Milling Tools
These are the tools currently available for use with the milling machine

T1 Milling Tool

The missile-shaped T1 milling tools are the highest precision of T-Tech's milling tools. They are recommended for milling 0.008" to 0.012" mill paths. The shank diameter missiles from 1/8" near the base to 1/16" near the 60-degree angle point. T-Tech recommends the T-1 milling tools for the majority of Quick Circuit applications.

T3 Milling Tool

T-Tech's T3 Milling Tools are 1/8" shank to the tip. The 60 degree point works well for mill paths 0.008" to 0.012". These tools offer the greatest rigidity. The T3 can also be used for scoring operations.

Carbide Endmills

T-Tech's Endmills are designed for effective maximum copper removal for circuit board prototyping. Endmills are recommended for use in all RF and Microwave PCB applications because they offer a dependable milling width, leave a perpendicular edge wall and remove a minimum amount of dielectric. Endmills are used for wide path milling and rubout applications. Stub length endmills offer greater rigidity and are recommended for the majority of endmill operations on the Quick Circuit. The only end mills bits currently stocked by the EE department are .031" wide.
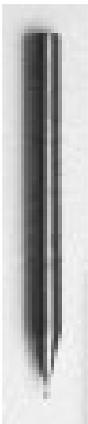
### .062" Routers (R2 Style)

T-Tech's Chipbreaker Routers are used to route a board outline from a piece of material or to perform interior routing.   Specify this width (.062") when creating cutout layers in your PCB layout program.

Widths of milling paths using T3 and T1 bits are often uncertain, because the depth of each cut is unknown. From the figure below, you might expect to achieve path widths approaching 2-3mils if the cutting depth is kept to a minimum. It has been found in practice, however, that this degree of accuracy is hard to obtain and tends to yield inconsistently milled paths, where some areas of the path don't cut completely through the copper layer. Based on the numbers provided by T-Tech, you might expect to get a consistent milling path width once you've cut down approximately 6-7 mils into the fiberglass layer.   This level accuracy is more practical and can be more easily achieved with the knurl nut depth adjustment.

When using the T1 and T3 bits, it is recommended that you assume a minimum 10mil path (i.e., no trace is closer than 10mils to any other trace) when laying out your PCB design in Protel.   7-8 mil paths are possible, but more difficult to achieve.

A simple method for checking the width of the milling path utilizing the *Relative Move* command under Quick Cam's *Options* menu is described in the milling procedure.   While it can provide a rough idea of path width, it is by no means an absolute measure. Critical path widths should be milled with end mill bits of the appropriate width.
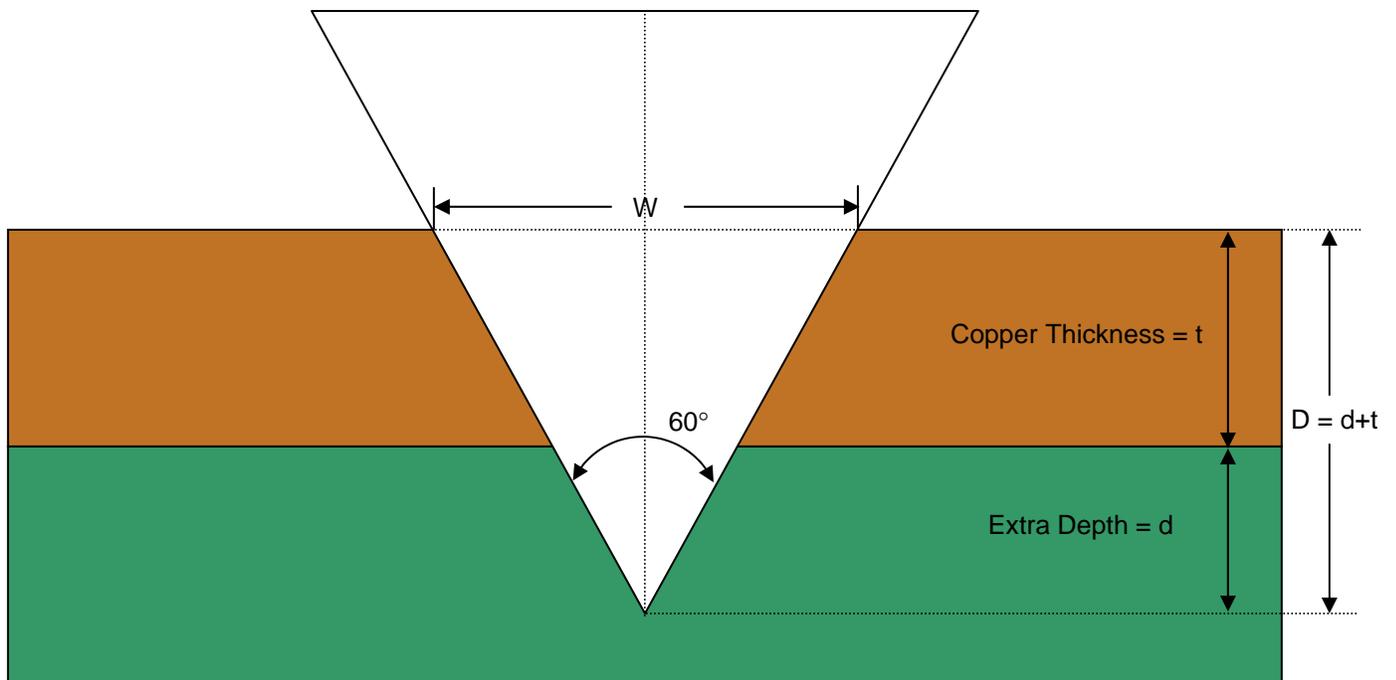
$$W = 2D \tan(30°)$$

| d = 1					d = 6			
CU weight	t (mils)	D (mils)	W(mils)		CU weight	t (mils)	D (mils)	W(mils)
1/2 oz.	0.7	1.7	1.96299		1/2 oz.	0.7	6.7	7.73649
1 oz.	1.4	2.4	2.77128		1 oz.	1.4	7.4	8.54478
2 oz.	2.8	3.8	4.38786		2 oz.	2.8	8.8	10.16136

For high-speed, RF, and microwave applications where careful control of micro strip dimensions is required, use of the end mill bits is recommended. These bits provide both perpendicular edge walls and a constant known milling path width regardless of bit depth.

The only end mill we currently have available is the .031" stub end mill. The bit width is the dimension that should be used both as a minimum distance between PCB traces in during layout and when specifying your tool width for isolation in IsoPro.

When using Protel, Be sure to specify the minimum distance between objects in the design rules to be certain that complete isolation can be achieved with the appropriate tool width in IsoPro. Often there is a temptation not to bother with manipulating Protel's design rules, but if the width of the isolating tool is wider than the minimum distance between PCB traces or pads, IsoPro will fail to create the data necessary to separate objects closer together than the specified tool width. Many students attempt to compensate for this behavior by entering a very small tool width value when carrying out the isolation operation. While this will result in a completely isolated circuit, problems may arise when the actual milling is carried out.

The figure on the left below shows the results of an isolation operation, where W is the desired width of the PCB trace and W_T is the tool width specified in IsoPro. The position of the dotted center line is calculated by IsoPro from these two values.   This line is the data that is displayed in IsoPro and passed on to Quick Cam to guide the path of the milling tool.

The figure on the right shows the result of milling the isolated design with a tool wider than W_T. Here, W_A is the actual width of the milling tool, which follows the same path specified for the smaller tool. The result is a trace with effective width $W_{eff} = W - W_A + W_T$. In the some situations, depending on your application, the difference between W and W_{eff} may not be significant; in other extreme cases, where W_{eff} turns out to be < 0, your circuit traces will be eliminated completely. Either way, it is preferable to enter the proper parameters in Protel and IsoPro so your prototype matches your original design parameters.
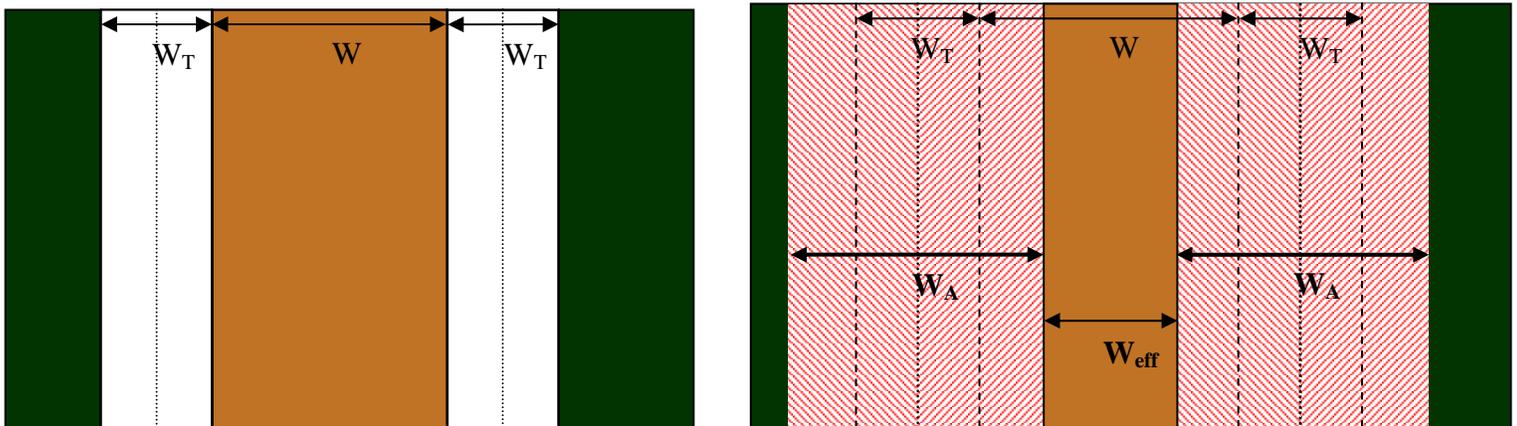
$$W_{eff} = W - W_A + W_T$$

Steps For PCB Milling

Board Preparation

1. Tape PCB material to backing board
2. Drill dowel holes using 1/8" t-tech bit. Note the position of the fixed dowel hole in the surface of the table. Be sure you drill your holes so that the both the PCB board and the backing material can be kept completely on the table surface.
3. Make sure mill table is free of dust, tape, and debris.
4. Position backing board and PCB material to mill table with dowel pins
5. Secure with masking tape

Milling Procedure

Preparation-

1. Log in to computer
2. Turn on Mill Controller
3. Open Quick Cam, wait for mill to zero itself.

Drilling Holes -

4. Open Drill file
5. Set proper x and y position offsets (*Edit → Offset*)
6. Select *Options → Tool Change* (ctrl + c)
7. Remove current bit, install smallest bit shown in tool table;
8. With 3/8" driver, raise head completely; Click *'OK'*.
9. Adjust head height so bit tip is no higher above surface than width of allen wrench
10. Click near table edge; select *'Jump to Point'*. This option can be accessed by left-clicking anywhere on the board area in QuickCam.
11. Use *Options → Jog Milling Tool* (ctrl + j) to move head so that bit is just off the edge of, but foot is still over board material.
12. Click *'Turn Spindle On'*, then click *'Lower Tool'*; Adjust plunge depth with knurl nut so that drill bit will slightly penetrate backing material.
13. Click *'Raise Tool'*, then *'Turn Spindle Off'*, then *'OK'*
14. Select *Mill → Mill/Drill File*. Click *'OK'* when prompted for tool change.
15. Change bits to next tool in tool table when prompted. No further adjustment of head height or plunge depth should be necessary.

Milling Top Side –

16. Open file containing isolation data for top layer. Choose 'no' when asked if board has been flipped since last operation. Choose 'yes' to apply the same net offset applied to the drill file.
17. Replace drill bit with desired milling tool using the same procedure described in steps 6-9.
18. Move tool to unused portion of PCB material using *'Jump to Point'* .
19. Select *Options → Jog Milling Tool* (ctrl +J); Click *Turn Spindle On*, then *Lower Tool*.

20. Adjust the cutting depth of the tool with the knurl nut. Make test cuts by moving the head via the dialog box.   Don't forget to lower the foot below the tip of the bit before setting depth! Some milling bits (like end mills) are longer than others and could cause damage if lowered to the same depth as previous tools.

21. For critical applications, milling path widths of T1 and T3 bits can be approximated by first cutting a sample path along one direction using the *Jog Milling Tool* option. Once you have a path long enough to examine easily, choose *Options → Relative Move* and enter an offset equal to the width of your desired path width in the direction perpendicular to your sample path. Cut another path parallel to the first and examine the result. If the two paths overlap, the tool is set to cut too deep; if there is copper remaining between the paths, the tool is not cutting deeply enough. Repeat the procedure until the two paths barely overlap. In many cases, this will result in a tiny shaving of copper that clings slightly between the paths. For many projects, this step is far more trouble than it's worth.

22. Once the cutting depth is adjusted, select *Mill → Mill/Drill File* and Click *OK* when prompted for tool change.

23. Repeat steps 16-22 for other top-side files isolated with different tool sizes.

Milling Bottom Side -

24. Choose *Mill → Material Change*.

25. Remove the PCB material from the table, flip it over along its long axis (facing the mill this left/right, not front/back), realign the holes with the dowel pins, and re-tape.

26. Open a file containing isolation data for bottom layer, which should have been mirrored along with the cutout layer in IsoPro. Choose 'yes' when asked if board has been flipped since last operation. Choose 'yes' to apply the same net y offset and the negative of the net x offset applied to the drill file.

27. Repeat steps 16-22 for each tool width. When opening subsequent bottom-side mill files, choose 'No' when asked if the board has been flipped since the last operation.

Cutting Out PCB Outline -

28. Open file containing cutout information. Select when asked if board has been flipped since last operation. Choose 'yes' to apply the same net offset applied to the bottom mill file.

29. Repeat steps 6-13, inserting the .062" router instead of a drill bit.

30. Choose *Mill/Contour Route* and click *'OK'* when prompted for tool change. DO NOT select *Mill/Drill File. Contour Route* uses a much lower feed rate that keeps the router bit from snapping off in the material.

Clean-up -

31. Select *Options → Tool Change* (ctrl + c) and remove router bit.

32. Choose *Mill → Material Change*, and remove remaining PCB material and backing board.

33. Make sure milling table is free of tape residue, dust, and PCB debris.

34. Make sure all tools, wrenches, pins, etc. are returned to the storage box and locked up.

35. Make sure area surrounding mill is clean.

36. Quit Quick Cam, turn off controller, and log out of the machine.