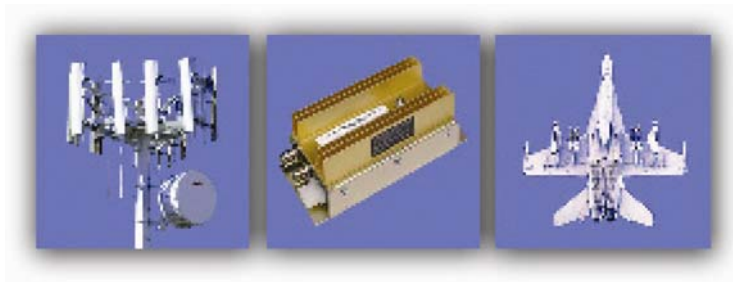




## TacPreg® TP-32 & TacLam® TL-32

### General Processing Guidelines



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TacPreg® TP-32 & TacLam® TL-32  
General Processing Guidelines

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## General Information

The TacLam® TL-32 laminate is part of the Taconic product offering designed specifically for the High Speed Digital market. Coupled with the TacPreg® TP-32 prepreg, TacLam® TL-32 enables the use of low electrical loss PTFE materials in high multilayer count boards with digital data rates exceeding 10 Gigabits per second. The thermoset properties of the bonding agent enable multiple laminations and thermal excursions during standard circuit board fabrication without delamination of the multilayer package.

TacLam® TL-32 utilizes PTFE resin and ceramic for low electrical loss, woven fiberglass for dimensional stability, and a high performance thermoset resin as a bonding agent for the copper foil. The associated prepreg, TacPreg® TP-32, uses the same materials with a partially cured thermoset resin to facilitate bonding of multiple inner layers of TacLam® TL-32 and/or foil cap layers. DESIGN NOTE: In order to achieve adequate filling around etched features, the number of Tacpreg plies and ply thickness should be determined using the following guidelines in Table 1. These guidelines are based on high layer count multilayer designs with stacked traces which create high and low pressure areas during lamination. The recommendations are conservative and other designs may realize satisfactory results using fewer or thinner bond plies

| Copper Weight        | Tacpreg Product | Number of Plies |
|----------------------|-----------------|-----------------|
| ½ ounce              | TP32-0045-35    | 1               |
| ½ ounce              | TP32-0050-40    | 1               |
| 1 ounce              | TP32-0045-35    | 2               |
| 1 ounce              | TP32-0050-40    | 1               |
| 1 ounce plus plating | TP32-0050-40    | 2               |

Table 1 – TacPreg ply/thickness guidelines

For inner or outer layers requiring plating such as for blind or buried vias, two plies of TP-32 – 40% should be used as shown in the table above.

Processing TacLam® TL-32 can be readily accomplished using standard epoxy circuit board processing methods coupled with either plasma or sodium treatment of the PTFE hole walls. The following process recommendations are based on circuit boards produced at several facilities. It should be noted that each board shop may have different equipment and methods that will require modifications to these recommendations. Drill and routing parameters and artwork compensation data are very dependent on circuit board thickness and design and should be adjusted based on the experience of each facility. The treatment of hole walls prior to plating must be done using a plasma or sodium treatment system.

| Material Properties |                     |             |               |               |                          |
|---------------------|---------------------|-------------|---------------|---------------|--------------------------|
|                     | Dielectric Constant |             | Loss Tangent  |               | Thickness Range          |
|                     | 10 GHz              | 1 MHz       | 10 GHz        | 1 MHz         |                          |
| <b>TLT</b>          | n/a                 | 2.45 – 2.65 | n/a           | 0.0006        | 0.0020" – 0.3750"        |
| <b>TLY</b>          | 2.17 – 2.40         | n/a         | 0.0009        | n/a           | 0.0050" – 0.1870"        |
| <b>TLX</b>          | 2.45 – 2.65         | n/a         | 0.0019        | n/a           | 0.0020" – 0.3750"        |
| <b>TLC</b>          | 2.75-3.20           | n/a         | 0.0030        | n/a           | 0.0100" – 0.2500"        |
| <b>TLE</b>          | 2.95-3.00           | n/a         | 0.0028        | n/a           | 0.0015" – 0.1250"        |
| <b>TL-32</b>        | <b>3.20</b>         | <b>3.20</b> | <b>0.0030</b> | <b>0.0022</b> | <b>0.0040" – 0.0900"</b> |
| <b>RF-35</b>        | 3.50                | 3.50        | 0.0028        | 0.0018        | 0.0100" – 0.1200"        |
| <b>RF-35P</b>       | 3.50                | 3.50        | 0.0035        | 0.0025        | 0.0020" – 0.1250"        |

Table 2 – Material properties

## Handling of TacLam® TL-32 Laminates

PTFE is a thermoplastic material which is very stable electrically and chemically when compared with common thermosetting resins such as epoxy, polyphenyleneoxide, polyimide and cyanate ester. Part of what gives PTFE its superior performance over frequency and temperature also makes the pure resin relatively soft and dimensionally unstable. It is for this reason that all Taconic laminates are reinforced with glass fabric. The glass fabric reinforcement of the substrate greatly increases stability in the X and Y axis over non-woven or unreinforced PTFE products. While the glass fabric provides very good dimensional stability and increased stiffness, the relative softness of the PTFE resin requires that the following process and handling precautions should be taken to prevent damage or deformation of the laminate during fabrication.

- **Do not mechanically scrub the material**

As with thin core or flexible substrates, mechanically scrubbing will stretch and deform the material. The pinch rollers used to move the panel during scrubbing can also cause dents as particle or brush material are pressed into the surface of the laminate. Chemical cleaning is preferred. Eliminating mechanical cleaning and unnecessary handling will improve the dimensional accuracy of subsequent processes by preventing mechanical distortion of the laminate.

- **Do not pick up a panel horizontally by one end or edge**

By allowing the material to flop over you may stretch the copper and substrate. Lift the panel by two parallel edges; preferably the two closest dimensionally.

- **Prevent contaminant deposits on the material or copper**

The use of clean protective gloves and slip sheets will prevent contamination and staining. You will not need to remove oils, grease or fingerprints if you don't deposit them.

- **Do not stack panels directly on top of each other**

Particles or debris on the surface of the panel can become imprinted into the copper and substrate of adjacent panels. The preferred method of storage is to rack the panels vertically. If panels must be stacked use clean, soft, slip sheet material between each panel and keep stack height to a minimum.

## Inner Layer Preparation

Multilayer applications require that two or more laminates be bonded together to form a single circuit board. There are two important considerations when processing the circuit board. The first is registration of the features from one layer to another. The second is the condition of the bond surface prior to lamination.

**Registration:** Layer to layer registration is often a critical requirement of the finished circuit board and misregistration can cause a variety of issues such as open circuits and poor coupler performance. Therefore, it is important that the material be acclimated to the processing environment and the correct artwork compensation used. Acclimation to the processing environment is simply making sure that the laminate is at ambient temperature prior to processing. It is recommended that if the laminate has seen extreme temperatures during shipment or storage, it should be placed in ambient conditions for 24 hours prior to processing.

All laminates experience movement after the copper foil has been etched. Various factors such as laminate thickness, glass style, construction, copper foil thickness, and circuit design all contribute to the characteristic known as dimensional stability. The dimensional change data for TacLam® laminates is listed below in Table 3. The data is reference only and, again, is dependent on the factors listed above. Most printed circuit board shops determine artwork compensation data by running samples or estimating based on previous experience.

| Material Designation | Dimensional Change in Parts Per Million (PPM) |
|----------------------|---|
| TLC                  | 200 – 400                                     |
| TLE                  | 220 – 400                                     |
| TLT                  | 400 – 600                                     |
| TLX                  | 400 – 600                                     |
| TLY                  | 400 - 800                                     |
| RF-35, 35P           | 200 – 400                                     |
| RF60                 | 400 – 600                                     |
| Cer-10               | 400 – 600                                     |
| <b>TacLam® TL-32</b> | <b>200 – 400</b>                              |

Table 3 – Typical dimensional change

## Lamination

TacLam® TL-32 laminate is used in conjunction with TacPreg® TP-32 prepreg to produce multilayer boards for the digital market. TacLam® TL-32 laminate and TacPreg® TP-32 prepreg, when used in a symmetrical board design, will result in optimum electrical and mechanical performance. Because of the thermoset properties of the bonding agent, multiple bonding cycles can be achieved without worry of delamination. In addition, the recommended press temperature of 392°F [200°C] is within reach of most board shops.

### Taconic recommends the following press cycle:

- Vacuum Lamination Recommended
- Heat rise 3°F - 10°F / minute [1.5°C – 5.5°C] to 392°F [200°C] \*
  - Flow window is 130°F [80°C] – 302°F [150°C]
- Maintain pressure at 73 psi [5 bar] until package reaches 100°F [37°C] then apply full pressure of 450 psi [31 bar]
- Hold (cure) for 1 hour
- Cool package under full pressure at < 6°F [3°C] / minute

\*For high layer count boards, best flow and fill has been seen at low heat-up rates. For low layer count multilayers, a low heat-up rate is less critical.

The prepreg cure is not very advanced. For best gap filling it is desirable to achieve the maximum amount of flow prior to the advancement of the resin. The earliest application of pressure will help, certainly below the melt of the epoxy (140°F [60°C]), coupled with a 3°F - 10°F [1.5°C -5.5°C] rate of rise. A cold start of the press is desirable. A hot start of the press will advance the cure of the resin before the best flow is achieved and the optimal amount of flow will not be achieved.

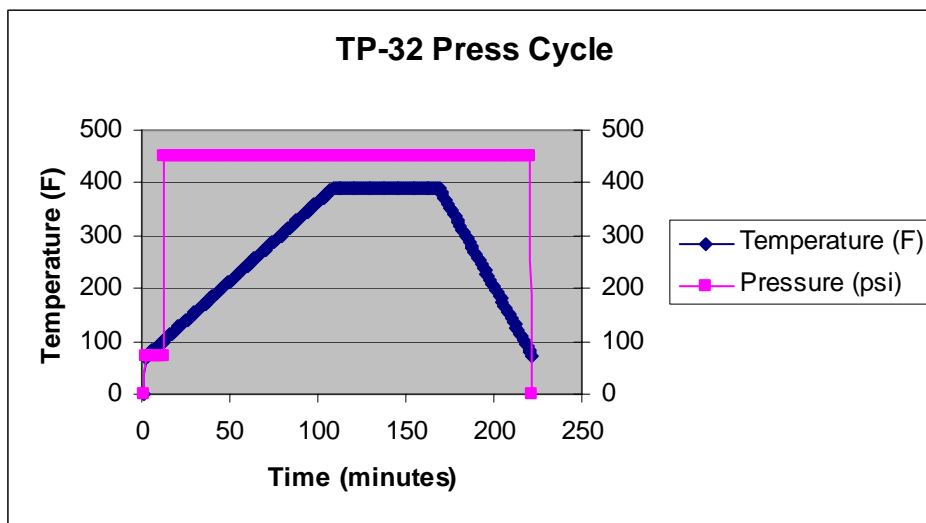


Figure 1 – TacPreg Press Cycle

## Drilling

Good hole quality can be achieved using Taconic recommended drill parameters. Standard 130° point geometry, PCB carbide drills work well with all Taconic PTFE-based laminates. Under cut drills help clear debris and reduce drill temperature and are recommended, although straight shank drills may also be acceptable. Drill wrap, or birdnesting, is common with PTFE-based materials and difficult to eliminate. Using maximum vacuum on the drill machine, quality drill bits, and optimizing the speeds and feeds is recommended if the birdnesting affects the plated hole quality. The primary objective in drilling is to keep heat build up on the drill to a minimum. Hole quality is affected by drill sharpness; therefore Taconic recommends using new, brand name drills for the best hole quality. Stack height should not exceed 2/3 the flute length of the smallest diameter drill being used. The pressure of the drill foot should be a minimum of 40 psi [2.75bar]. Standard phenolic entry material ( $\approx 0.020$ " [0.5mm] thickness) has been found to be marginal. The recommended entry material is aluminum/paper/aluminum entry, or even a 0.012" [0.3mm] thick aluminum entry for multilayers thicker than 0.060" [1.58mm]. Studies using a lubricated entry material have been encouraging and should be investigated if hole quality is not satisfactory. A hard phenolic backup board ( $\approx 0.090$ " to 0.125" [2.3mm – 3.2mm] thickness) is recommended to reduce bottom-side burring.

### **Taconic recommends the following drill conditions:**

- Entry material: Aluminum sheet or aluminum-paper-aluminum or lubricated entry material or a combination thereof
- One high stack
- Backup material: Hard phenolic of thickness from 0.060" to 0.125"
- Drill parameters as found in the drill appendix. For microdrilling (<0.020" diameter) use the highest speed column parameters that equipment will allow
- Optimize drill parameters to reduce or eliminate birdnesting, burrs, and smearing
- Peck drilling

The number of hits per drill will vary depending on the drill parameters, hole size, stack height, and laminate thickness. A worn drill bit usually results in an abnormally high number of nodules or gouges which may not be noticed until after plating. A typical hit count can range from 200 – 700 hits for TacLam® TL-32, depending on drill size and board thickness.

All drilling debris must be removed prior to hole wall preparation such as plasma or sodium treatment. Thoroughly remove all debris in the holes with a high pressure air or water blast. If water is used, bake the laminate for 1 hour at 250° F [120°C] to remove moisture prior to through hole treatment.

Burring can occur if drilling conditions are not correct. If burring occurs, sanding is not recommended. Pumice scrubbing has been known to be effective, however Taconic does not recommend any process that may cause distortion of the laminate. The best solution to prevent burrs is by thoroughly understanding and implementing the optimum drilling process and parameters for your equipment.

Smearing is a condition where the PTFE resin has been heated to a point where it softens and is easily moved within the hole. It usually appears as a line between the copper foil and the plated copper. Assuming that sharp drill bits are being used, the solution is to reduce the speed (thus surface feet per minute) of the drill to prevent heat buildup. The chip load will increase so careful inspection for protrusions should be done after the electroless plating step, if possible. Protrusions may not be noticeable until after the electroless plating process, even if a high magnification microscope is used. See Section 6 for hole-wall preparation. Hole wall tear-out, or gouging, is another possible defect caused during the drilling process. Gouging is usually an indicator of either a dull drill or an excessively high chip load. Another factor that can influence gouging is the fiberglass weave style. A coarse glass is more prone to gouging than a medium or fine glass style. If gouging occurs, first check for worn drill bits before adjusting the drill parameters. If gouging persists, reduce the chip load. Care should be taken to keep drill bit temperatures to a minimum by keeping the surface feet per minute low while adjusting chip loads downward.

Due to the thickness of high-count digital multilayer boards, peck drilling may be required for acceptable hole wall quality. The thermoplastic nature of the PTFE resin and the thickness of the board may result in the inability of the drill bit to clear debris which may result in smearing and burrs. Peck drilling with a full withdrawal of the drill bit after each peck will reduce heat buildup and debris accrual. A general rule of thumb for peck depth is 20 to 30 mils per peck and should be optimized at the board shop.

Figure 2 is a typical example of a multilayer board made with TacLam® TL-32 and TacPreg® TP-32.

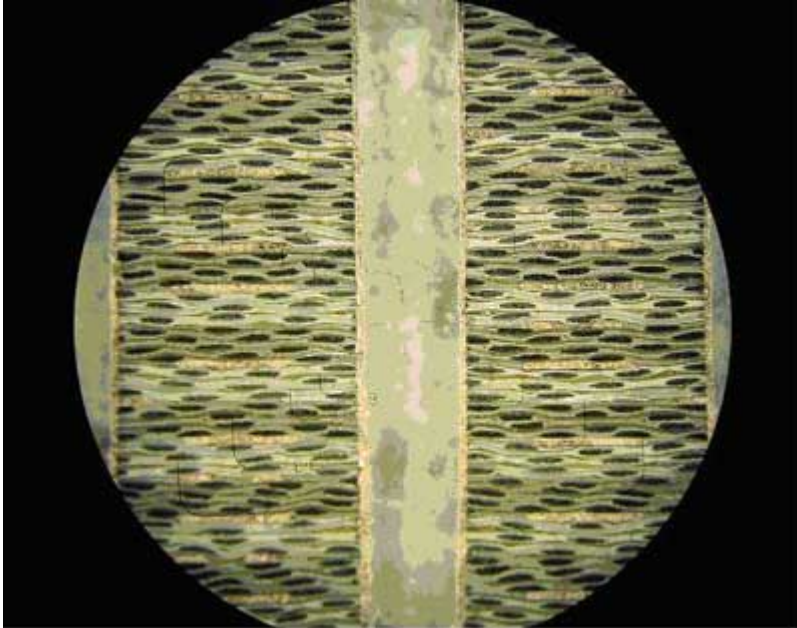


Figure 2 – Multilayer board made with TacLam® TL-32 and TacPreg® TP-32

## Hole Wall Preparation

Due to the relative softness of PTFE resin, small fiberglass protrusions may occasionally occur. These protrusions will plate up and cause small nodules in the holes that may result in finished hole sizes being smaller than desired. If changes in drill parameters do not eliminate the fiber protrusions, it is recommended that the drilled hole size be increased to the maximum tolerance so that the finished hole size is within specification. Another method to reduce the size of the fiberglass protrusion is to use a glass etch process. Care should be taken to not overetch the glass as uneven hole walls or wicking into the fiber bundle may occur.

PTFE based laminates require that drilled holes be subjected to a process that will prepare the PTFE resin system for subsequent plating. Since TacLam® TL-32 contains PTFE resin; it requires treatment prior to plating. There are two hole wall treatment processes that have been shown capable of providing void-free copper plating. One process is chemical in nature and involves a sodium-based solution that strips the fluorine atoms from the PTFE molecules. This process has been used for many years in the industry with great success. The advantages of sodium etching include long shelf life of the hole wall treatment, fast treatment time, and complete coverage. The primary disadvantage of sodium etchant is the volatility of the chemical. Various manufacturers and etchant services are available.

Another method of preparing the holes for plating is plasma etching. If the proper gases and cycles are used, plasma will allow plating to the PTFE resin. Experience has

shown that the best gases to use are a mixture of hydrogen and nitrogen. Helium can also be used in many cases. The advantage of plasma etching is that it is a relatively safe procedure. Disadvantages include relatively long cycle times (35 to 60 minutes) and short shelf life of the effect (4 – 24 hours).

The TacLam® TL-32 product also contains a thermoset resin as the bonding agent. This requires a desmear process in addition to the PTFE treatment. There are also two common methods of desmearing thermoset resin systems. One of the desmear processes involves dipping the boards in a permanganate chemical which dissolves the resin. The second method is plasma. Generally speaking, the gases used to desmear the thermoset resin do not affect the PTFE resin, nor do the gases used for treating the PTFE resin desmear the thermoset resin very well if at all. Also, the sodium solution commonly used to treat the PTFE resin will not affect the thermoset resins system. No matter which method is used for desmearing the thermoset resin, the BT/epoxy resin should be desmeared prior to treatment of the PTFE resin.

Permanganate desmear has been shown to be very aggressive, due to the relatively small amount of BT/epoxy in the product, and can cause excessive etchback. Permanganate will not affect the PTFE resin found in TacLam. Desmearing of the BT epoxy can be more closely controlled with a plasma desmear cycle. In addition, hole wall treatment of the PTFE can also be done successfully with plasma and it is possible to have back-to-back desmear and hole treatment without removing the product from the plasma machine.

**Taconic recommends the following hole wall treatment:**

- Thoroughly clean holes prior to treatment. If water cleaning is used, bake the boards at 220°F (105°C) for 1 hour
- Plasma treat the epoxy component using a standard epoxy desmear gases and power and a 15 minute cycle time to reduce overetching of the epoxy
- Continue plasma cycle with a PTFE cycle shown below

**Sodium Treatment:** A sodium-based chemical treatment process does an excellent job of preparing the PTFE through-hole surface prior to the plated through hole process. Follow the manufacturer's recommended treatment process. Bake for 1 hour at 250° F [120°C] prior to plating to remove moisture that may have been absorbed during the sodium treatment process. NOTE: Do not subject the treated holes to heavily concentrated chlorine-based chemical processes prior to electroless copper plating or direct metallization. Chlorine can have adverse effects on the sodium treatment and result in plating voids.

**Plasma Etching:** Plasma treatment of the PTFE resin using a 30-70% Hydrogen, 70-30% Nitrogen gas mixture has been shown to be very effective. If Hydrogen is not available, a 100% Helium should also suffice. Power setting for the RF-signal generator

should be 60-75% of full rated power for 30-60 minutes depending on the hole diameter, number of holes, and thickness of the board. Boards with relatively higher aspect ratios will require longer plasma cycle times. Industry experience has shown that gases such as helium and CF<sub>4</sub> are not as effective as hydrogen as evidenced by sporadic plating voids and higher contact angles.

**Note:** Regardless of which method of hole wall treatment is used, desmearing of the thermoset resin should be done prior to treatment of the PTFE resin.

## Plating

After the hole wall has been properly prepared, TacLam® TL-32 will accept either electroless copper or direct metallization plating. The electrolytic plating process is the same for PTFE or epoxy based materials. Typical plating consists of 1 – 1.5 mils [25µm - 35µm] of copper plate in the holes and/or on the surface.

## Image, Develop, Etch, Strip

Prepare the copper surface, apply dry film, and image and develop using a standard process. The copper surface preparation should consist of microetching the copper. Scrubbing is not recommended for thin core PTFE-based materials or multilayer inner layers due to possible registration issues.

The etching process is the same as for a standard printed circuit board. Machine settings should be appropriate for the copper thickness of the multilayer inner layers. Strip the photoresist using a standard process.

## Solder Mask

TacLam® TL-32 readily accepts LPI soldermask and requires no special treatment.

## Solder Reflow

Hot air solder leveling is a common method of protecting exposed copper circuitry. Two basic types of hot air level machines are used in the industry, horizontal and vertical. By far the more popular of the two is the vertical machine. It is less expensive and easier to maintain than the horizontal type. However, the vertical machine subjects the printed circuit board to a more severe level of thermal shock than the horizontal. Once the board is clamped in the vertical machine, the only preheat the board sees is the few seconds above the solder pot prior to immersion. Typical immersion times are 5 – 6 seconds from entry into the solder pot to complete withdrawal. This minimal preheat

time can be particularly harsh on PTFE based laminates due to their z axis expansion characteristics. When using hot air solder leveling on PTFE laminates, Taconic recommends a bake cycle of 2 – 3 hours at 300° F [150°C] just prior to the HASL process. The solder pot temperature should be maintained at 460° – 480° F [238°C – 250°C] for optimal performance. Cycle time should be 5 – 6 seconds from the time of entry to the complete withdrawal of the board. Dwell time in the solder pot should not exceed 2 seconds.

## Machining

Machining of TacLam® TL-32 is typically more difficult than epoxy-based substrates due to the softness of the PTFE resin system. The style of fiberglass used in the substrate also affects the quality of routing with respect to burrs and fibers. The heavier the fiberglass weave, the more difficult it is to cut.

TacLam® can be successfully machined using standard router bits or end mills when the recommended methods and rout parameters are used. In addition to the rout parameters, an equally important factor in successful routing is having intimate contact throughout the routed package. The following illustration shows a typical rout stack with phenolic entry and backer material on either side of the circuit board. Notice that the entry material rides on top of the copper traces leaving an air gap between the entry material and the PTFE substrate. Many circuit board applications also have soldermask on top of the copper traces which increases the gap further. The solution to a cleaner cut is to introduce a material between the copper traces and the phenolic entry material that will conform at the edge and will help fill in the air gap. As the router pressure foot applies pressure, the edge of the phenolic entry and the paper will conform and help fill the air gap, allowing for a cleaner cut of the substrate edge. One type of paper that has been shown to work well is the paper found between artwork film. It is thick and will conform enough to help fill in the normal air gap and cuts without generating as much debris as other paper such as Kraft paper.

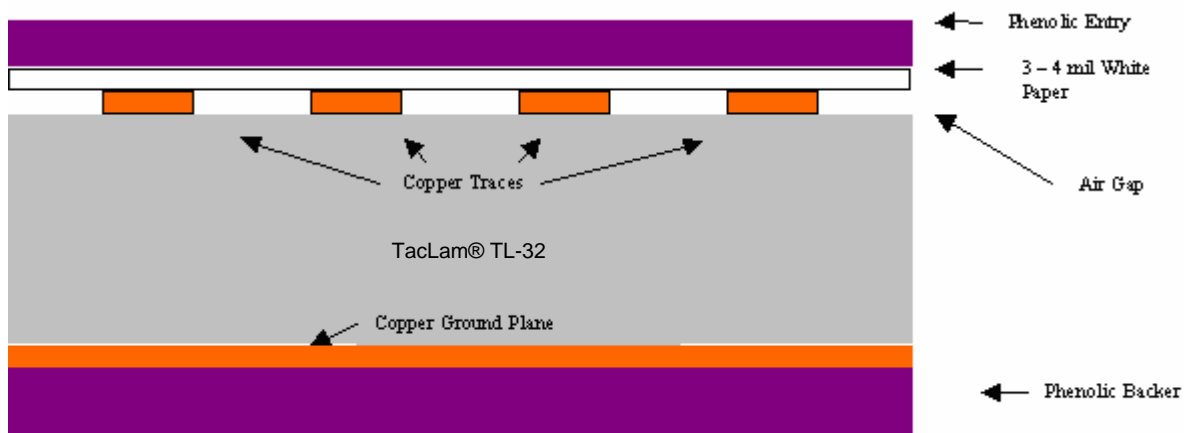


Figure 3 – Typical rout stack

The following routing parameters in Tables 4 and 5 have been proven to work well on PTFE double-sided boards and are good starting points for TacLam® multilayer boards with thicknesses of 0.060" [1.58mm] or less. For thicker multilayers, a single flute, 3/32" [2.38mm] carbide bit or a diamond burr tool has been shown to work well at an infeed rate of 24" [0.6m] per minute and a speed of 45,000 rpm.

| Recommended Routing Parameters for All Taconic Materials |                     |                     |                    |                     |                    |                              |                           |
|--|---------------------|---------------------|--------------------|---------------------|--------------------|------------------------------|---------------------------|
| Tool Diameter (mils)                                     | Chipload (mils/rev) | Spindle Type        |                    |                     |                    | Z – Feed Rate                |                           |
|  |                     | 60,000 max          |                    | 80,000 max          |                    | Without predrilling (in/min) | With predrilling (in/min) |
|  |                     | Spindle Speed (rpm) | Feed Rate (in/min) | Spindle Speed (rpm) | Feed Rate (in/min) |                              |                           |
| 31.5   | 0.24                | 50000               | 11.8               | 50000               | 11.8               | 0.0                          | 20                        |
| 35.4   | 0.26                | 45000               | 11.8               | 45000               | 11.8               | 0.0                          | 20                        |
| 39.4   | 0.30                | 40000               | 11.8               | 40000               | 11.8               | 0.0                          | 79                        |
| 43.3   | 0.32                | 37000               | 11.8               | 37000               | 11.8               | 0.0                          | 79                        |
| 47.2   | 0.35                | 34000               | 11.8               | 34000               | 11.8               | 0.0                          | 79                        |
| 51.2   | 0.51                | 31000               | 15.8               | 31000               | 15.8               | 0.0                          | 79                        |
| 55.1   | 0.54                | 29000               | 15.8               | 29000               | 15.8               | 0.0                          | 79                        |
| 59.1   | 0.59                | 27000               | 15.8               | 27000               | 15.8               | 0.0                          | 79                        |
| 63   | 0.79                | 25000               | 19.7               | 25000               | 19.7               | 0.0                          | 197                       |
| 66.9   | 0.82                | 24000               | 19.7               | 24000               | 19.7               | 0.0                          | 197                       |
| 70.8   | 1.03                | 23000               | 23.6               | 23000               | 23.6               | 0.0                          | 197                       |
| 74.8   | 1.12                | 21000               | 23.6               | 21000               | 23.6               | 0.0                          | 197                       |
| 78.7   | 1.38                | 20000               | 27.6               | 20000               | 27.6               | 0.0                          | 197                       |
| 82.7   | 1.58                | 20000               | 31.5               | 20000               | 31.5               | 0.0                          | 197                       |
| 86.6   | 1.58                | 20000               | 31.5               | 20000               | 31.5               | 0.0                          | 197                       |
| 90.6   | 1.58                | 20000               | 31.5               | 20000               | 31.5               | 0.0                          | 197                       |
| 94.5   | 1.77                | 20000               | 35.4               | 20000               | 35.4               | 0.0                          | 197                       |
| 98.4   | 1.77                | 20000               | 35.4               | 20000               | 35.4               | 0.0                          | 197                       |
| 118.1  | 2.17                | 20000               | 43.3               | 20000               | 43.3               | 0.0                          | 197                       |
| 125  | 2.17                | 20000               | 43.3               | 20000               | 43.3               | 0.0                          | 197                       |

Table 4 – Recommended routing parameters for all Taconic materials

| Suggested Routing Parameters for All Taconic Materials (metric) |  |                           |                         |                           |                         |                                   |                                |
|---|--|---------------------------|-------------------------|---------------------------|-------------------------|-----------------------------------|--------------------------------|
| Tool Diameter<br>(mm)   | Chipload<br>( $\mu\text{m}/\text{rev}$ ) | Spindle Type              |                         |                           |                         | Z – Feed Rate                     |                                |
|   |  | 60,000 max                |                         | 80,000 max                |                         | Without<br>predrilling<br>(m/min) | With<br>predrilling<br>(m/min) |
|   |  | Spindle<br>Speed<br>(rpm) | Feed<br>Rate<br>(m/min) | Spindle<br>Speed<br>(rpm) | Feed<br>Rate<br>(m/min) |                                   |                                |
| 0.80  | 5  | 50000                     | 0.25                    | 50000                     | 0.25                    | 0                                 | 0.50                           |
| 0.90  | 6  | 45000                     | 0.27                    | 45000                     | 0.27                    | 0                                 | 0.50                           |
| 1.00  | 8  | 40000                     | 0.32                    | 40000                     | 0.32                    | 0                                 | 2.00                           |
| 1.10  | 9  | 37000                     | 0.33                    | 37000                     | 0.33                    | 0                                 | 2.00                           |
| 1.20  | 10                                       | 34000                     | 0.34                    | 34000                     | 0.34                    | 0                                 | 2.00                           |
| 1.30  | 12                                       | 31000                     | 0.37                    | 31000                     | 0.37                    | 0                                 | 2.00                           |
| 1.40  | 14                                       | 29000                     | 0.41                    | 29000                     | 0.41                    | 0                                 | 2.00                           |
| 1.50  | 16                                       | 27000                     | 0.43                    | 27000                     | 0.43                    | 0                                 | 2.00                           |
| 1.60  | 18                                       | 25000                     | 0.45                    | 25000                     | 0.45                    | 0                                 | 5.00                           |
| 1.70  | 22                                       | 24000                     | 0.53                    | 24000                     | 0.53                    | 0                                 | 5.00                           |
| 1.80  | 26                                       | 23000                     | 0.60                    | 23000                     | 0.60                    | 0                                 | 5.00                           |
| 1.90  | 30                                       | 21000                     | 0.63                    | 21000                     | 0.63                    | 0                                 | 5.00                           |
| 2.00  | 34                                       | 20000                     | 0.68                    | 20000                     | 0.68                    | 0                                 | 5.00                           |
| 2.10  | 38                                       | 20000                     | 0.76                    | 20000                     | 0.76                    | 0                                 | 5.00                           |
| 2.20  | 40                                       | 20000                     | 0.80                    | 20000                     | 0.80                    | 0                                 | 5.00                           |
| 2.30  | 42                                       | 20000                     | 0.84                    | 20000                     | 0.84                    | 0                                 | 5.00                           |
| 2.40  | 44                                       | 20000                     | 0.88                    | 20000                     | 0.88                    | 0                                 | 5.00                           |
| 2.50  | 46                                       | 20000                     | 0.92                    | 20000                     | 0.92                    | 0                                 | 5.00                           |
| 3.00  | 53                                       | 20000                     | 1.06                    | 20000                     | 1.06                    | 0                                 | 5.00                           |
| 3.18  | 55                                       | 20000                     | 1.10                    | 20000                     | 1.10                    | 0                                 | 5.00                           |

Table 5 – Recommended routing parameters for all Taconic materials (metric)

## Appendix

| TacLam® TL-32 Microdrilling Parameters |                   |                        |                       |                        |                       |                        |                       |                          |
|--|-------------------|------------------------|-----------------------|------------------------|-----------------------|------------------------|-----------------------|--------------------------|
| Drill Size<br>(in)                     | Chipload<br>(mil) | 80,000 max             |                       | 110,000 max            |                       | 125,000 max            |                       | Retract Rate<br>(in/min) |
|  |                   | Spindle Speed<br>(rpm) | Feed Rate<br>(in/min) | Spindle Speed<br>(rpm) | Feed rate<br>(in/min) | Spindle Speed<br>(rpm) | Feed Rate<br>(in/min) |                          |
| 0.0039                                 | 0.3               | 80,000                 | 24                    | 110,000                | 35                    | 125,000                | 39                    | 118                      |
| 0.0059                                 | 0.5               | 80,000                 | 39                    | 110,000                | 55                    | 125,000                | 63                    | 177                      |
| 0.0079                                 | 0.7               | 80,000                 | 59                    | 110,000                | 79                    | 125,000                | 91                    | 236                      |
| 0.0098                                 | 1.0               | 80,000                 | 79                    | 110,000                | 106                   | 125,000                | 122                   | 295                      |
| 0.0118                                 | 1.2               | 80,000                 | 94                    | 110,000                | 130                   | 125,000                | 146                   | 354                      |
| 0.0138                                 | 1.3               | 80,000                 | 106                   | 110,000                | 146                   | 119,000                | 157                   | 413                      |
| 0.0157                                 | 1.5               | 80,000                 | 118                   | 104,000                | 154                   | 104,000                | 154                   | 472                      |
| 0.0177                                 | 1.7               | 80,000                 | 134                   | 92,000                 | 154                   | 92,000                 | 154                   | 531                      |
| 0.0197                                 | 1.9               | 80,000                 | 150                   | 83,000                 | 157                   | 83,000                 | 157                   | 590                      |

Table 6 – TacLam® TL-32 microdrilling parameters

| TacLam® TL-32 Drilling Parameters |                   |                        |                       |                          |                    |                   |                        |                       |                          |
|-----------------------------------|-------------------|------------------------|-----------------------|--------------------------|--------------------|-------------------|------------------------|-----------------------|--------------------------|
| Drill Size<br>(in)                | Chipload<br>(mil) | Spindle speed<br>(rpm) | Feed rate<br>(in/min) | Retract Rate<br>(in/min) | Drill Size<br>(in) | Chipload<br>(mil) | Spindle speed<br>(rpm) | Feed rate<br>(in/min) | Retract Rate<br>(in/min) |
| 0.0217                            | 1.8               | 80,000                 | 140                   | 400.0                    | 0.0748             | 2.4               | 27,000                 | 65                    | 500.0                    |
| 0.0236                            | 1.8               | 77,500                 | 141                   | 400.0                    | 0.0768             | 2.5               | 26,000                 | 65                    | 500.0                    |
| 0.0256                            | 1.9               | 75,000                 | 140                   | 400.0                    | 0.0787             | 2.5               | 26,000                 | 65                    | 500.0                    |
| 0.0276                            | 1.9               | 72,500                 | 135                   | 400.0                    | 0.0807             | 2.5               | 26,000                 | 65                    | 500.0                    |
| 0.0295                            | 1.9               | 70,000                 | 130                   | 400.0                    | 0.0827             | 2.6               | 25,000                 | 65                    | 500.0                    |
| 0.0315                            | 1.9               | 66,000                 | 125                   | 400.0                    | 0.0846             | 2.7               | 24,000                 | 65                    | 500.0                    |
| 0.0335                            | 1.9               | 62,000                 | 120                   | 400.0                    | 0.0866             | 2.7               | 24,000                 | 65                    | 500.0                    |
| 0.0354                            | 2.0               | 60,000                 | 120                   | 500.0                    | 0.0886             | 2.8               | 23,000                 | 65                    | 500.0                    |
| 0.0374                            | 2.0               | 57,000                 | 115                   | 500.0                    | 0.0906             | 2.8               | 23,000                 | 65                    | 500.0                    |
| 0.0394                            | 2.0               | 54,000                 | 110                   | 500.0                    | 0.0925             | 2.7               | 22,000                 | 60                    | 500.0                    |
| 0.0413                            | 2.1               | 51,000                 | 105                   | 500.0                    | 0.0945             | 2.8               | 21,500                 | 60                    | 500.0                    |
| 0.0433                            | 2.1               | 48,000                 | 100                   | 500.0                    | 0.0965             | 2.6               | 21,000                 | 55                    | 500.0                    |
| 0.0453                            | 2.1               | 45,000                 | 95                    | 500.0                    | 0.0984             | 2.7               | 20,500                 | 55                    | 500.0                    |
| 0.0472                            | 2.1               | 43,000                 | 90                    | 500.0                    | 0.1004             | 2.5               | 20,000                 | 50                    | 500.0                    |
| 0.0492                            | 2.0               | 42,000                 | 85                    | 500.0                    | 0.1024             | 2.5               | 20,000                 | 50                    | 500.0                    |
| 0.0512                            | 2.0               | 40,000                 | 80                    | 500.0                    | 0.1043             | 2.5               | 20,000                 | 50                    | 500.0                    |
| 0.0531                            | 2.1               | 39,000                 | 80                    | 500.0                    | 0.1063             | 2.3               | 19,500                 | 45                    | 500.0                    |
| 0.0551                            | 2.1               | 38,000                 | 80                    | 500.0                    | 0.1083             | 2.3               | 19,500                 | 45                    | 500.0                    |
| 0.0571                            | 2.2               | 36,000                 | 80                    | 500.0                    | 0.1102             | 2.4               | 19,000                 | 45                    | 500.0                    |
| 0.0591                            | 2.4               | 34,000                 | 80                    | 500.0                    | 0.1122             | 2.2               | 18,500                 | 40                    | 500.0                    |
| 0.0610                            | 2.3               | 32,000                 | 75                    | 500.0                    | 0.1142             | 2.2               | 18,500                 | 40                    | 500.0                    |
| 0.0630                            | 2.3               | 32,000                 | 75                    | 500.0                    | 0.1161             | 2.2               | 18,000                 | 40                    | 500.0                    |
| 0.0650                            | 2.3               | 32,000                 | 75                    | 500.0                    | 0.1181             | 2.0               | 17,500                 | 35                    | 500.0                    |
| 0.0669                            | 2.4               | 31,000                 | 75                    | 500.0                    | 0.1201             | 2.0               | 17,500                 | 35                    | 500.0                    |
| 0.0689                            | 2.3               | 30,000                 | 70                    | 500.0                    | 0.1220             | 2.1               | 17,000                 | 35                    | 500.0                    |
| 0.0709                            | 2.4               | 29,000                 | 70                    | 500.0                    | 0.1240             | 1.8               | 17,000                 | 30                    | 500.0                    |
| 0.0728                            | 2.5               | 28,000                 | 70                    | 500.0                    | 0.1250             | 1.9               | 16,000                 | 30                    | 500.0                    |

Table 7 – TacLam® TL-32 drilling parameters

| TacLam® TL-32 Microdrilling Parameters (Metric) |                  |                        |                      |                        |                      |                        |                      |                         |
|---|------------------|------------------------|----------------------|------------------------|----------------------|------------------------|----------------------|-------------------------|
| Drill Size<br>(mm)                              | Chipload<br>(um) | 80,000 max             |                      | 110,000 max            |                      | 125,000 max            |                      | Retract Rate<br>(m/min) |
|   |                  | Spindle Speed<br>(rpm) | Feed Rate<br>(m/min) | Spindle Speed<br>(rpm) | Feed Rate<br>(m/min) | Spindle Speed<br>(rpm) | Feed Rate<br>(m/min) |                         |
| 0.10  | 7.6              | 80,000                 | 0.61                 | 110,000                | 0.89                 | 125,000                | 1.00                 | 2.99                    |
| 0.15  | 12.5             | 80,000                 | 1.00                 | 110,000                | 1.40                 | 125,000                | 1.60                 | 4.49                    |
| 0.20  | 18.8             | 80,000                 | 1.50                 | 110,000                | 2.00                 | 125,000                | 2.30                 | 5.98                    |
| 0.25  | 25.0             | 80,000                 | 2.00                 | 110,000                | 2.70                 | 125,000                | 3.10                 | 7.48                    |
| 0.30  | 30.0             | 80,000                 | 2.40                 | 110,000                | 3.30                 | 125,000                | 3.70                 | 8.98                    |
| 0.35  | 33.7             | 80,000                 | 2.70                 | 110,000                | 3.70                 | 119,000                | 4.00                 | 10.47                   |
| 0.40  | 37.5             | 80,000                 | 3.00                 | 104,000                | 3.90                 | 104,000                | 3.90                 | 11.97                   |
| 0.45  | 42.5             | 80,000                 | 3.40                 | 92,000                 | 3.90                 | 92,000                 | 3.90                 | 13.47                   |
| 0.50  | 47.5             | 80,000                 | 3.80                 | 83,000                 | 4.00                 | 83,000                 | 4.00                 | 14.96                   |

Table 8 – TacLam® TL-32 microdrilling parameters (metric)

| TacLam® TL-32 Drilling Parameters (Metric) |                  |                        |                      |                         |                    |                  |                        |                      |
|--|------------------|------------------------|----------------------|-------------------------|--------------------|------------------|------------------------|----------------------|
| Drill Size<br>(mm)                         | Chipload<br>(um) | Spindle speed<br>(rpm) | Feed Rate<br>(m/min) | Retract Rate<br>(m/min) | Drill Size<br>(mm) | Chipload<br>(um) | Spindle Speed<br>(rpm) | Feed Rate<br>(m/min) |
| 0.55                                       | 44.4             | 80,000                 | 3.55                 | 10.2                    | 1.90               | 61.1             | 27,000                 | 1.65                 |
| 0.60                                       | 46.2             | 77,500                 | 3.58                 | 10.2                    | 1.95               | 63.5             | 26,000                 | 1.65                 |
| 0.65                                       | 47.4             | 75,000                 | 3.55                 | 10.2                    | 2.00               | 63.5             | 26,000                 | 1.65                 |
| 0.70                                       | 47.3             | 72,500                 | 3.43                 | 10.2                    | 2.05               | 63.5             | 26,000                 | 1.65                 |
| 0.75                                       | 47.1             | 70,000                 | 3.30                 | 10.2                    | 2.10               | 66.0             | 25,000                 | 1.65                 |
| 0.80                                       | 48.1             | 66,000                 | 3.17                 | 10.2                    | 2.15               | 68.7             | 24,000                 | 1.65                 |
| 0.85                                       | 49.1             | 62,000                 | 3.05                 | 10.2                    | 2.20               | 68.7             | 24,000                 | 1.65                 |
| 0.90                                       | 50.8             | 60,000                 | 3.05                 | 12.7                    | 2.25               | 71.7             | 23,000                 | 1.65                 |
| 0.95                                       | 51.2             | 57,000                 | 2.92                 | 12.7                    | 2.30               | 71.7             | 23,000                 | 1.65                 |
| 1.00                                       | 51.7             | 54,000                 | 2.79                 | 12.7                    | 2.35               | 69.2             | 22,000                 | 1.52                 |
| 1.05                                       | 52.3             | 51,000                 | 2.66                 | 12.7                    | 2.40               | 70.8             | 21,500                 | 1.52                 |
| 1.10                                       | 52.9             | 48,000                 | 2.54                 | 12.7                    | 2.45               | 66.5             | 21,000                 | 1.40                 |
| 1.15                                       | 53.6             | 45,000                 | 2.41                 | 12.7                    | 2.50               | 68.1             | 20,500                 | 1.40                 |
| 1.20                                       | 53.1             | 43,000                 | 2.28                 | 12.7                    | 2.55               | 63.5             | 20,000                 | 1.27                 |
| 1.25                                       | 51.4             | 42,000                 | 2.16                 | 12.7                    | 2.60               | 63.5             | 20,000                 | 1.27                 |
| 1.30                                       | 50.8             | 40,000                 | 2.03                 | 12.7                    | 2.65               | 63.5             | 20,000                 | 1.27                 |
| 1.35                                       | 52.1             | 39,000                 | 2.03                 | 12.7                    | 2.70               | 58.6             | 19,500                 | 1.14                 |
| 1.40                                       | 53.4             | 38,000                 | 2.03                 | 12.7                    | 2.75               | 58.6             | 19,500                 | 1.14                 |
| 1.45                                       | 56.4             | 36,000                 | 2.03                 | 12.7                    | 2.80               | 60.1             | 19,000                 | 1.14                 |
| 1.50                                       | 59.7             | 34,000                 | 2.03                 | 12.7                    | 2.85               | 54.9             | 18,500                 | 1.02                 |
| 1.55                                       | 59.5             | 32,000                 | 1.90                 | 12.7                    | 2.90               | 54.9             | 18,500                 | 1.02                 |
| 1.60                                       | 59.5             | 32,000                 | 1.90                 | 12.7                    | 2.95               | 56.4             | 18,000                 | 1.02                 |
| 1.65                                       | 59.5             | 32,000                 | 1.90                 | 12.7                    | 3.00               | 50.8             | 17,500                 | 0.89                 |
| 1.70                                       | 61.4             | 31,000                 | 1.90                 | 12.7                    | 3.05               | 50.8             | 17,500                 | 0.89                 |
| 1.75                                       | 59.2             | 30,000                 | 1.78                 | 12.7                    | 3.10               | 52.3             | 17,000                 | 0.89                 |
| 1.80                                       | 61.3             | 29,000                 | 1.78                 | 12.7                    | 3.15               | 44.8             | 17,000                 | 0.76                 |
| 1.85                                       | 63.5             | 28,000                 | 1.78                 | 12.7                    | 3.18               | 47.6             | 16,000                 | 0.76                 |

Table 9 – TacLam® TL-32 drilling parameters (metric)