32-04 Solution

Contour Change Points 2

The best approach for the calculations is to identify each point and each dimension to be calculated. Then, use mathematical formulas in the proper order and fill-in the calculated values. Many programmers have no real problem to use trigonometry in calculating triangles. What many programmers find difficult is to actually *see the triangle to calculate*. This project is as good an example as any to look at some general guidelines in solving trigonometric problems.

Mathematical calculations are vital part of programming for CNC machine tools. Geometrically more complex parts will require more calculations, but not necessarily more complex calculations. Common arithmetical and algebraic calculations, combined with the solution of right angle triangles, are virtually all the tools of mathematics you need. A right angle triangle has three sides and three angles. Only two sides may have the same length, and one angle must be 90 degrees, never used in calculations. The section of mathematics dealing with the solution of right angle triangles is called *trigonometry*. Often the word 'trigonometry' is treated with a negative attitude. Yet, solving trigonometric problems can be quite a simple and routine work. Various charts and formulas can come handy, such as the one mentioned above.

What is the most important issue in solving any problem is to approach the attempt at solution in an *orderly* and *organized* way. Solving triangles for a CNC program is no different. The most important key to solving trigonometric problems is the ability to visualize the triangle you want to solve. Such a triangle is not always obvious in the drawing or the sketch and must be found first. In this respect, there are only a few suggestions, and they may or may not work for everybody.

In order to solve a right angle triangle, there are some very basic mathematical rules you have to understand. The most important rule deals with the known dimensions of a triangle:

1. Two sides of a right angle triangle - OR - one side and one angle of the right angle triangle must be known
2. The sum of angles in a triangle is always 360 degrees
3. Complementary angles in a right angle triangle are always 90 degrees

Other rule states that opposite angles are equal. The *Law of Similar Triangles* is also useful. Based on these rules, all calculations can be approached in a planned way:

- Identify each contour point by a reference number (P1, P2,...), including all quadrant points, even if they will not be used
- Fill-in a coordinate sheet for all points whose coordinates are known
- Identify points that are arc centers by a reference number (for example, P90, P91, ..)
- Draw thin lines to join arc center points with all endpoints on the arc
- Draw ***X*** and ***Y*** lines to create right angle triangles - always through existing points !
- Fill-in drawing dimensions already known (for example, length, angle, radius, ...)
- Identify unknown dimensions along the axes (for example, X1, Y1, X2, Y2, ...)
- Write a formula list for all unknown values, such as:

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X1 = FORMULA     for example ......    X1 = 1.125 x cos28
X1 = SOLUTION    for example ......    X1 = 0.993316
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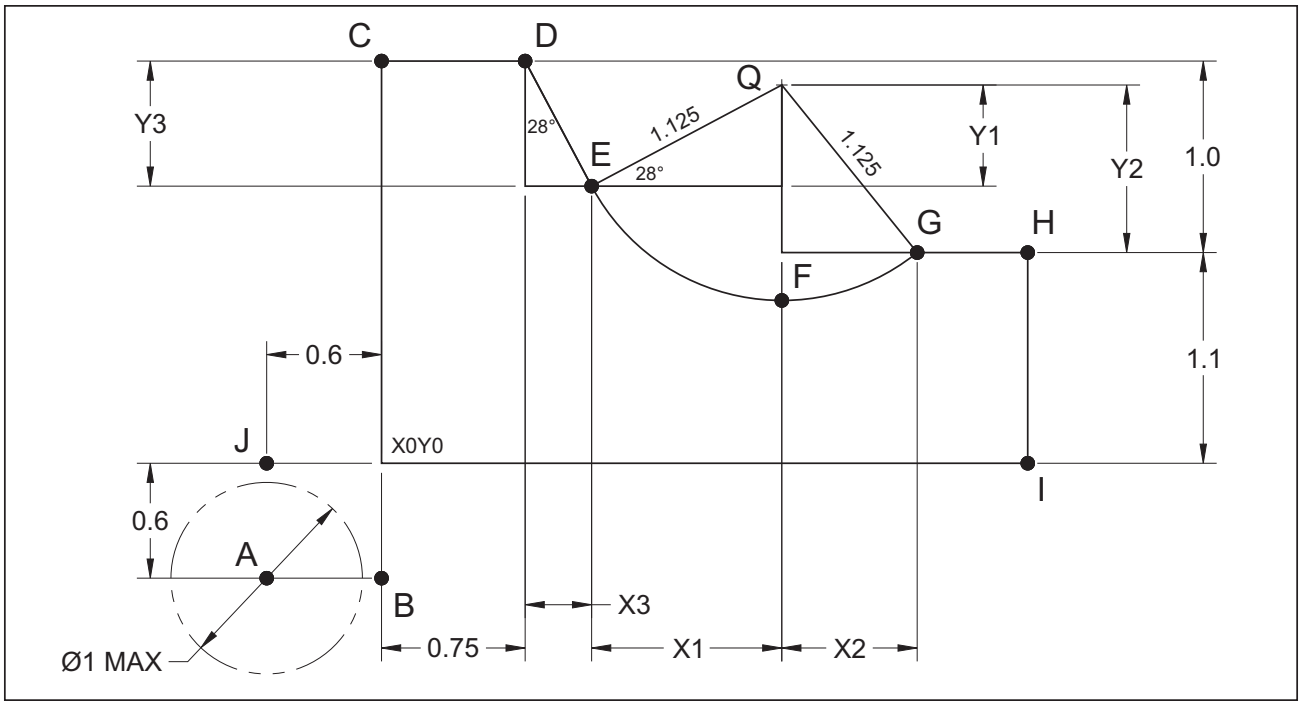
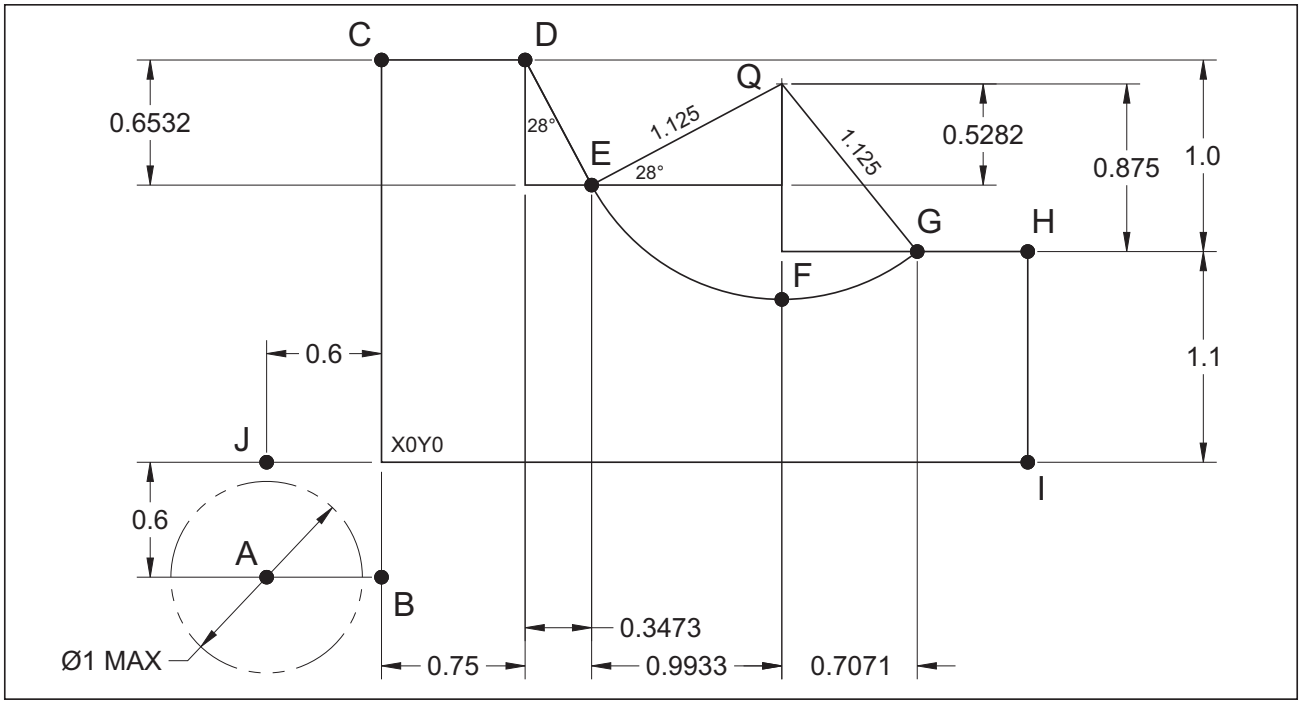
- Make sure all known sides and known angles of the triangles to be calculated are identified
- Calculate X1, Y1, etc., for each triangle as needed - highlight the triangles!



X1 = 1.125 x cos28 = 0.993316	Y2 = 1.125 - 0.25 = 0.875	Y3 = 1.0 - Y2 + Y1 = 0.6531555
Y1 = 1.125 x sin28 = 0.5281555	$X2 = \sqrt{1.125^2 - Y2^2} = 0.7071068$	X3 = Y3 x tan28 = 0.3472889



This procedure may have to be modified in some cases, but it presents general ideas for a development of a personalized approach to solving trigonometric problems.

Once the calculations are completed, the part program itself should be easy to develop:

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(32-04 - CONTOUR CHANGE POINTS CALCULATIONS)
(T01 - 1.0 DIA END MILL - IN THE SPINDLE AT START)
(X0Y0 LOWER LEFT CORNER OF PART - Z0 TOP FACE OF PART)

N1 G20
N2 G17 G40 G80
N3 G90 G54 G00 X-0.6 Y-0.6 S458 M03                (START POINT A)
N4 G43 Z1.0 H01 M08
N5 G01 Z-0.55 F20.0
N6 G41 X0 D01 F10.0                                (POINT B)
N7 Y2.1                                            (POINT C)
N8 X0.75                                           (POINT D)
N9 X1.0973 Y1.4468                                 (POINT E)
N10 G03 X2.7977 Y1.1 I0.9933 J0.5282               (POINT G)
N11 G01 X3.375                                     (POINT H)
N12 Y0                                             (POINT I)
N13 X-0.6                                          (POINT J)
N14 G40 G00 Y-0.6                                  (START POINT A)
N15 Z1.0 M09
N16 G28 X-0.6 Y-0.6 Z1.0 M05
N17 M30
%
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📖 *Specific references in the CNC Programming Handbook - Chapter 53:*

Trigonometric formulas
The Law of Similar Triangles