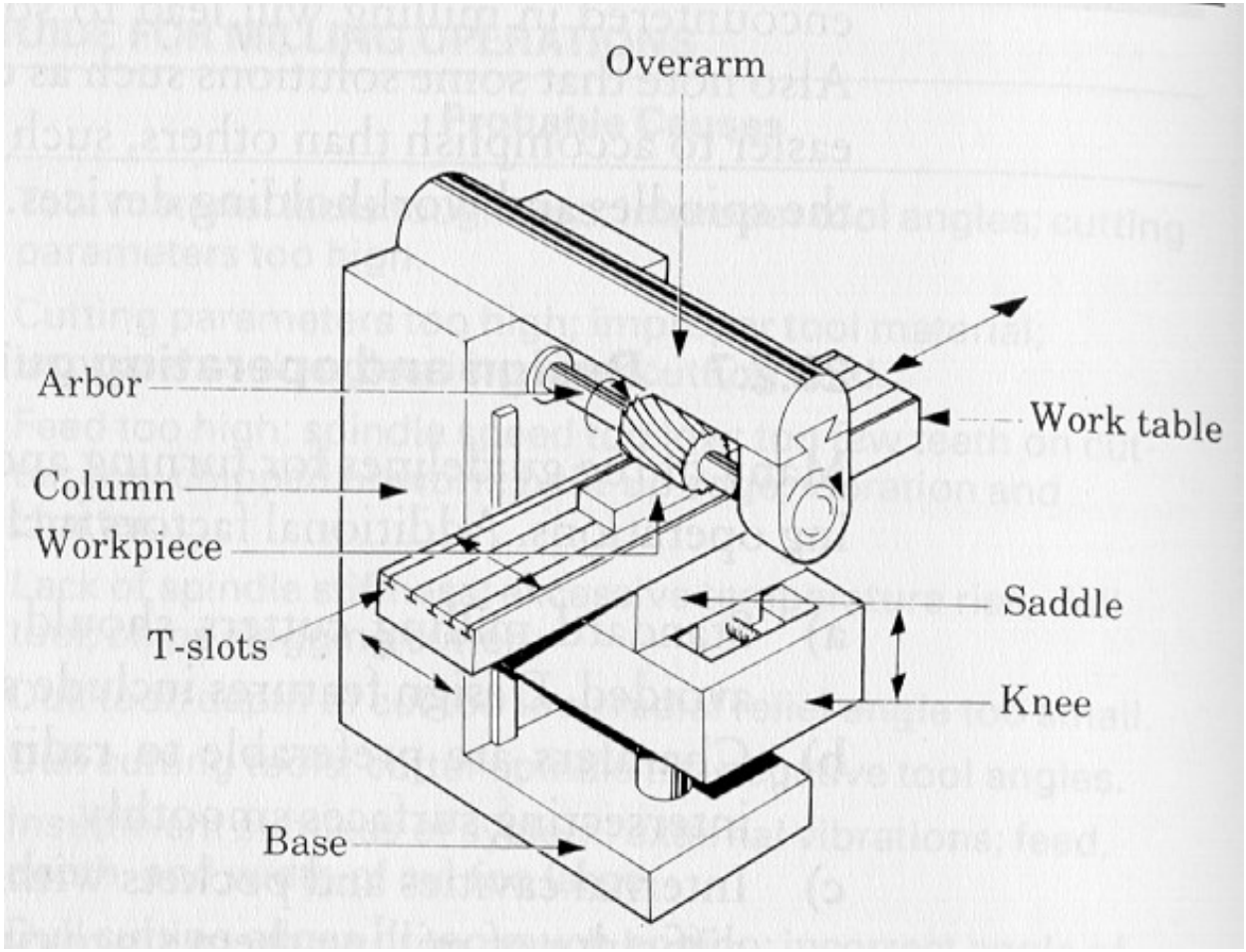
Conventional milling machines

Vertical Milling machine architecture



Conventional milling machines

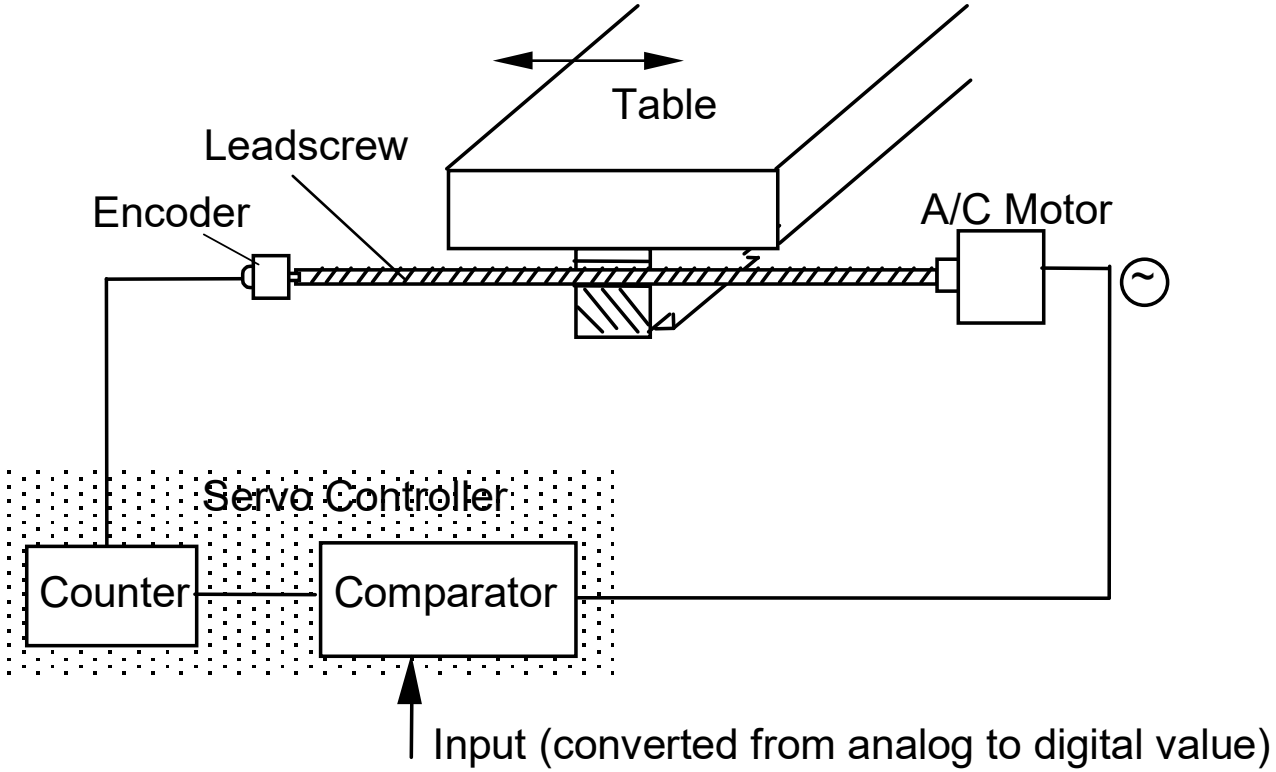
Horizontal Milling machine architecture



How does the table move along X- Y- and Z- axes ?

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:

1. Data Processing Unit (DPU)
2. Control-Loops Unit (CLU)

Controller components

Data Processing Unit:

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.

Control Loops Unit:

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

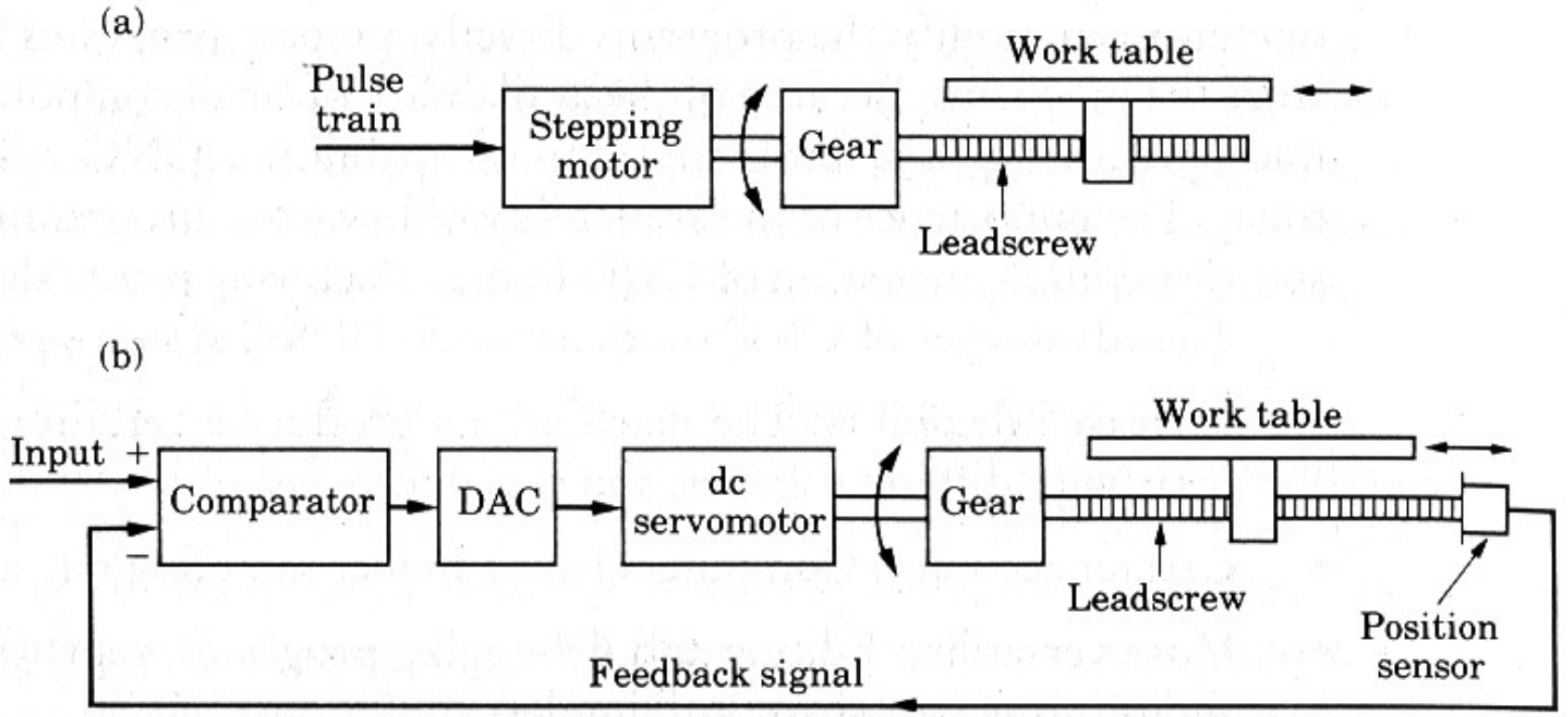
Based on Power Supply:

Electric or Hydraulic or Pneumatic

Based on Positioning System

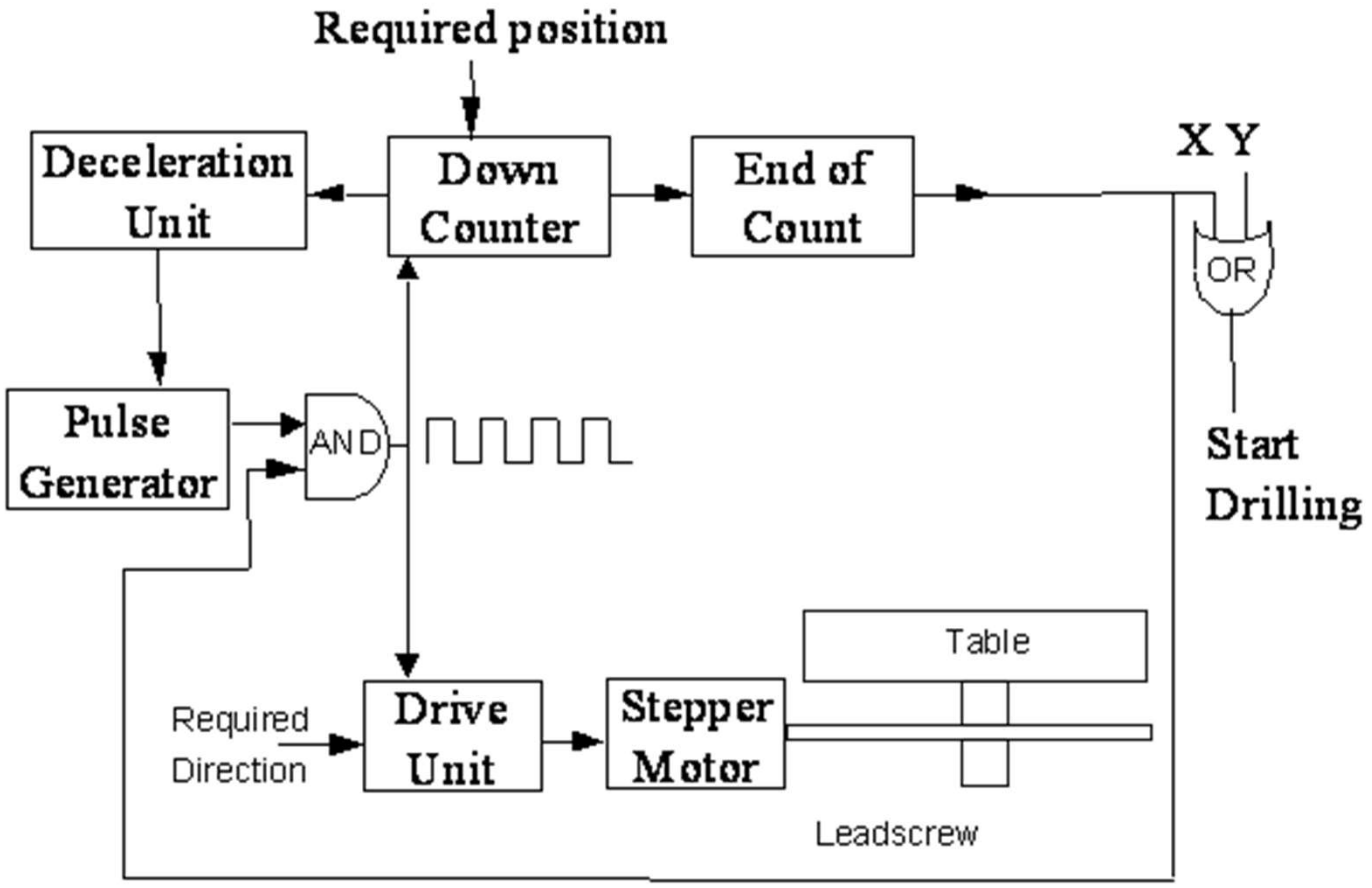
Incremental or Absolute

Open Loop vs. Closed Loop controls

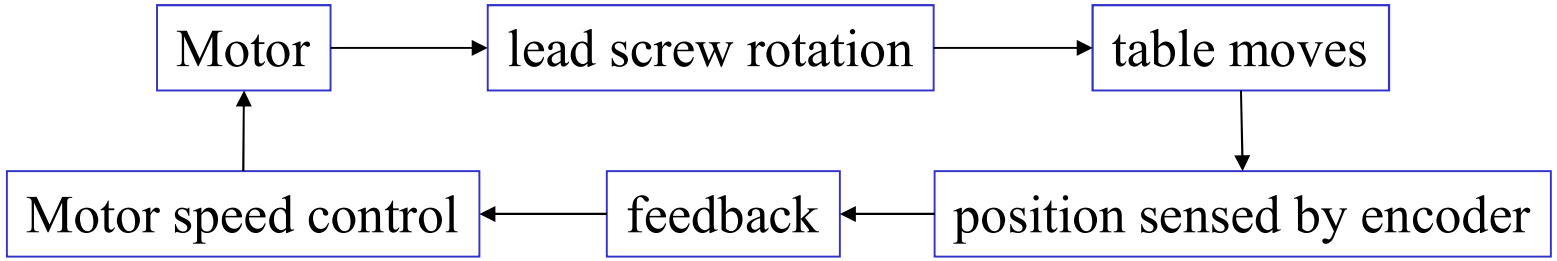


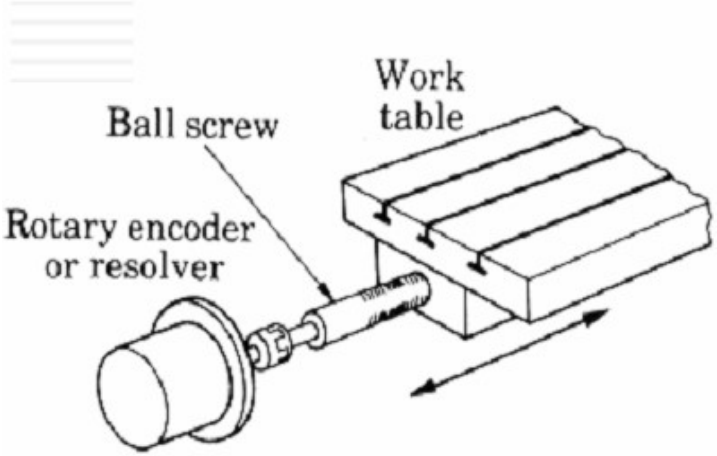
Open loop control of a Point-to-Point NC drilling machine

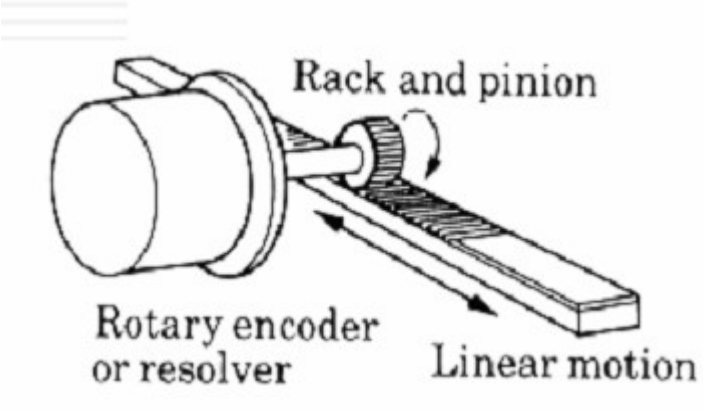
NOTE: this machine uses stepper motor control



Components of Servo-motor controlled CNC







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.

Standard Part programming language: RS 274-D (Gerber, GN-code)

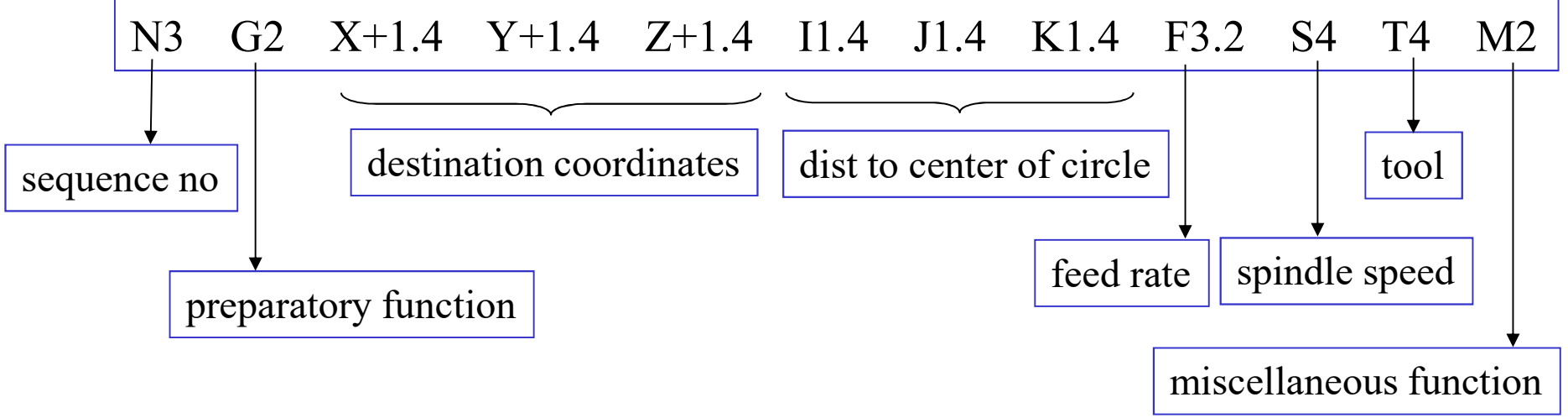
History of CNC

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

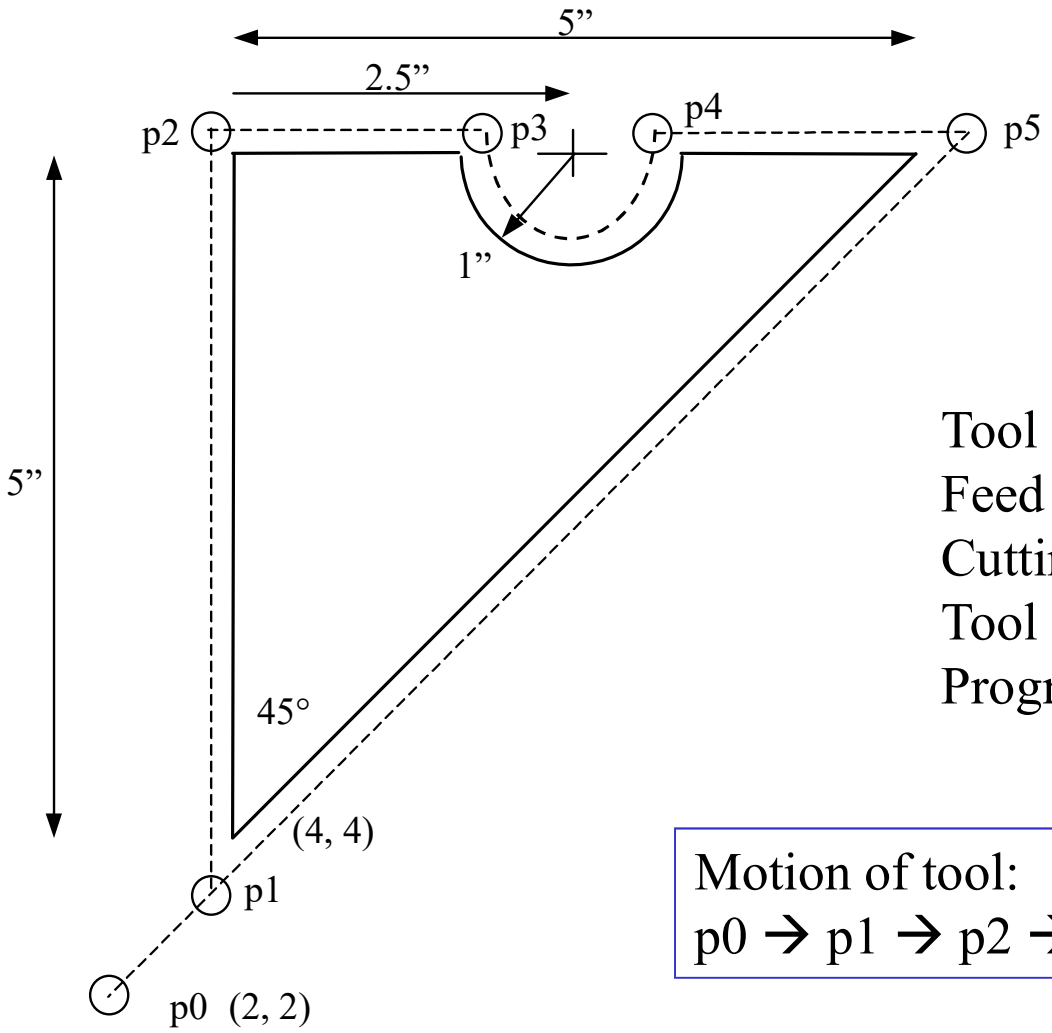
Each line of program == 1 **block**

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

Sequence and format of words:



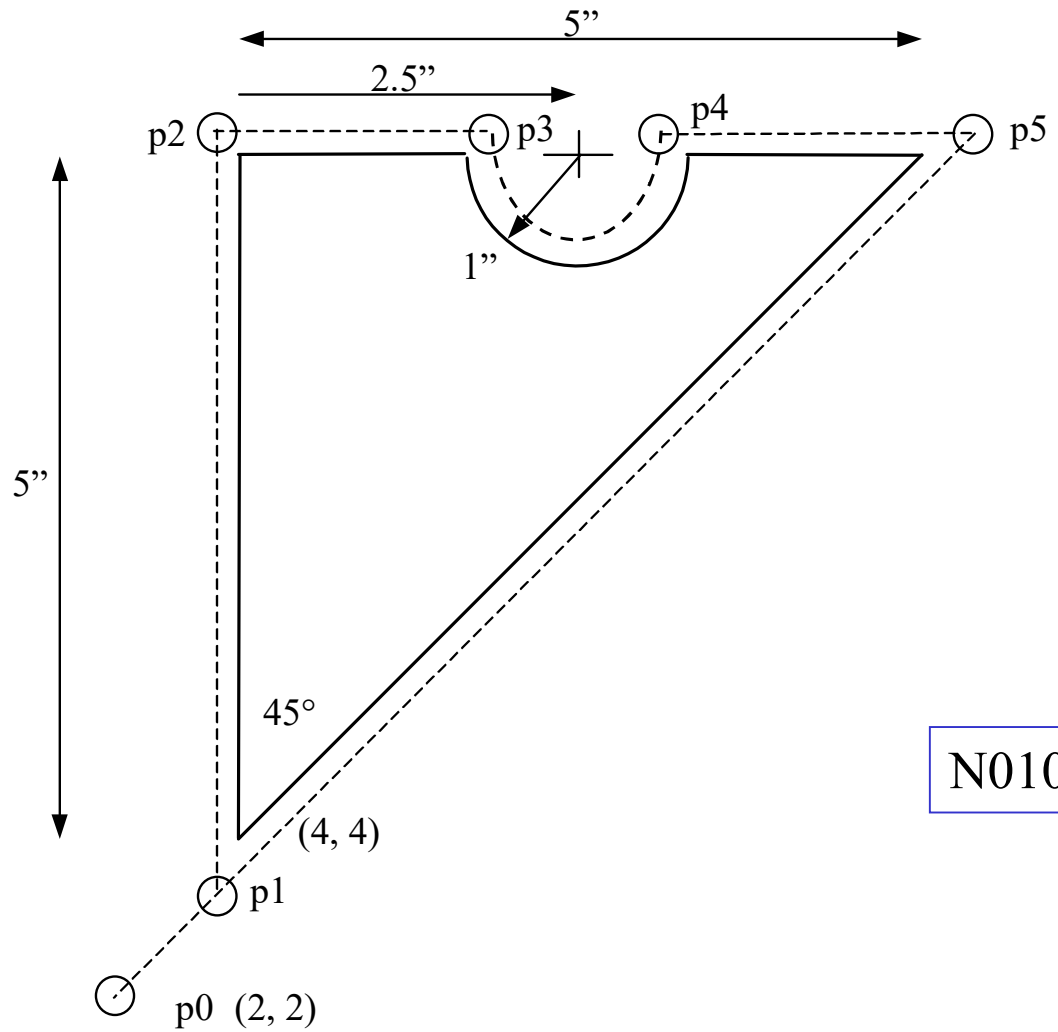
Manual Part Programming Example



Tool size = 0.25 inch,
Feed rate = 6 inch per minute,
Cutting speed = 300 rpm,
Tool start position: 2.0, 2.0
Programming in inches

Motion of tool:
p0 → p1 → p2 → p3 → p4 → p5 → p1 → p0

1. Set up the programming parameters



Programming in inches

Use absolute coordinates

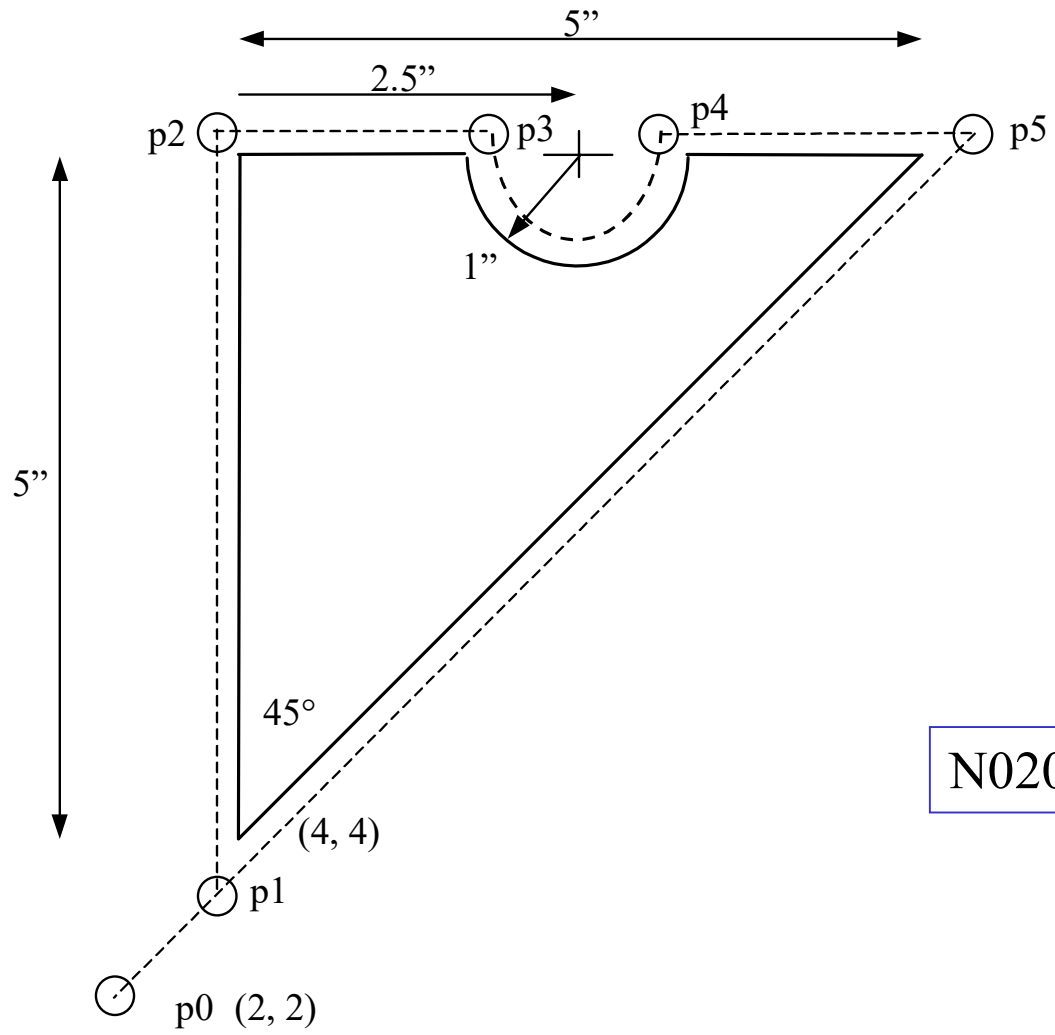
Feed in ipm

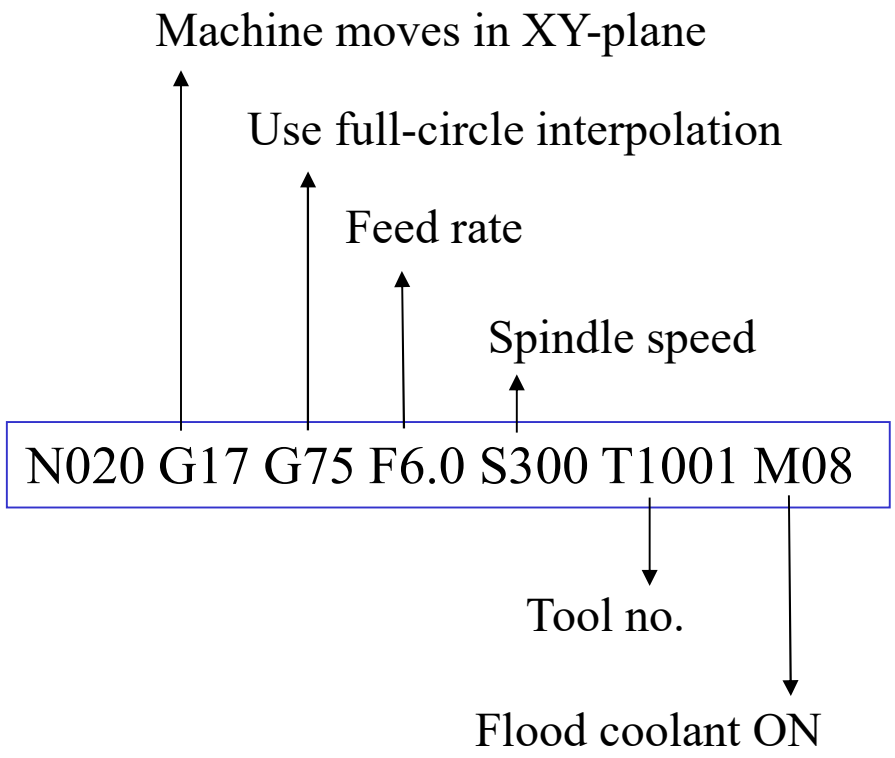
N010 G70 G90 G94 G97 M04

Spindle speed in rpm

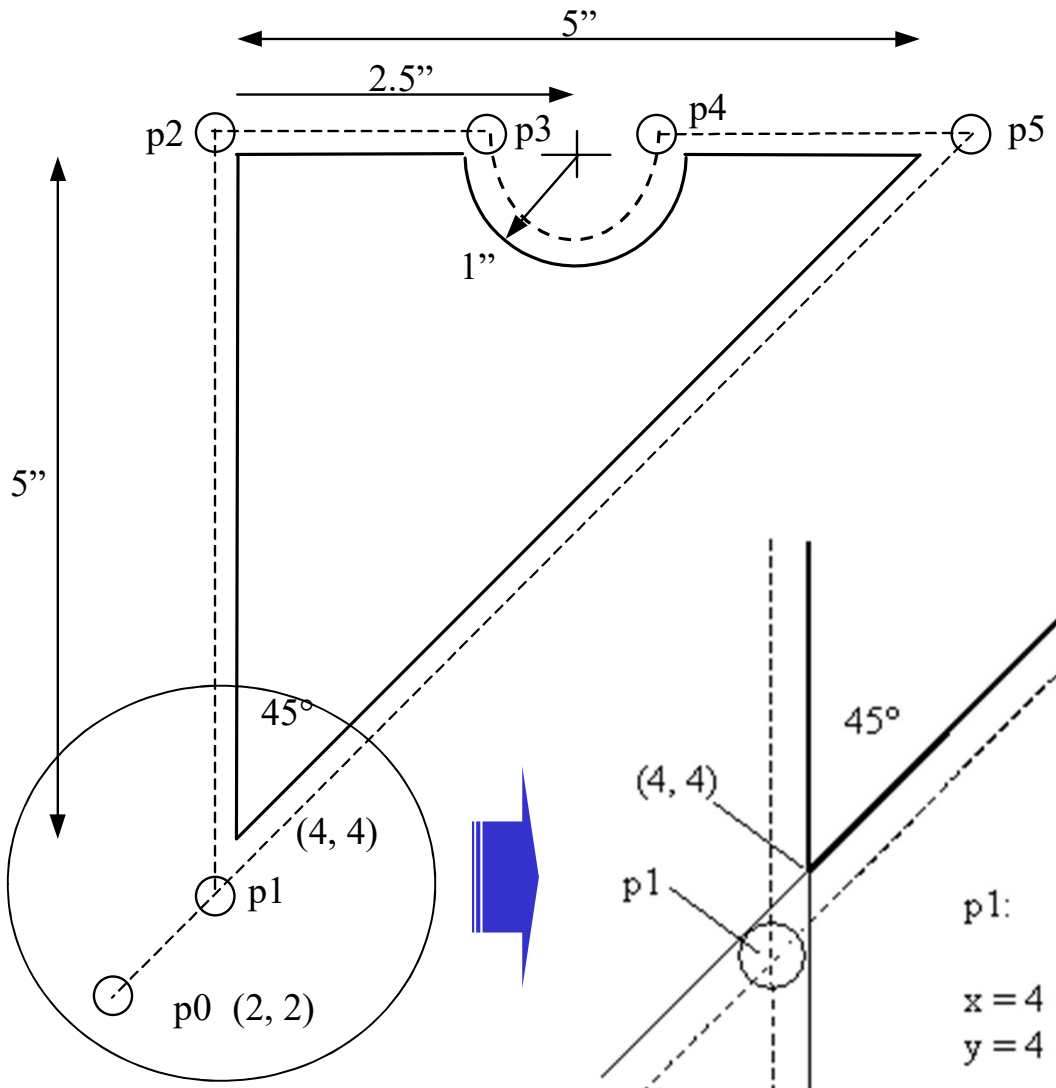
Spindle CCW

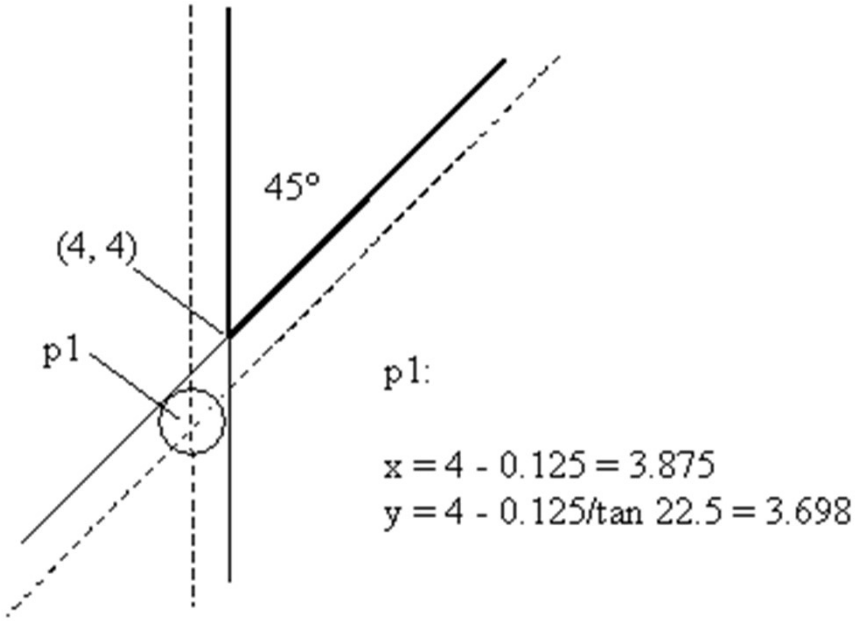
2. Set up the machining conditions





3. Move tool from p0 to p1 in straight line



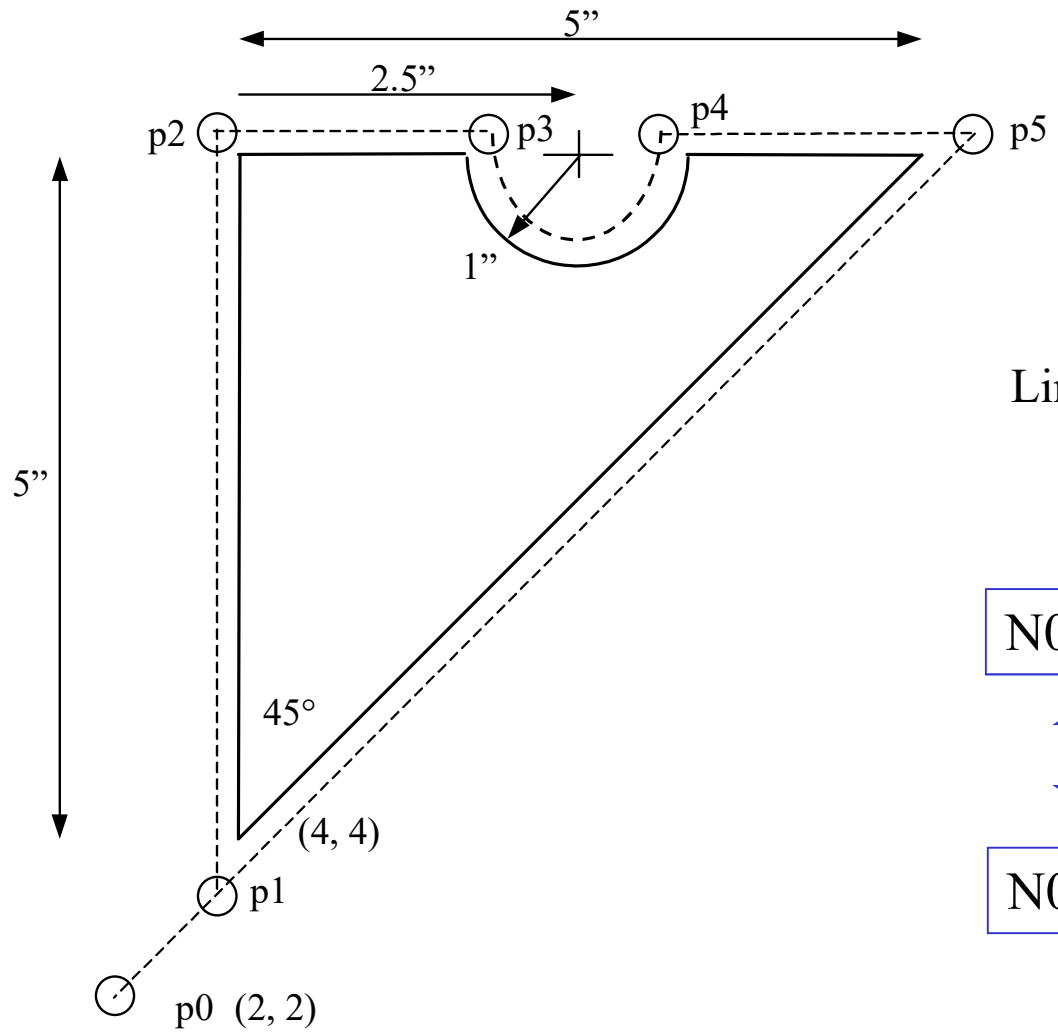


Linear interpolation

target coordinates

N030 G01 X3.875 Y3.698

4. Cut profile from p1 to p2



Linear interpolation

target coordinates

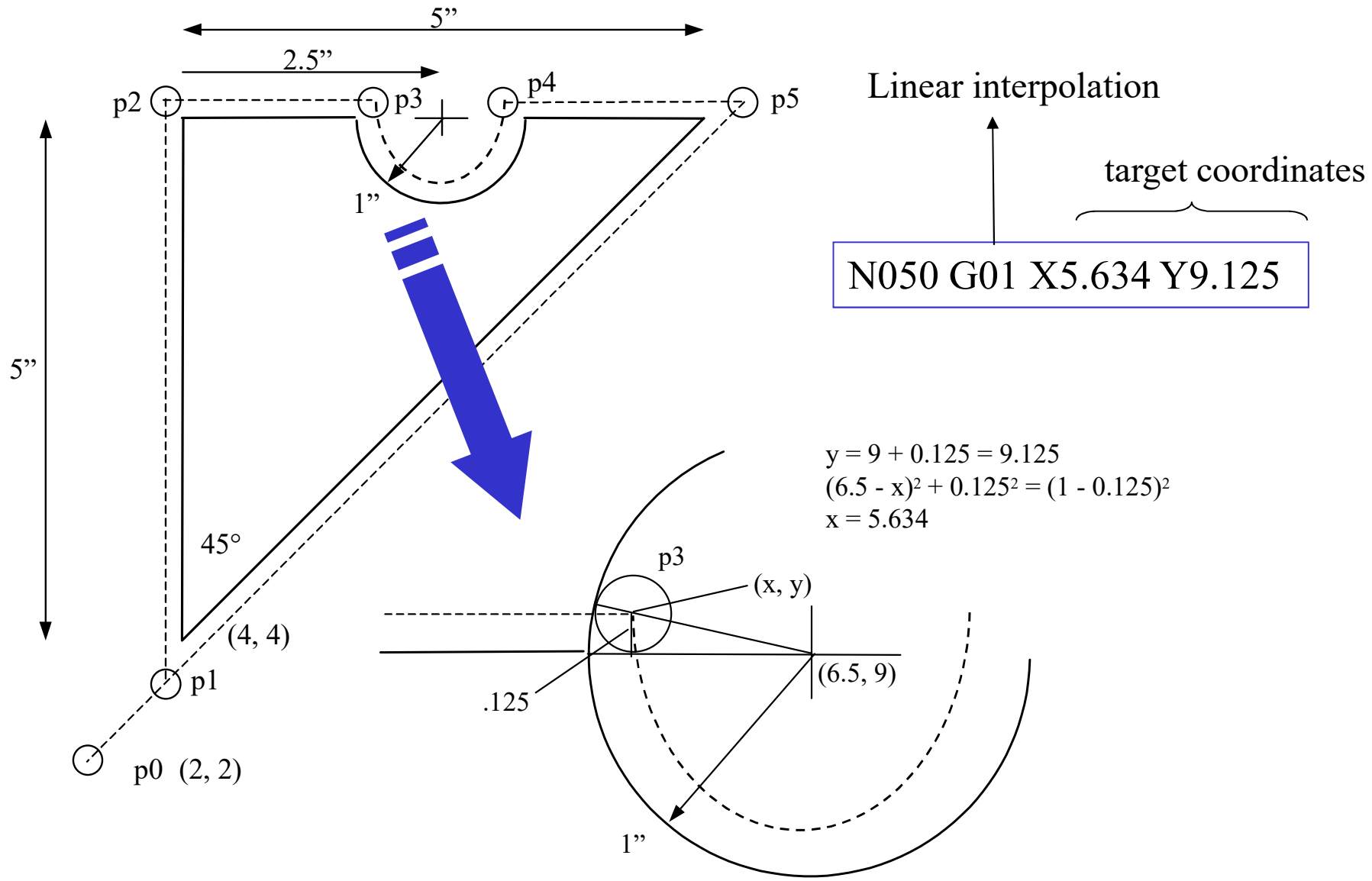
N040 G01 X3.875 Y9.125

or

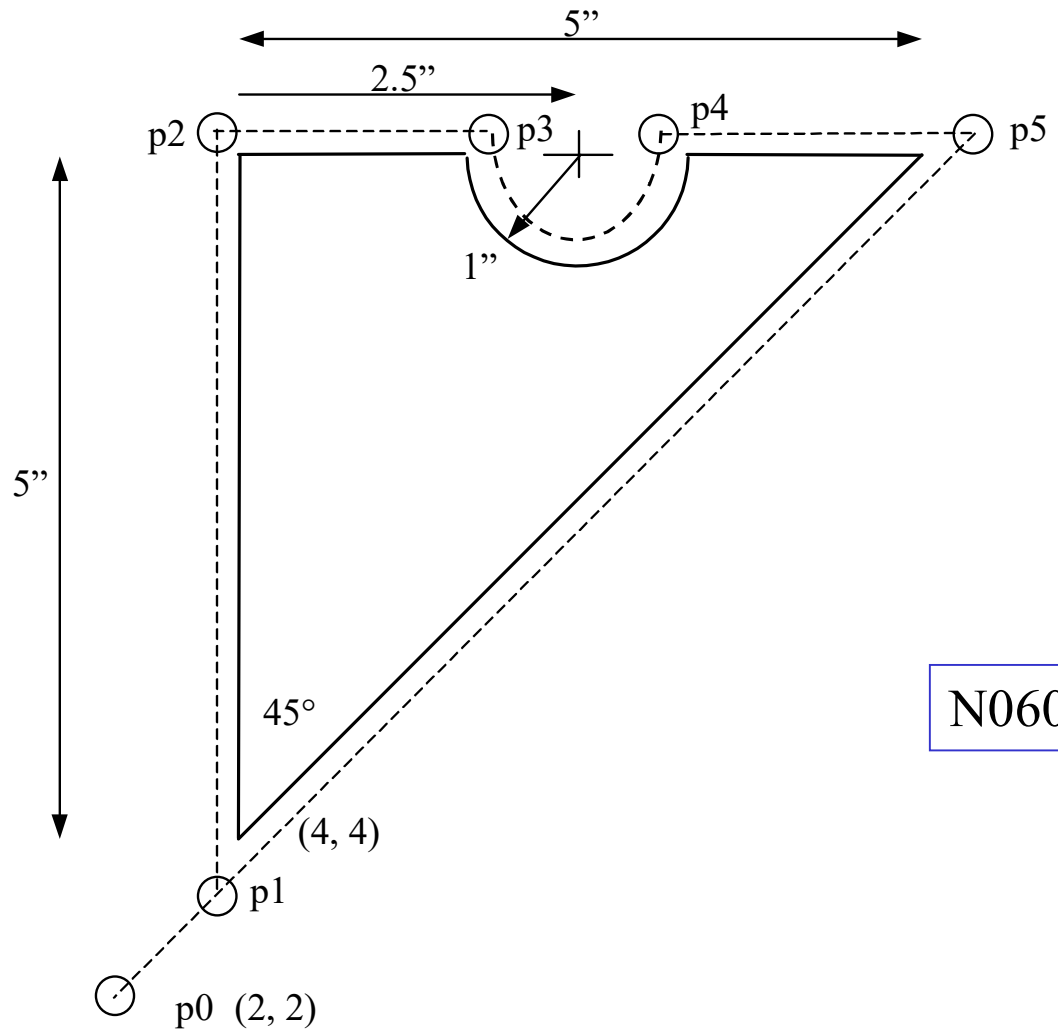
N040 G01 Y9.125

X-coordinate does not change ➔ no need to program it

5. Cut profile from p2 to p3



6. Cut along circle from p3 to p4



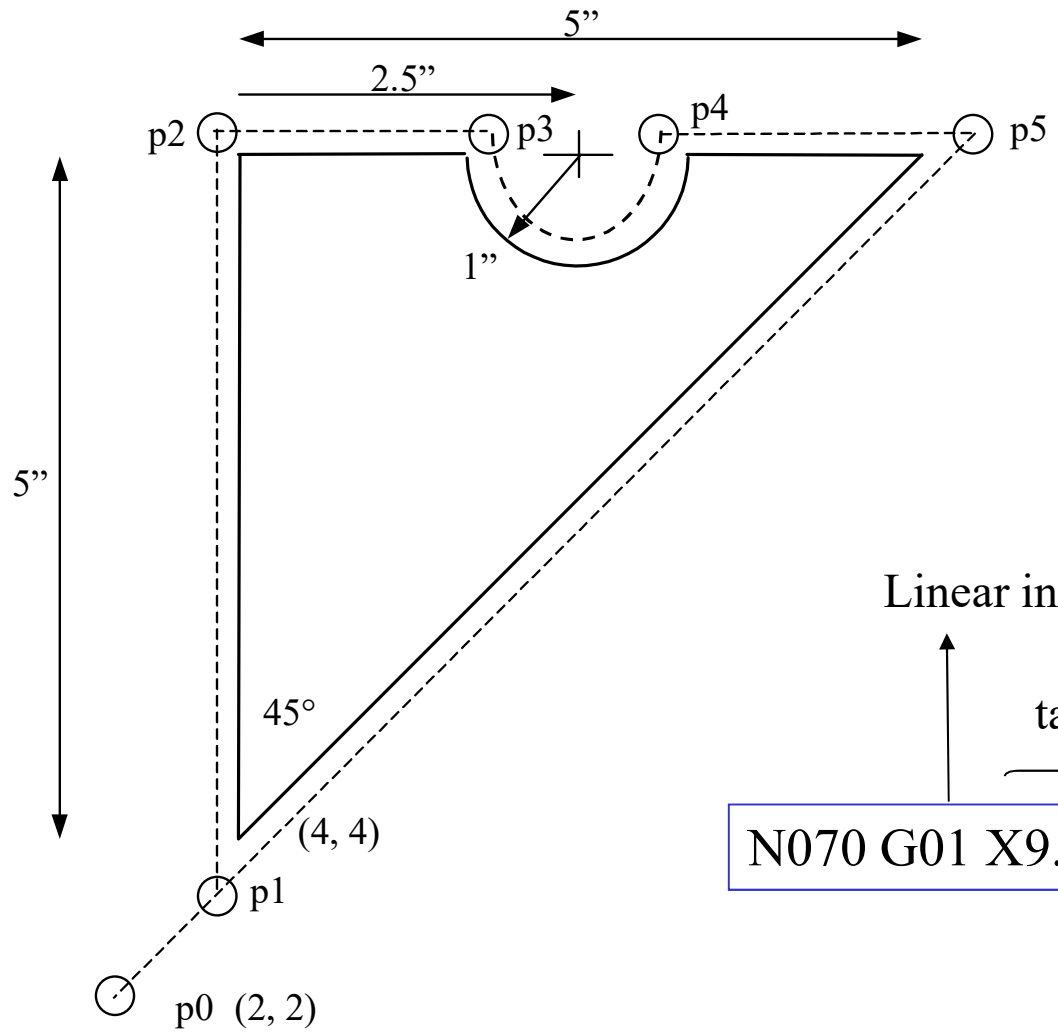
circular interpolation, CCW motion

target coordinates

N060 G03 X7.366 Y9.125 I6.5 J9.0

coordinates of center of circle

7. Cut from p4 to p5

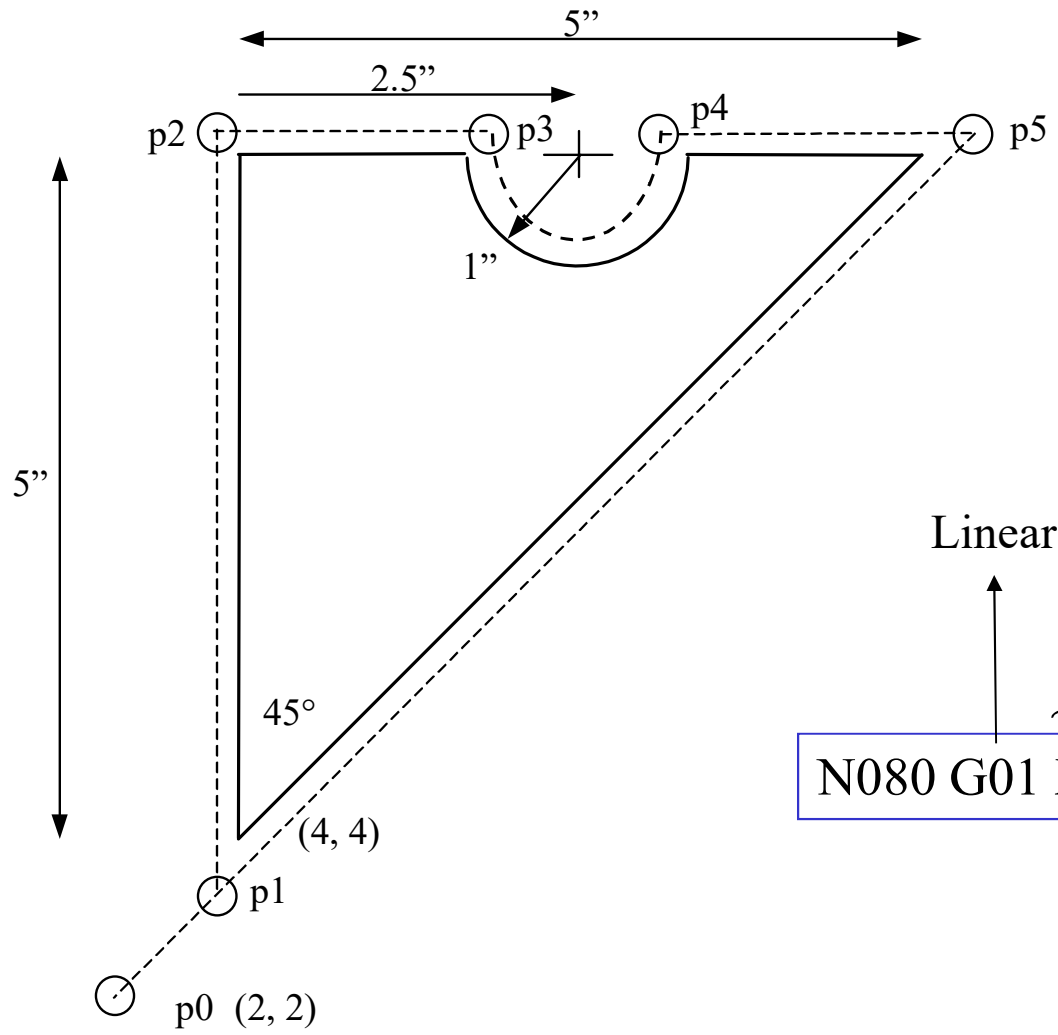


Linear interpolation

target coordinates (Y is unchanged)

N070 G01 X9.302

8. Cut from p5 to p1

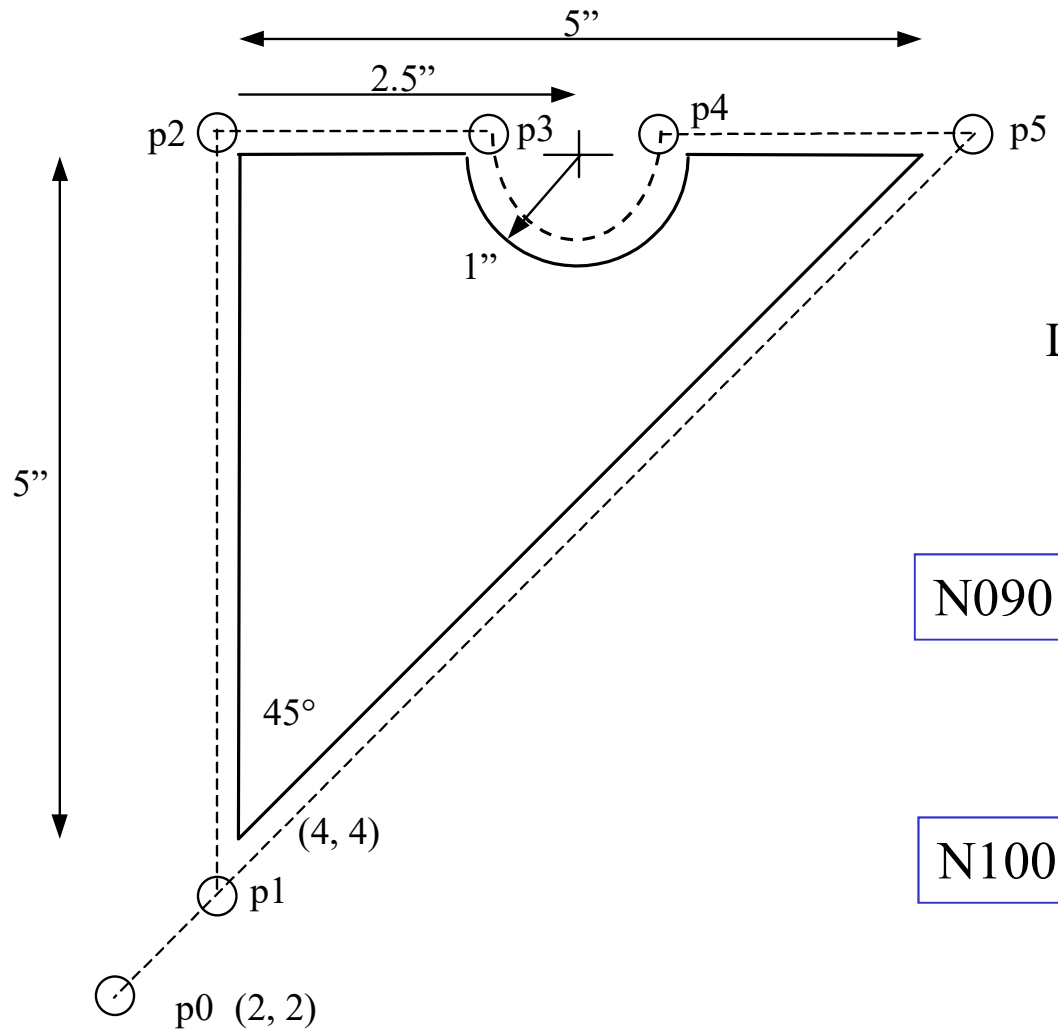


Linear interpolation

target coordinates (see step 3)

N080 G01 X3.875 Y3.698

9. Return to home position, stop program



Linear interpolation

target coordinates (see step 3)

N090 G01 X2.0 Y2.0 M30

end of data

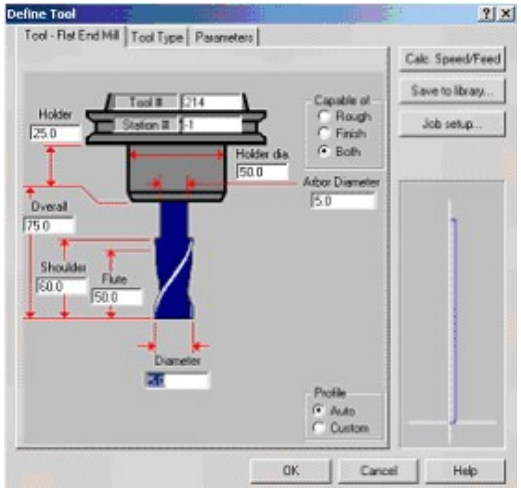
N100 M00

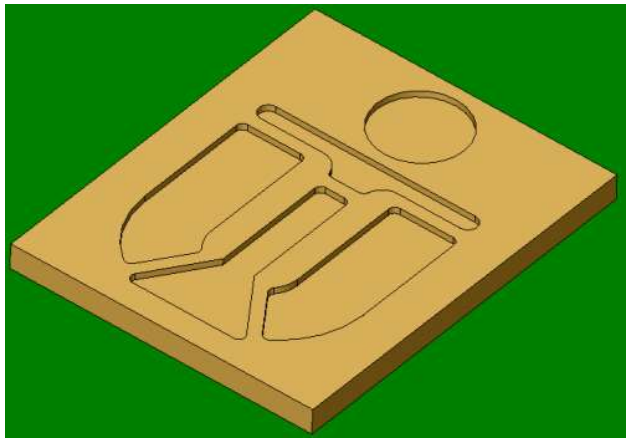
program stop

Automatic Part Programming

Software programs can automatic generation of CNC data

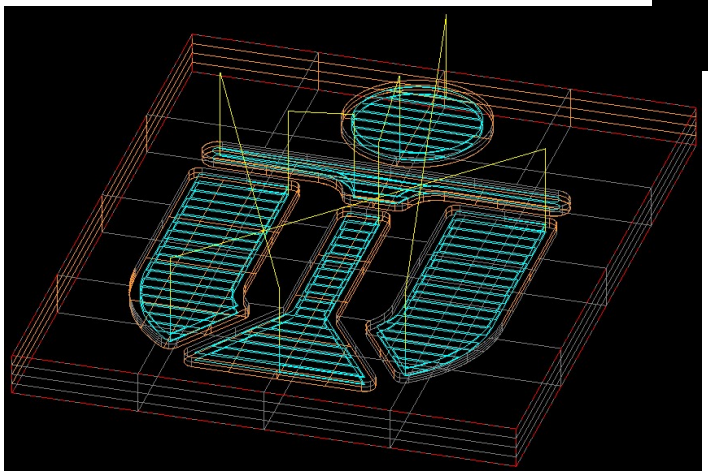
Define Tool

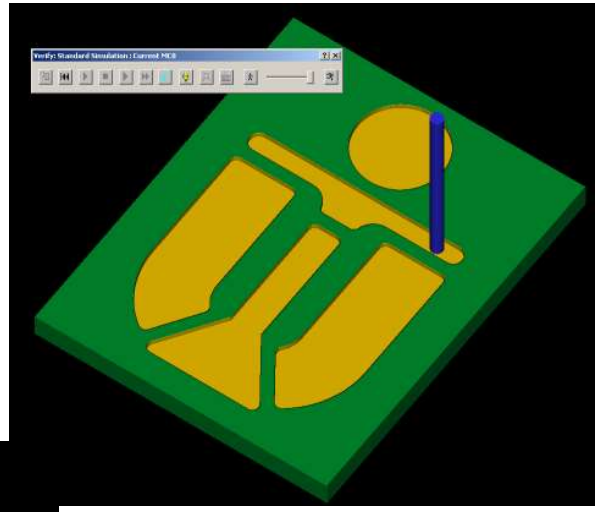




Make 3D model

CNC data





Simulate cutting

Automatic part programming and DNC

Very complex part shapes ➔ very large NC program

NC controller memory may not handle HUGE part program