NC and CNC machines and Control Programming

Introduction to NC and CNC machines

CNC controls and RS274 programming

Motivation

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

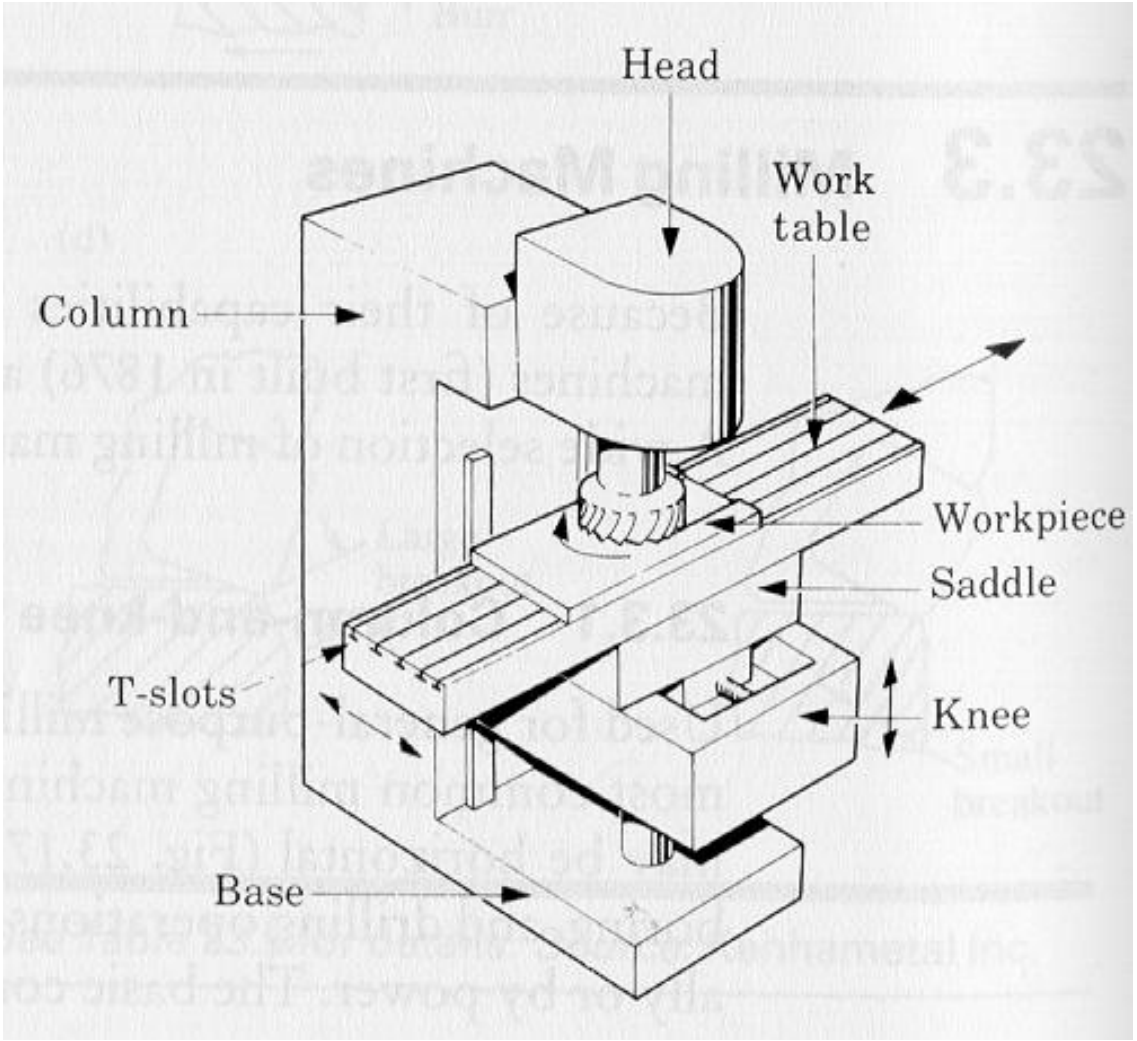
Unmanned machining operations

Conventional milling machines

Vertical milling machine

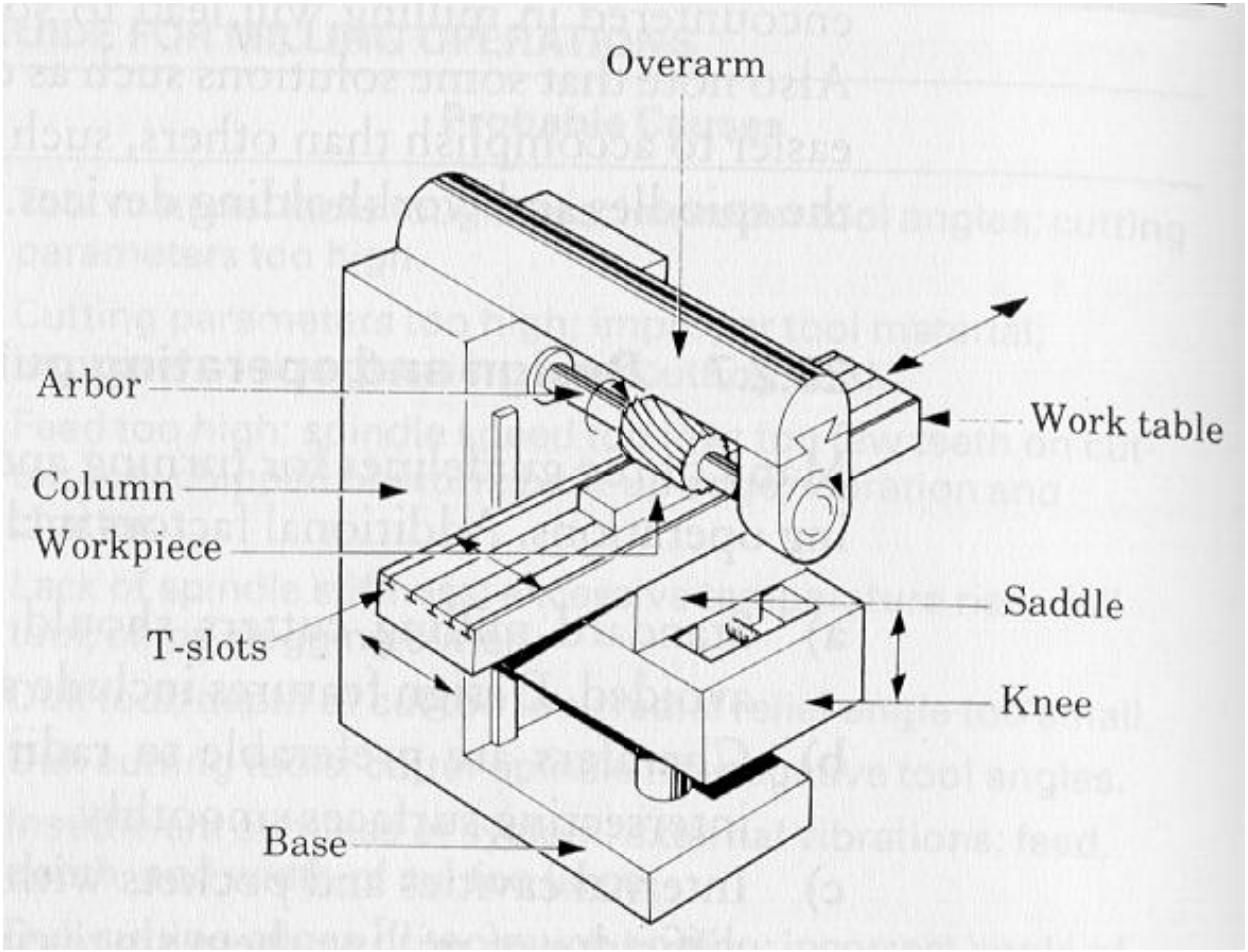
Conventional milling machines

Vertical Milling machine architecture



Conventional milling machines

Horizontal Milling machine architecture



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

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)

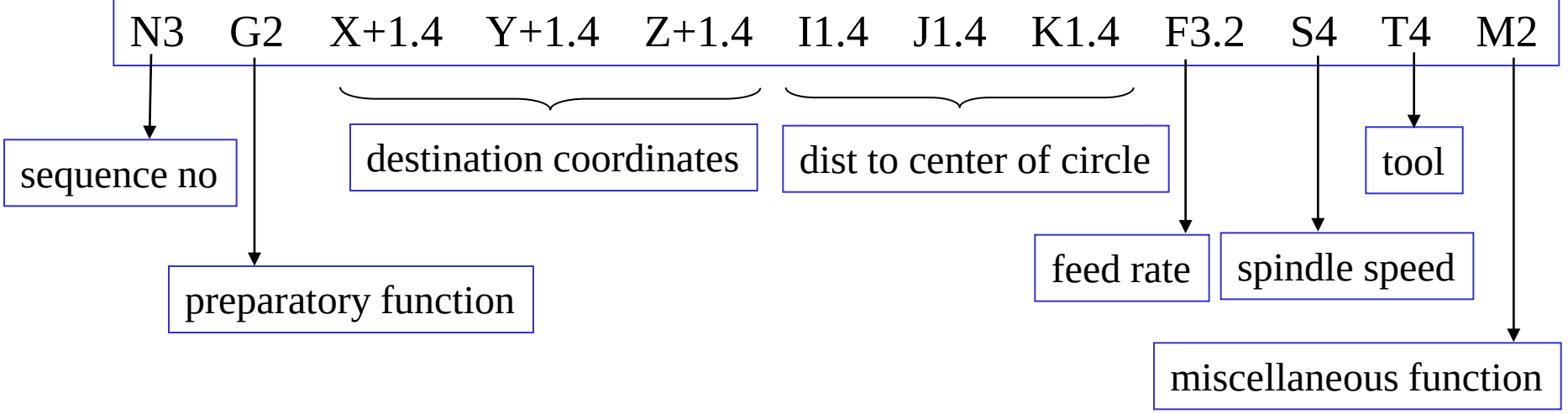
Controlling a CNC machine: RS 274

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

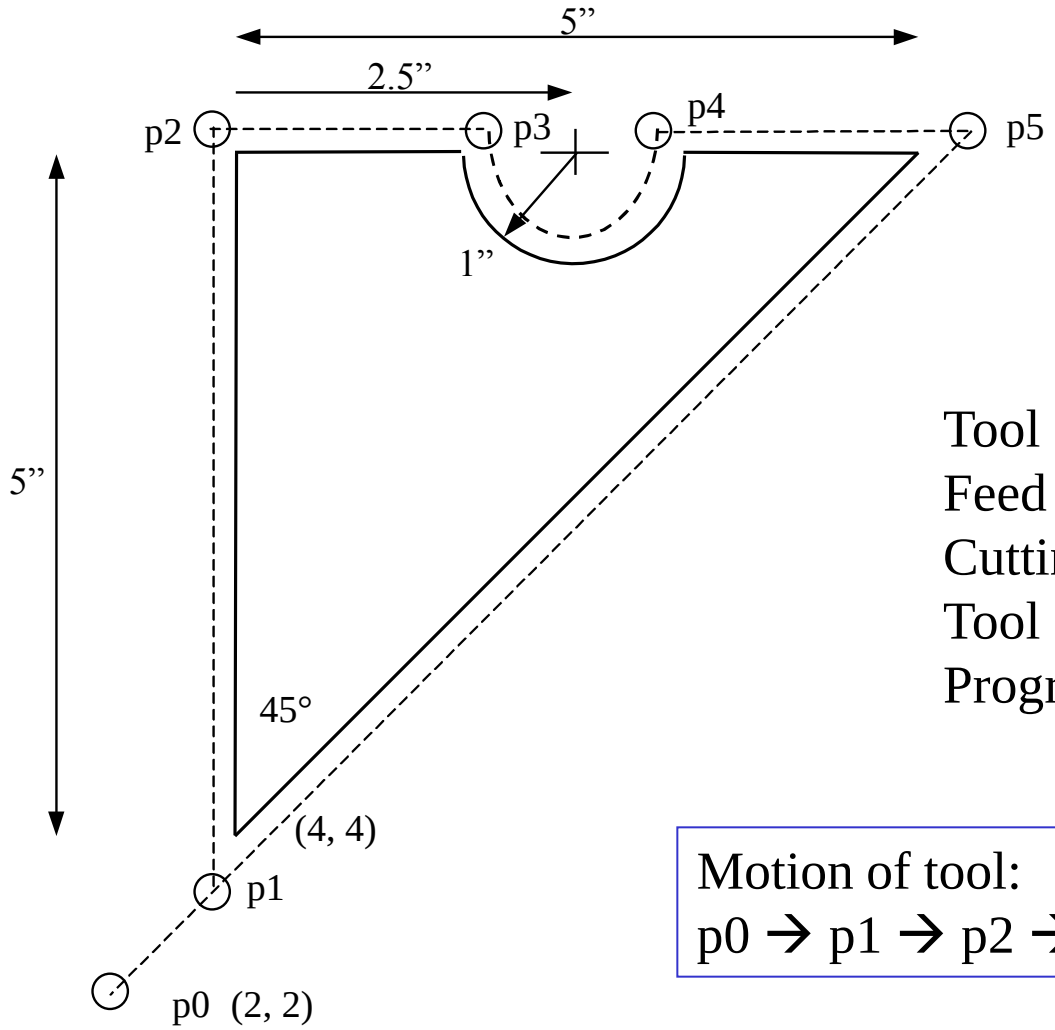
Each line of program == 1 **block**

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

Sequence and format of words:



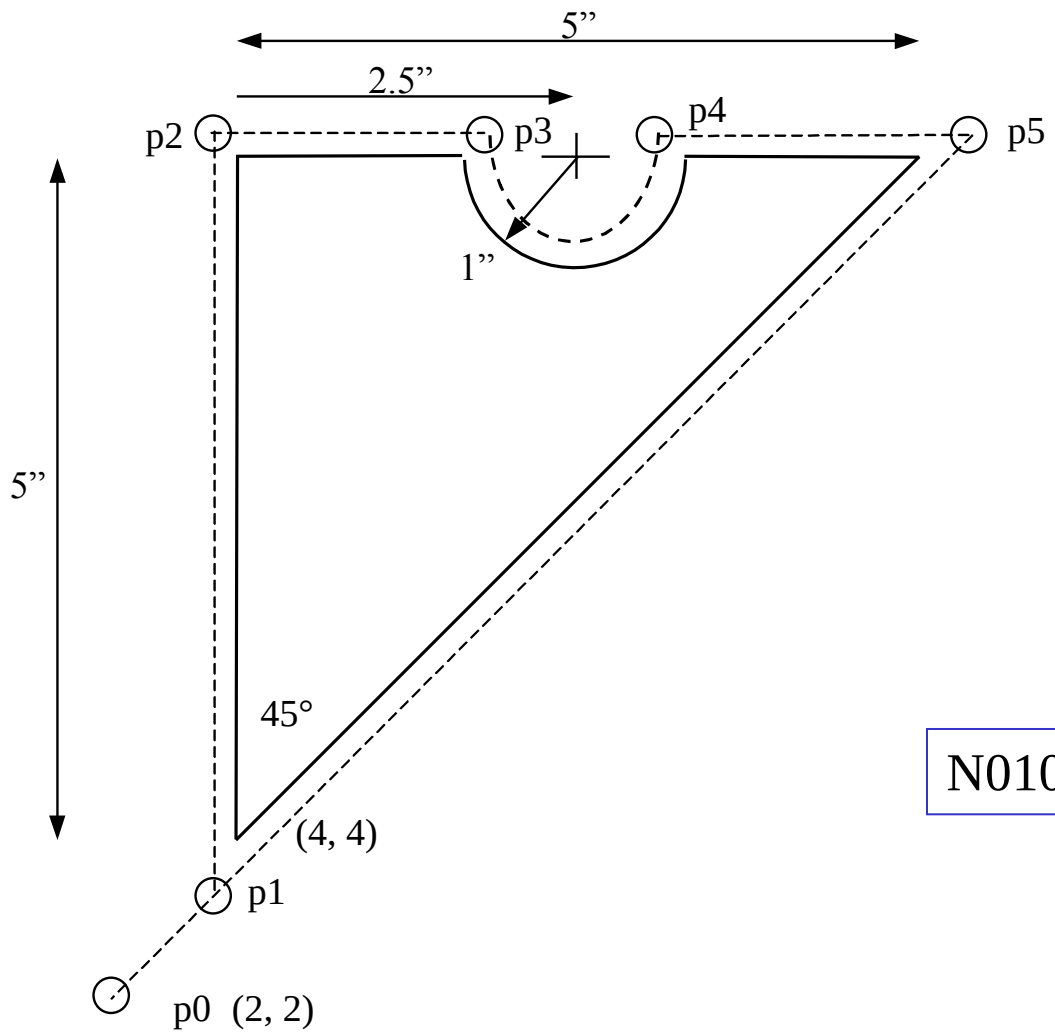
Manual Part Programming Example



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

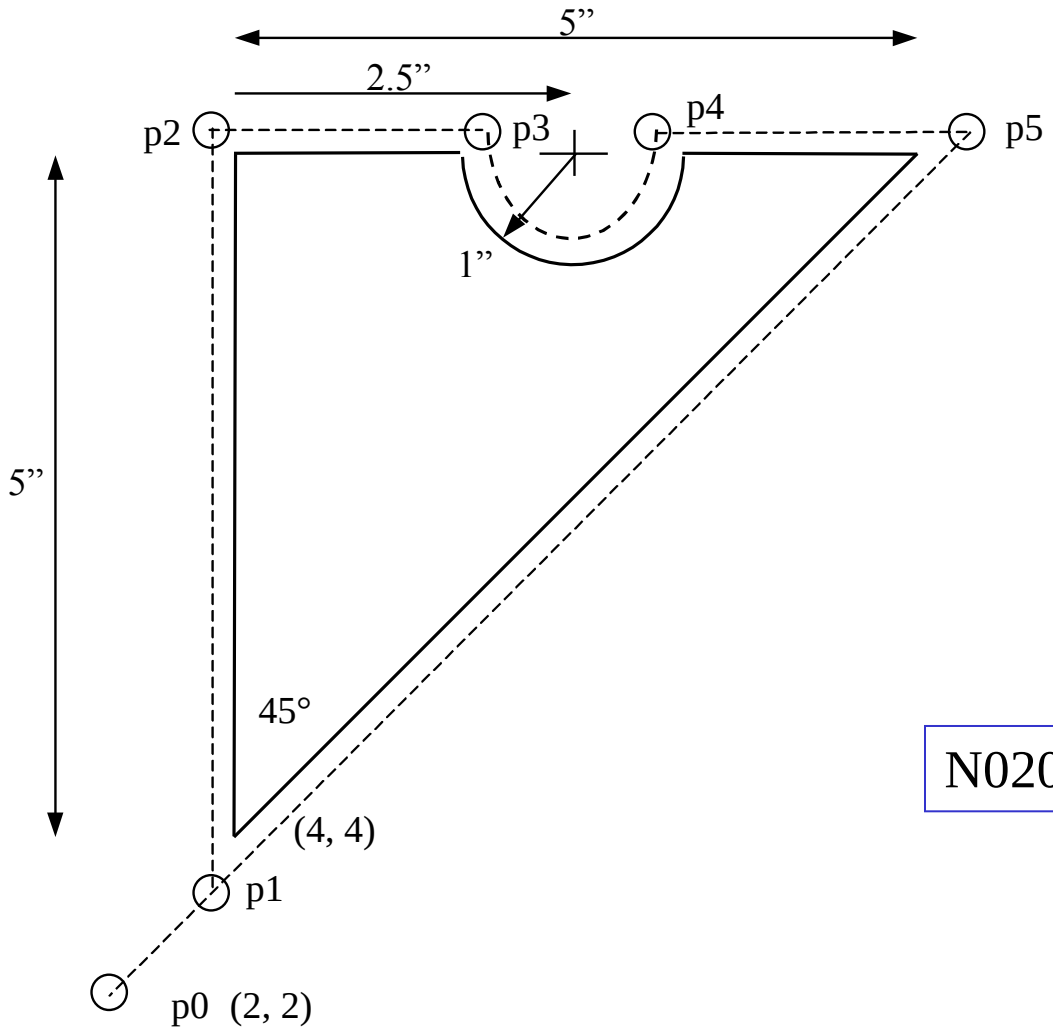
Feed in ipm

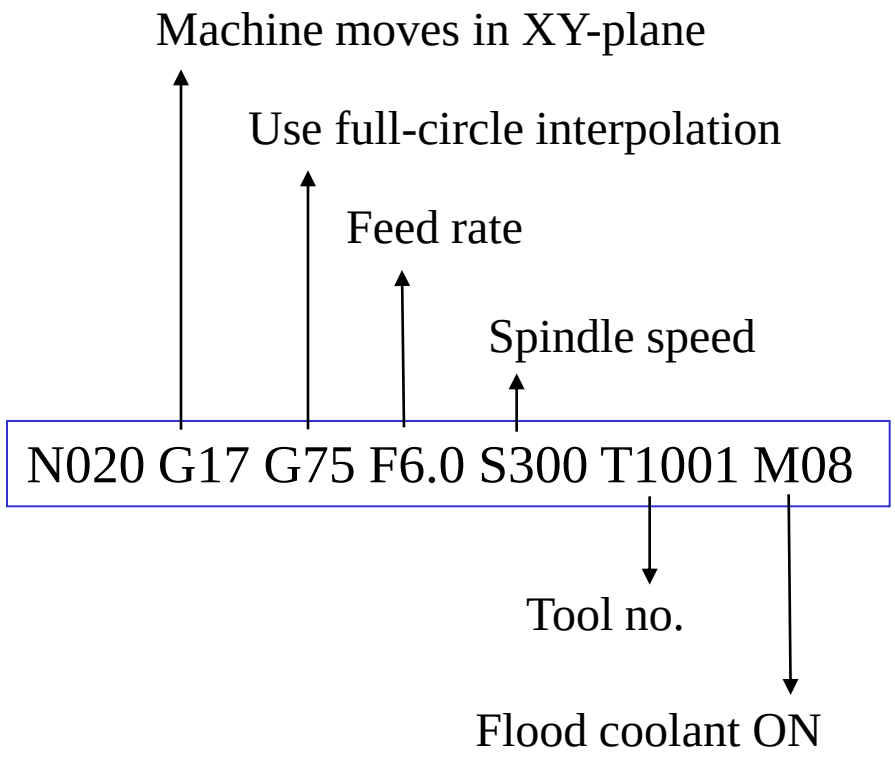
N010 G70 G90 G94 G97 M04

Spindle speed in rpm

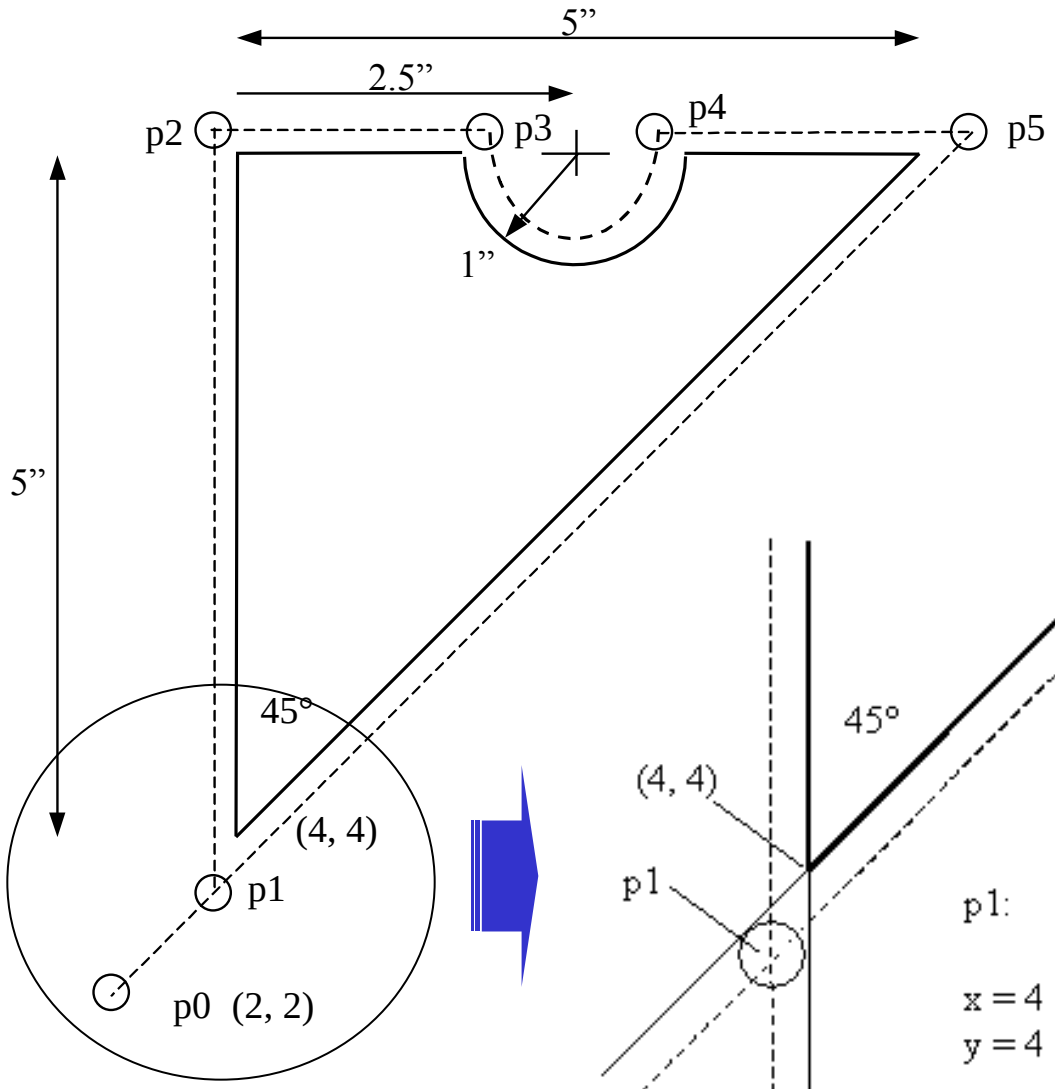
Spindle CCW

2. Set up the machining conditions





3. Move tool from p0 to p1 in straight line



Linear interpolation

target coordinates

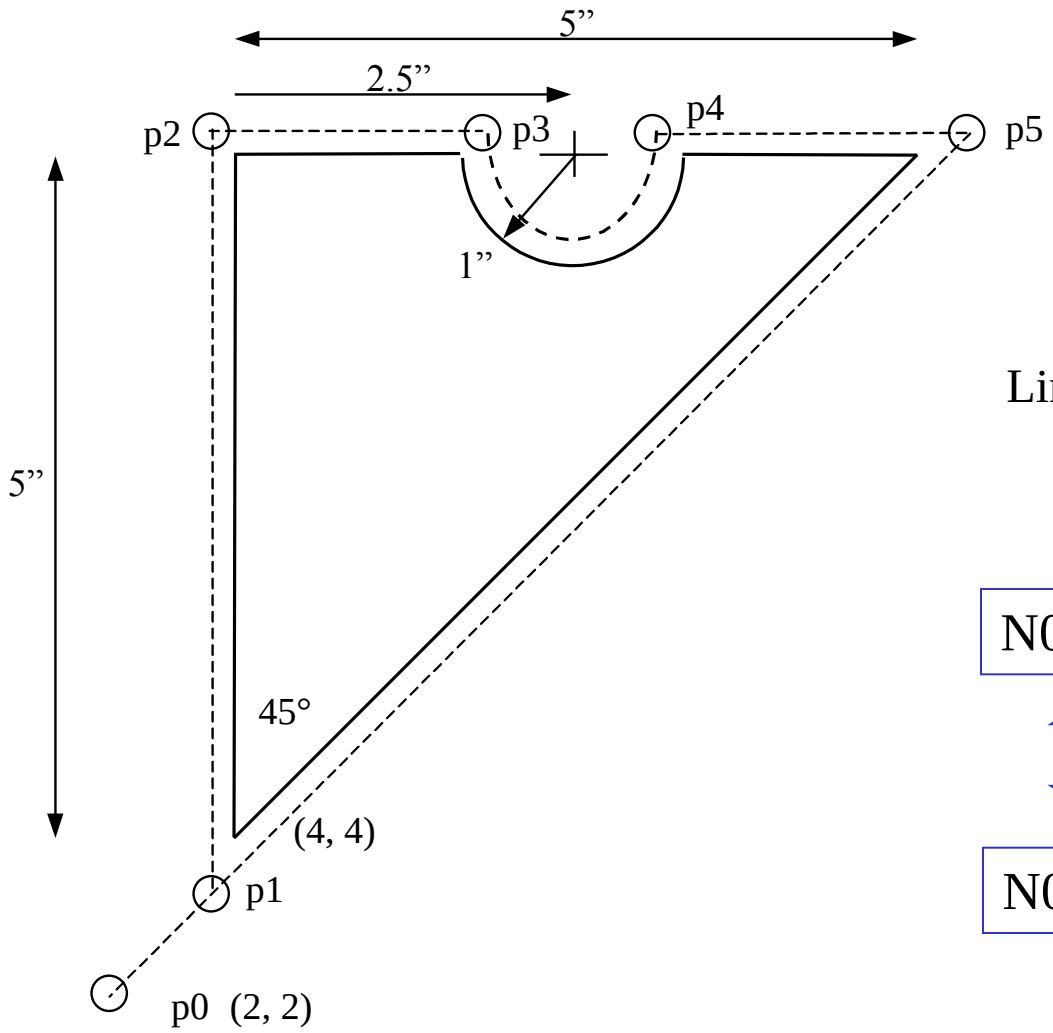
N030 G01 X3.875 Y3.698

p1:

x = 4 - 0.125 = 3.875

y = 4 - 0.125/tan 22.5 = 3.698

4. Cut profile from p1 to p2



Linear interpolation

target coordinates

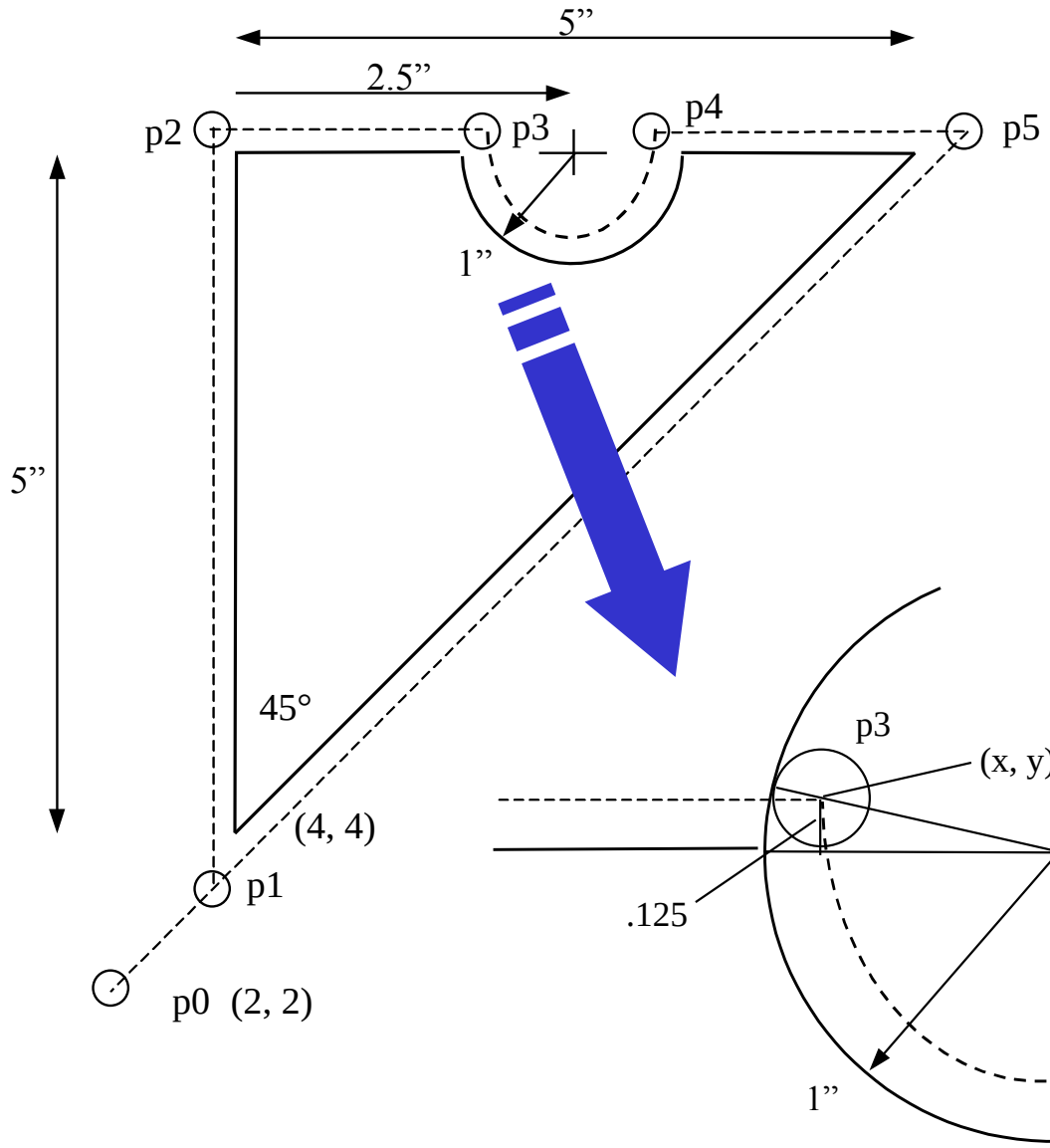
N040 G01 X3.875 Y9.125

or

N040 G01 Y9.125

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

5. Cut profile from p2 to p3



Linear interpolation

target coordinates

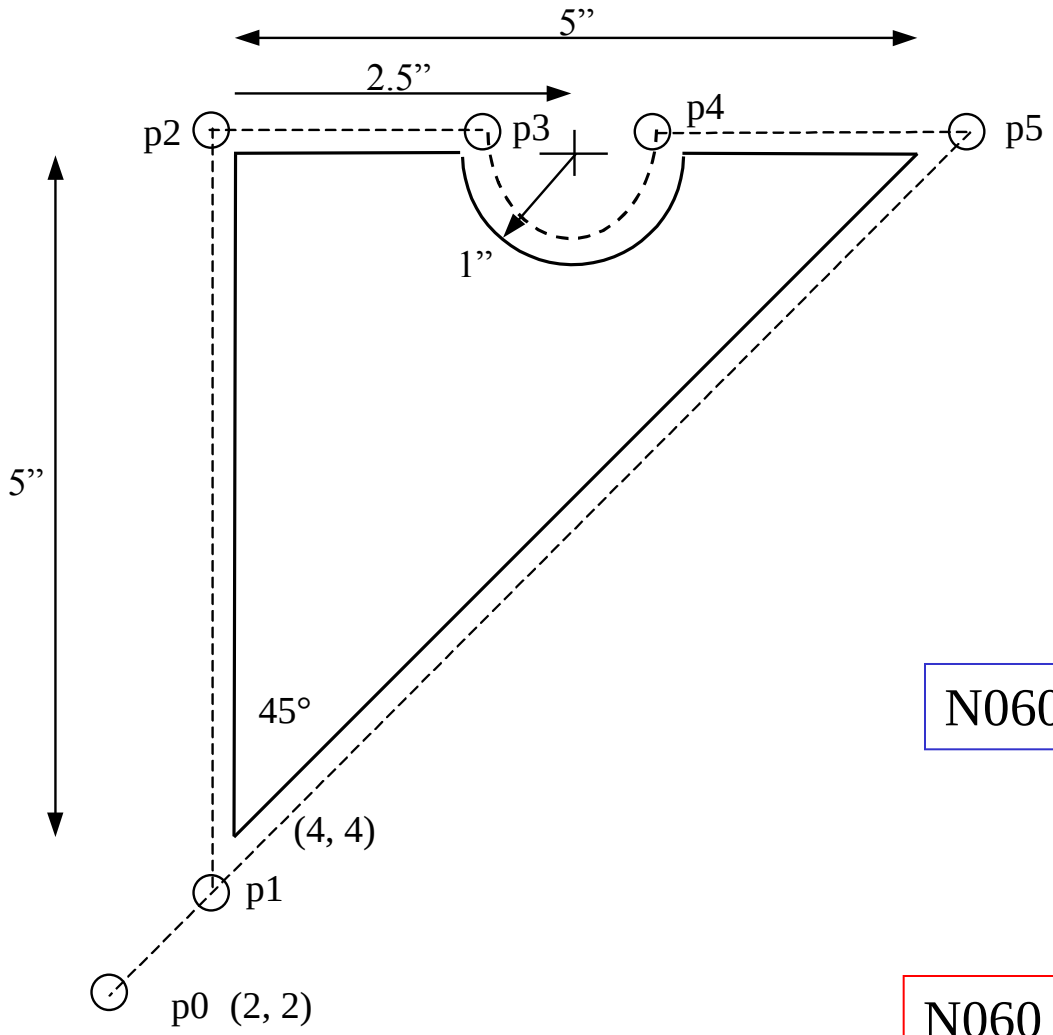
N050 G01 X5.634 Y9.125

$y = 9 + 0.125 = 9.125$

$(6.5 - x)^2 + 0.125^2 = (1 - 0.125)^2$

$x = 5.634$

6. Cut along circle from p3 to p4



circular interpolation, CCW motion

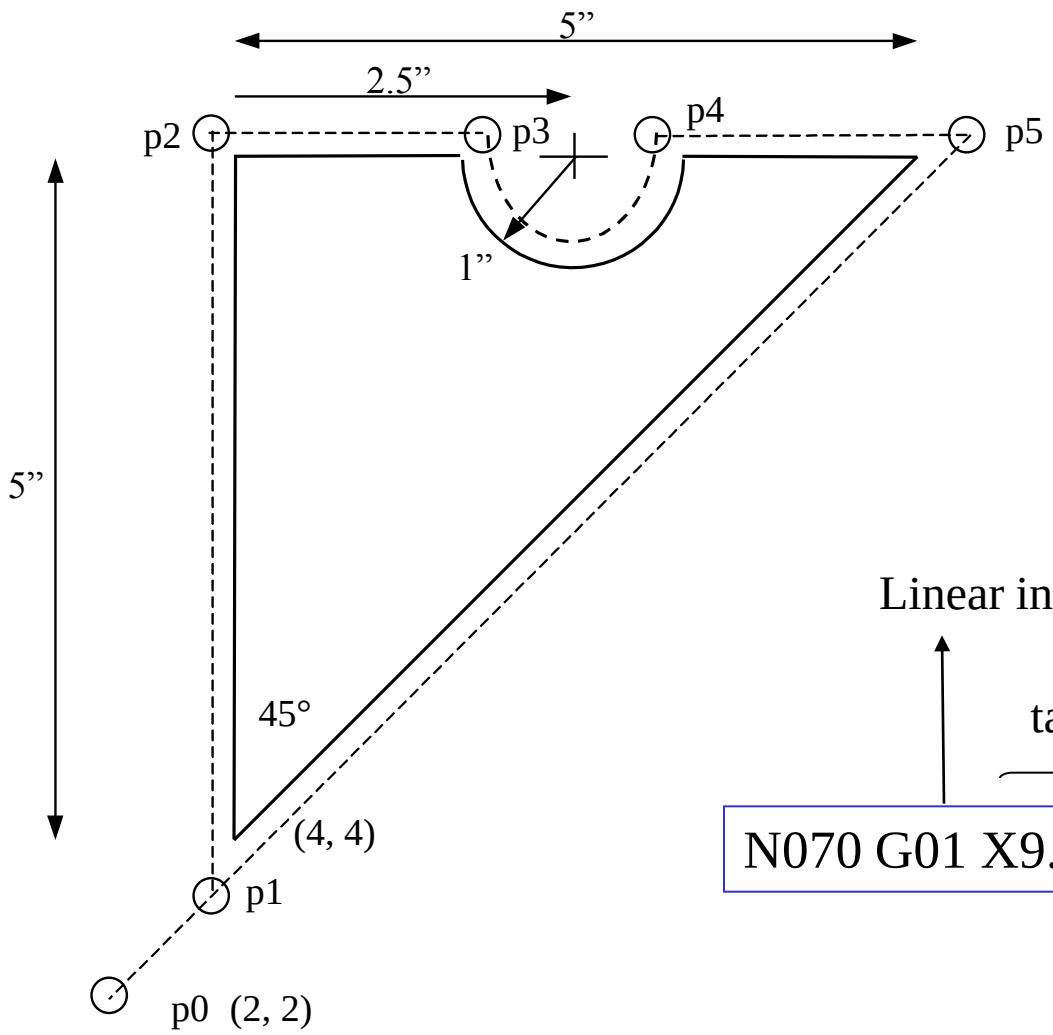
target coordinates

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

coordinates of center of circle

N060 G03 X7.366 Y9.125 I0.866 J-0.125

7. Cut from p4 to p5

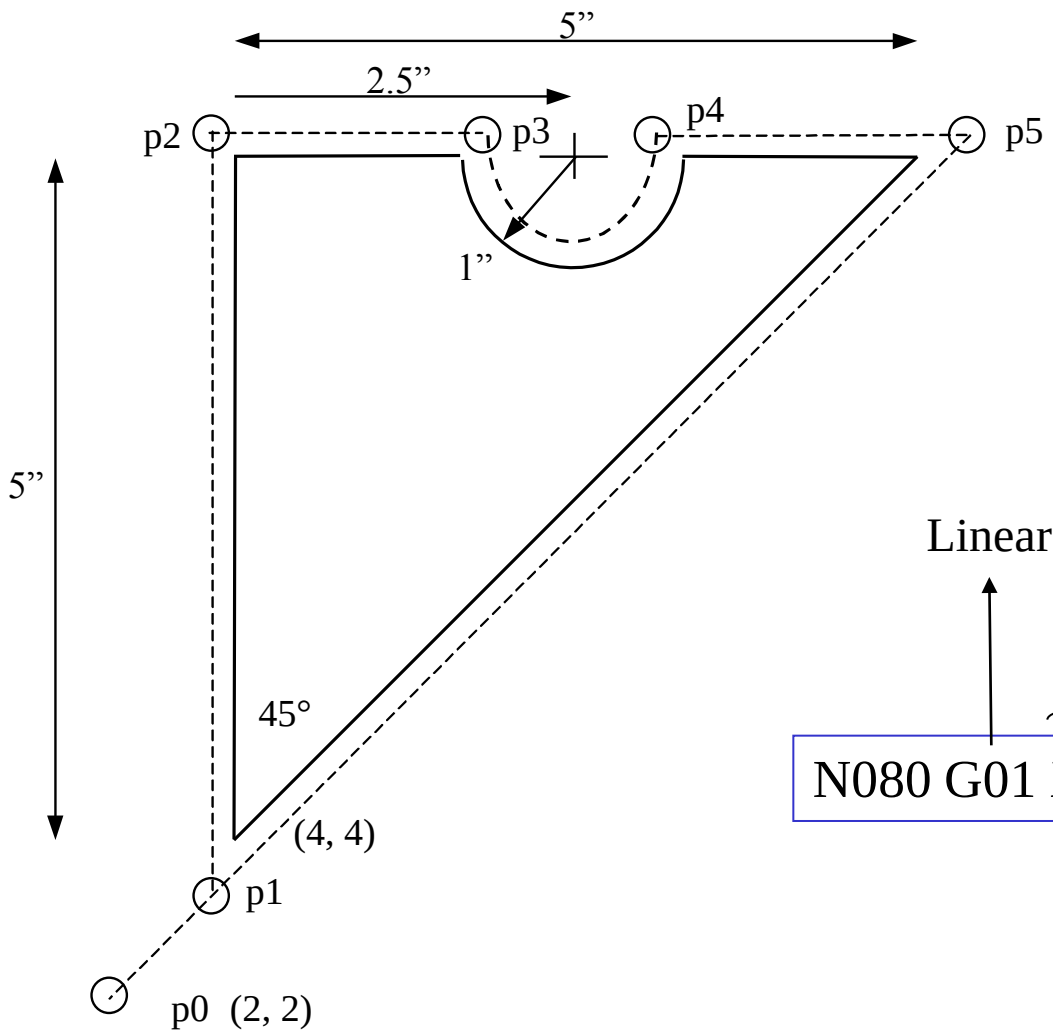


Linear interpolation

target coordinates (Y is unchanged)

N070 G01 X9.302

8. Cut from p5 to p1

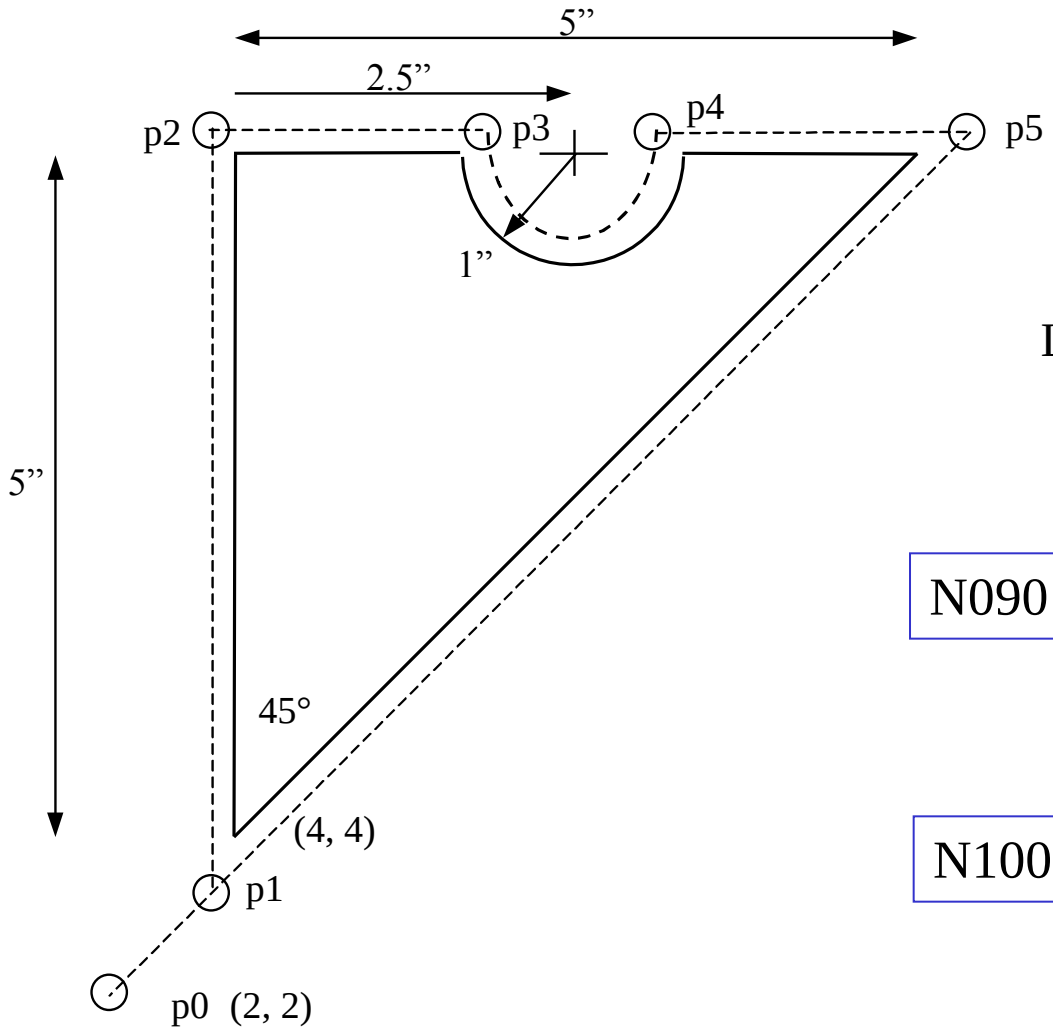


Linear interpolation

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

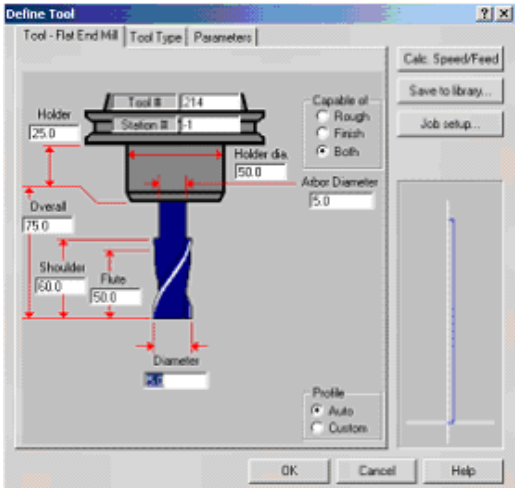
10. Complete RS-274 program

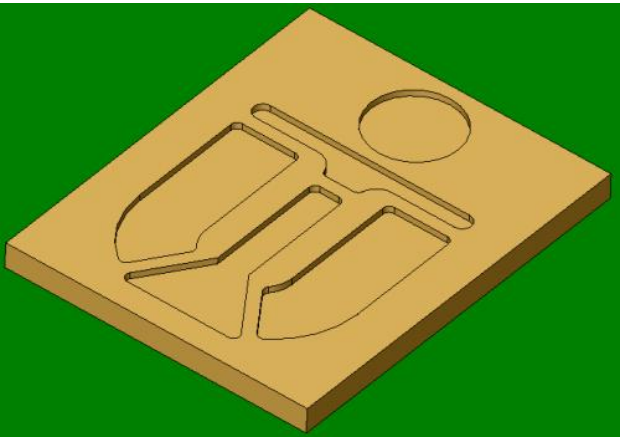
```
N010 G70 G90 G94 G97 M04
N020 G17 G75 F6.0 S300 T1001 M08
N030 G01 X3.875 Y3.698
N040 G01 X3.875 Y9.125
N050 G01 X5.634 Y9.125
N060 G03 X7.366 Y9.125 I0.866 J-0.125
N070 G01 X9.302
N080 G01 X3.875 Y3.698
N090 G01 X2.0 Y2.0 M30
```

Automatic Part Programming

Software programs can automatic generation of CNC data

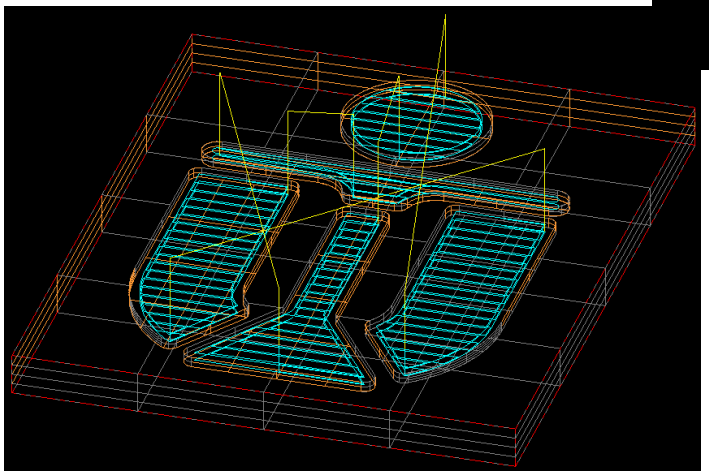
Define Tool

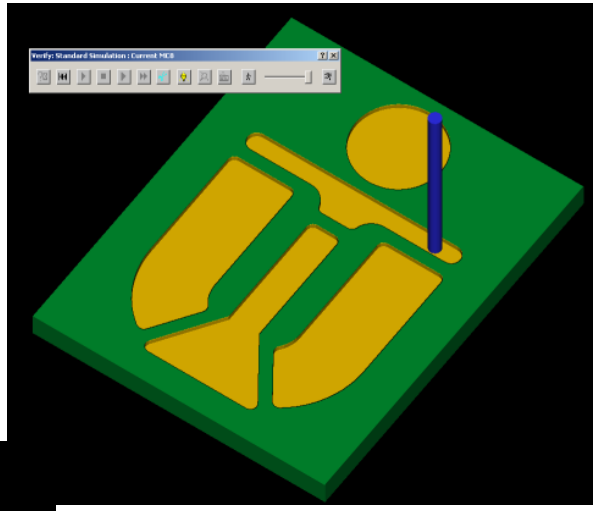




Make 3D model

CNC data



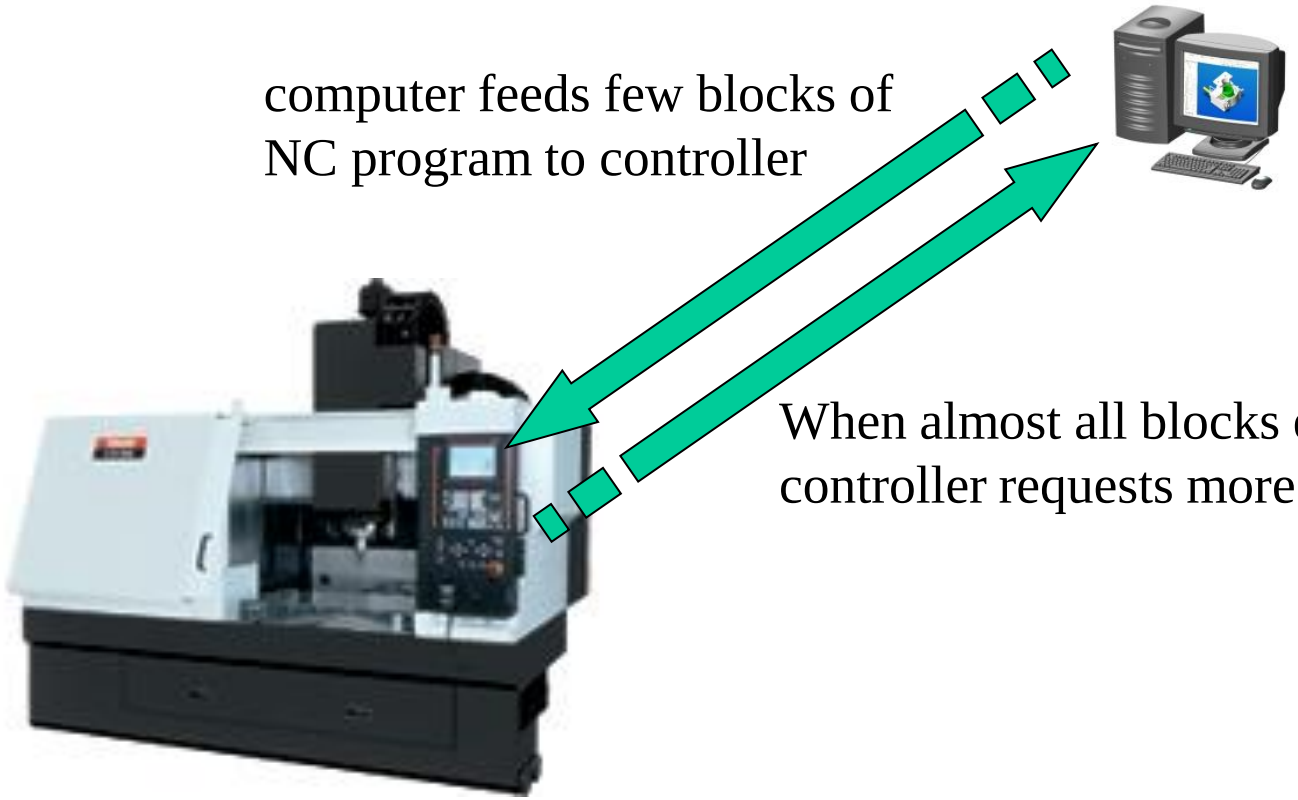


Simulate cutting

Automatic part programming and DNC

Very complex part shapes ➔ very large NC program

NC controller memory may not handle HUGE part program



Summary

CNC machines allow precise and repeatable control in machining

CNC lathes, Milling machines, etc. are all controlled by NC programs

NC programs can be generated manually, automatically

Additional references: RS274D code descriptions