ROGERS CORPORATION

Fabrication Notes

Routing Guidelines for TMM® Microwave Laminates

TMM® laminates can be successfully routed using conventional carbide tools. With appropriate routing conditions and tool selection, useful tool life in excess of 250 linear inches can be obtained when machining TMM-10 laminates. Tool life is somewhat lower for the lower dielectric constant grades. This application note discusses factors which effect tool wear and routed edge quality. Recommended routing conditions and tool life estimates for various tool sizes and TMM grades are provided in quick reference tables.

TMM Microwave Materials, consist of a hydrocarbon matrix highly filled with ceramic filler. This provides TMM laminates with its low thermal expansion and makes it possible to offer a wide variety of dielectric constants.

Due to the abrasive nature of the ceramic filler, some precautions are required when routing TMM materials. High tool surface speed (>400 SFM) should be avoided whenever possible to prevent excessive tool wear and reduced edge quality.

Recommendations provided below are based on testing completed using an Excellon EX driller/router. A range of carbide tool geometries from several tool suppliers were evaluated.

TABLE 1
Recommended Routing Parameters

Recommended Tools:	Diamond cut carbide tools or sprial chipbreaker with at least 5 flutes
Lateral Chip Load:	0.0010" - 0.0015"
Surface Speed:	200-400 SFM
Entry:	Phoenolic (0.010"-0.030")
Exit:	Phoenolic (0.100")

Surface Speed and Chip Load:

Surface speed (SFM) is defined as the velocity (ft./min.) of the outer cutting edge of the tool. The following equation can be used to calculate the spindle speed for a particular tool diameter and surface speed.

$$\text{Spindle Speed (RPM)} = \frac{12 \times \text{Surface Speed (ft./min.)}}{\pi \times \text{Tool Diameter}}$$

Chip load is defined as the distance of tool travel per revolution. The following equation can be used to calculate feed rate for a particular chip load and spindle speed.

Lateral Feed Rate = Chip Load x Spindle Speed
(inches/min.) (inches/rev.) (rev./min.)

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Recommended TMM Routing Conditions and Tool Life:

Recommended routing conditions and useful tool life estimates provided in Tables 1 and 2 are based on quality considerations such as copper burring, channel width reductions, sidewall roughness as well as the ultimate life of the tool (inches to failure). The ultimate tool life values in the accompanying figures provide a good quantitative basis for comparing tool geometries and routing conditions. However, useful tool life can be significantly lower due to edge quality requirements. The useful tool life estimates provided in Table 2 are typically about 50% to 60% of the ultmate tool life. Tools may need to be replaced more frequently for highly demanding applications.

Table 2: Useful Tool Life Estimates (*):
Tool TYPE A - Diamond Cut Router Geometry
Tool TYPE B - Upward Spiral Chipbreaker (^{3} 5 flutes)

			Tool Diameter - TYPE A			Tool Diameter - TYPE B		
Material	**Speed (KRPM)**	**Lateral Feed Rate (in/min)**	**1/16'**	**3/32"**	**1/8"**	**1/16"**	**3/32"**	**1/8"**
TMM 3	15	19	80	120	120	90	100	100
TMM 3	20	25	50	50	50	40	40	40
TMM 3	25	31	30	20	X	30	20	X
TMM 4	15	19	100	140	140	100	120	120
TMM 4	20	25	70	70	70	60	60	60
TMM 4	25	31	45	40	X	45	40	X
TMM 6	15	19	150	180	180	120	150	150
TMM 6	20	25	100	100	100	100	100	100
TMM 6	25	31	70	70	X	70	70	X
TMM 10	15	19	250	250	250	250	250	250
TMM 10	20	25	250	250	250	250	250	250
TMM 10	25	31	250	250	250	250	250	250

(*) Notes:
1. This table is based on 0.060" thick constructions. Useful tool life will be significantly lower for thicker constructions. For example, tool life can drop by as much as 50%-60% if the construction thickness is doubled (0.120").
2. To maximize tool life and edge quality, the higher spindle speeds listed (20K RPM and 25K RPM) should not be used if lower spindle speeds are available.
3. This table assumes a minimum spindle speed of 15K RPM. If available, lower spindle speeds should be used when routing with larger tools (>100"). should be used when routing with larger tools (>100").

Factors Effecting Tool Life:
There are a variety of factors which effect useful tool life when machining TMM® laminates or bonded assemblies. They include TMM grade, surface speed, tool geometry, chip load, tool size and stack height.

TMM Grade:
The lower dielectric constant TMM grades contain a larger fraction of highly abrasive filler. Therefore, TMM-3 yields a shorter tool life then TMM-10. When appropriate routing conditions and tool geometries are used, TMM-3 can yield a useful tool life of about 120 linear inches. With TMM-10, useful tool life can exceed 250 linear inches.

Tool Surface Speed:
The effect of surface speed on ultimate tool life is shown in Figure #1 for TMM-3 machined with a variety of tool geometries. For all geometries tested, ultimate tool life decreased with increasing surface speed. The spindle speed examined ranged from 15K RPM to 25K RPM (3/32" tool).

Tool Geometry:
The tool geometries which were evaluated are listed in Table 3. Due to practical considerations, this study only included tools from three suppliers. However, similar tool geometries from other suppliers should provide similar results.

In general, tools with a larger number of cutting edges offered superior tool life. As shown in figure #1, the Precision Carbide R1U, R1D and Megatool RCS geometries offered the best ultimate tool life. These tools are typically used for routing conventional PWB materials such as FR4. Tool geometries which are typically used for routing PTFE based laminates such as the Presicion Carbide EM2 cutter yielded poor ultimate tool life due to their relatively small cross-sectional area.

Lateral Feed Rate (Chip Load):
The effect of chip load on ultimate tool life is shown in Figure #2 for various tool geometries. As chip load increases, the ultimate tool life decreases. However, very low chip loads (<0.001"/rev.) should be avoided due to a significant increase in copper burring.

Table 3
Tool Geometries Evaluated
(in order of decreasing tool life)

Abbreviation	Generic Description	Vendor
PCR1D	Diamond Cut (down-draft)	Precision Carbide
PCR1U	Diamond Cut (up-draft)	Precision Carbide
Mega RCS	Diamond Cut (up-draft)	Megatool
Tulon 44	Spiral Chip Breaker (5 flute)	Tuflon
Mega RI	Straight Endmill (3 flute)	Megatool
PCEM2	Spiral Endmill (2 flute)	Precision Carbide

Table 4
Tool Surface Speed (ft./min.)

Spindle Speed (RPM)	1/16" Tool	3/32" Tool	1/4" tool
15K	245	368	491
20K	327	491	654
25K	409	614	818

Tool Size:
As seen in Figure #3, larger tools typically yield better ultimate tool life at a given surface speed due to the increased tool crossectional area. Therefore, smaller tools often need to be replaced more frequently.

Stack Height:
The ultimate tool life also decreases with increased stack height (Figure #4). This is due to the increased lateral stress on the tool. As stack height increases, tools should be replaced more frequently.

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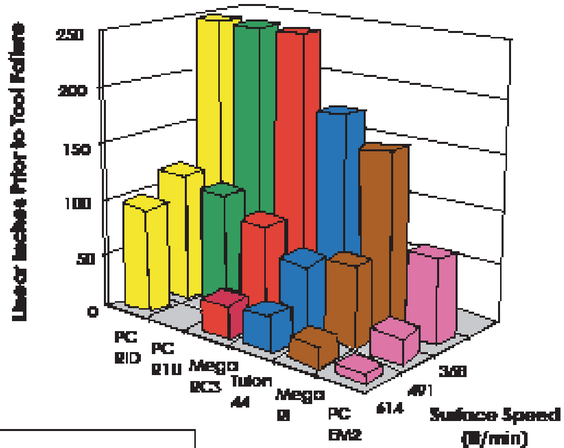
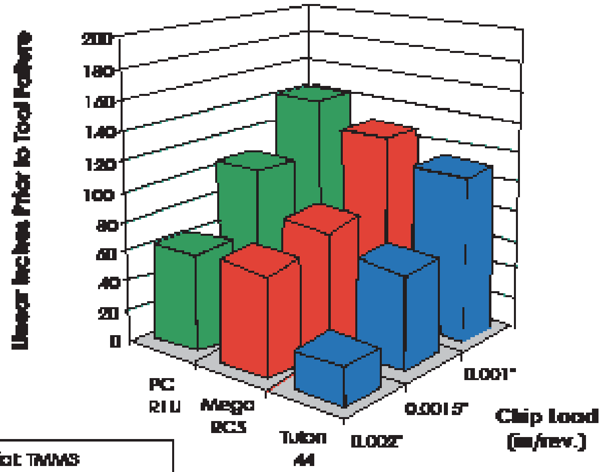
Figure #1
Ultimate Tool Life as a Function of Surface Speed



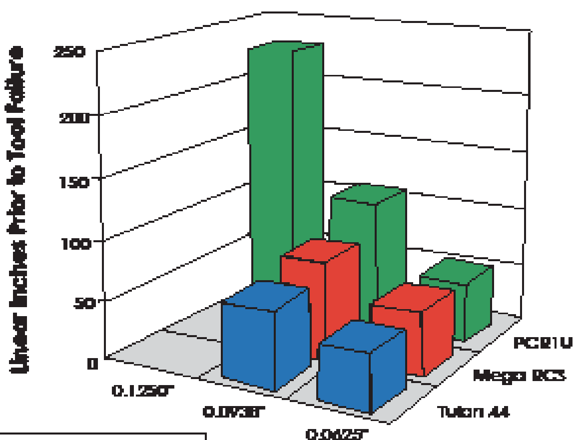
Material: TMM3
Chip Load: 0.0015/rev.
Tool Size: 3/32

Figure #2
Ultimate Tool Life as a Function of Chip Load



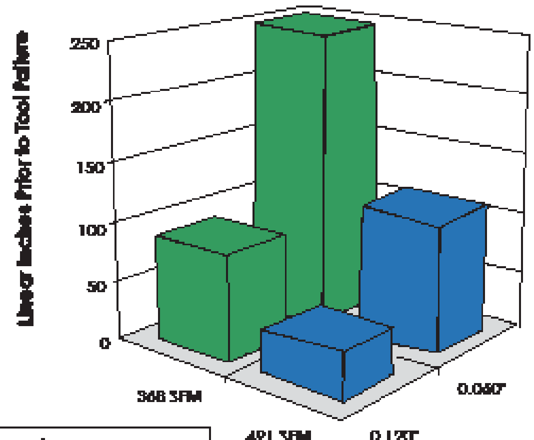
Material: TMM3
Surface Speed: 491 SFM
Tool Size: 3/32

Figure #3
Ultimate Tool Life as a Function of Tool Size



Material: TMM3
Surface Speed: 491 SFM
Chip Load: 0.0015"/rev.

Figure #4
Ultimate Tool Life as a Function of Stack Height



Material: TMM3
Chip Load: 0.0015"/rev
Tool Type: PCR1U (3/32")

Note: Prolonged exposure in an oxidative environment may cause changes in the dielectric properties of all hydrocarbon based dielectric materials, including TMM high frequency dielectric materials. Changes may be exacerbated by increased thermal exposure. Whether or not such changes occur, and whether or not they might result in a functional impact on a finished product, depends on a complex set of variables related to factors such as circuit design, functional tolerances, operating conditions and other circumstances that are unique to each product design. Although Rogers continues to seek ways to minimize the naturally occurring effects of oxidation by developing improved anti-oxidant formulations for the TMM family of high frequency materials, Rogers, as always, recommends that the circuit designer and/or the end user test the properties and performance of these materials in each proposed application to determine their fitness for use over the entire product life.

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