IPC-2222

Sectional Design Standard for Rigid Organic Printed Boards
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- Minimize time to market
- Contain simple (simplified) language
- Just include spec information
- Focus on end product performance
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Adopted October 6, 1998

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Thank you for your continued support.
Sectional Design Standard for Rigid Organic Printed Boards

Developed by the IPC-D-275 Task Group (D-31b) of the Rigid Printed Board Committee (D-30) of IPC

Users of this standard are encouraged to participate in the development of future revisions.

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FOREWORD

This standard is intended to provide information on the detailed requirements for organic rigid printed board design. All aspects and details of the design requirements are addressed to the extent that they can be applied to the unique requirements of those designs that use organic rigid (reinforced) materials or organic materials in combination with inorganic materials (metal, glass, ceramic, etc.) to provide the structure for mounting and interconnecting electronic, electromechanical, and mechanical components.

The information contained herein is intended to supplement generic engineering considerations and design requirements identified in IPC-2221. When coupled with the engineering design input, the complete disclosure should facilitate the appropriate selection process of the materials and the detailed organic rigid structure fabrication technology necessary to meet the engineering design objectives.

The selected component mounting and interconnecting technology for the printed board should be commensurate with the requirements provided and the specific focus of this sectional document.

IPC’s documentation strategy is to provide distinct documents that focus on specific aspect of electronic packaging issues. In this regard document sets are used to provide the total information related to a particular electronic packaging topic. A document set is identified by a four digit number that ends in zero (0).

Included in the set is the generic information which is contained in the first document of the set and identified by the four digit set number. The generic standard is supplemented by one or many sectional documents each of which provide specific focus on one aspect of the topic or the technology selected. The designer of the printed board, needs as a minimum, the generic, the sectional of the chosen technology, the generic engineering considerations, and the engineering description of the final product.

Failure to have all information available prior to starting a design may result in a product that is difficult to manufacture or exceeds the cost predictions or expectations of the printed board.

As technology changes, specific focus standards will be updated, or new focus standards added to the document set. The IPC invites input on the effectiveness of the documentation and encourages user response through completion of “Suggestions for Improvement” forms located at the end of each document.


### Acknowledgment

Any Standard involving a complex technology draws material from a vast number of sources. While the principal members of the IPC-D-275 Task Group (D-31b) of the Rigid Printed Board Committee (D-30) are shown below, it is not possible to include all of those who assisted in the evolution of this Standard. To each of them, the members of the IPC extend their gratitude.

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Sectional Design Standard for Rigid Organic Printed Boards

1.0 SCOPE
This standard establishes the specific requirements for the design of rigid organic printed boards and other forms of component mounting and interconnecting structures. The organic materials may be homogeneous, reinforced, or used in combination with inorganic materials; the interconnections may be single, double, or multilayered.

1.1 Purpose The requirements contained herein are intended to establish specific design details that shall be used in conjunction with IPC-2221 (see 2.0) to produce detailed designs intended to mount and attach passive and active components.

The components may be through-hole, surface mount, fine pitch, ultra-fine pitch, array mounting or un packaged bare die. The materials may be any combination able to perform the physical, thermal, environmental, and electronic function.

1.2 Document Hierarchy Document hierarchy shall be in accordance with the generic standard IPC-2221.

1.3 Presentation Presentation shall be in accordance with the generic standard IPC-2221.

1.4 Interpretation Interpretation shall be in accordance with the generic standard IPC-2221.

1.5 Classification of Products Classification of Products shall be in accordance with the generic standard IPC-2221 and as follows:

1.5.1 Board Type This standard provides design information for different board types. Board types are classified as:

Type 1 — Single-Sided Printed Board
Type 2 — Double-Sided Printed Board
Type 3 — Multilayer Board without Blind or Buried Vias
Type 4 — Multilayer Board with Blind and/or Buried Vias
Type 5 — Multilayer Metal-Core Board without Blind or Buried Vias
Type 6 — Multilayer Metal-Core Board with Blind and/or Buried Vias

1.6 Assembly Types A type designation signifies further sophistication describing whether components are mounted on one or both sides of the packaging and interconnecting structure. Type 1 defines an assembly that has components mounted on only one side; Type 2 is an assembly with components on both sides. Type 2, Class A is not recommended.

Figure 1-1 shows the relationship of two types of assemblies.

The need to apply certain design concepts should depend on the complexity and precision required to produce a particular land pattern or P&I structure. Any design class may be applied to any of the end-product equipment categories; therefore, a moderate complexity (Type 1B) would define components mounted on one side (all surface mounted) and when used in a Class 2 product (dedicated service electronics) is referred to as Type 1B, Class 2. The product described as a Type 1B, Class 2 might be used in any of the end-use applications: the selection of class being dependent on the requirements of the customers using the application.

2.0 APPLICABLE DOCUMENTS
The following documents form a part of this document to the extent specified herein. If a conflict of requirements exist between IPC-2222 and those listed below, IPC-2222 takes precedence.

The revision of the document in effect at the time of solicitation shall take precedence.

2.1 Institute for Interconnecting and Packaging Electronic Circuits (IPC)

IPC-EG-140 Specification For Finished Fabric Woven From “E” Glass for Printed Board
IPC-MF-150 Metal Foil for Printed Wiring Applications
IPC-CF-152 Composite Metallic Materials Specification for Printed Wiring Boards
IPC-D-279 Design Guidelines for Reliable Surface Mount Technology Printed Board Assemblies
IPC-TM-650 Test Methods Manual2
Method 2.1.1 Microsectioning
Method 2.1.6 Thickness of Glass Fabric
IPC-3M-782 Surface Mount Design and Land Pattern Standard

1. IPC, 2215 Sanders Road, Northbrook, IL 60062
Type 1 Components (mounted) on only one side of the board

Through-hole A

SMT B

SMT/TH C

THT SMT FTP BGA X

Y & Z Similar, with additional component types (not shown) as described in the legend.

Type 2 Components (mounted) on both sides of the board

A 2-Sided Thru-hole (NOT RECOMMENDED)

B

SMT FTP

TH/SMT C

SCP THT UFTP COB TAB Flip Chip

Z

X & Y See Legend

Legend:
Class A = Through-hole component mounting only
Class B = Surface mounted components only
Class C = Simplicit through-hole and surface mounting intermixed assembly
Class X = Complex intermixed assembly, through-hole, surface mount, fine pitch BGA
Class Y = Complex intermixed assembly, through-hole, surface mount, ultra fine pitch, chip scale
Class Z = Complex intermixed assembly, through-hole, ultra fine pitch, CCB, flip chip, TAB

Figure 1-1 Electrical assembly types
2.2 Underwriters Laboratories

UL 746E Standard Polymeric Materials, Materials Used in Printed Wiring Boards

3.0 GENERAL REQUIREMENTS
General requirements shall be in accordance with the generic standards IPC-2221.

3.1 Performance Requirements Finished rigid printed boards shall meet the performance requirements of IPC-6012.

4.0 MATERIALS

4.1 Material Selection Material Selection shall be in accordance with the generic standard IPC-2221.

4.2 Dielectric Base Materials (Including Prepregs and Adhesives) Dielectric base materials shall be in accordance with the generic standard IPC-2221 and the following:

4.2.1 Epoxy Laminates Epoxies are the most common resin materials which are combined with glass cloth to produce laminates. When compared to other laminate materials, epoxies offer advantages in availability and relative ease in processing. The many different types and blends of epoxies exhibit a wide range of selection for usage or soldering processes; epoxies with a T_g (glass transition temperature) from 110 to 120°C up to 180 to 190°C are available from most laminate suppliers with some of the most used in the 135 to 145°C range.

4.2.2 High-Temperature Laminates High temperature laminates include those made from resins such as Epoxy, Cyanate Ester, Triazine blends and polyimide. High temperature resin laminates offer the advantages of increased chemical and temperature resistance. Disadvantages include the need for specialized processing and higher material cost.

4.2.3 Special Clad Materials The use of surface mount technology may require the use of special clad materials when coefficient of thermal expansion matching is critical. Examples of these special materials are copper-clad Invar, epoxy or polyimide with aramid fiber and polyimide/quartz. The most common usage is for Class 3 boards, although there may also be some application for Class 2. These materials offer the advantages of performance for specialized applications; the need for unique processing during board fabrication is a disadvantage.

4.2.4 Other Laminates Laminates, such as paper-based phenolics etc., have acceptance in some consumer products where the complexity is quite low due to lesser material and manufacturing costs. These materials are associated with very high volume products with lower performance requirements than those usually associated with epoxy type laminates.

4.3 Laminate Materials Laminate materials shall be in accordance with the generic standard IPC-2221 and as follows:

When metal clad, foil type shall be as specified in IPC-MF-150. Unclad laminates without an adhesive, per IPC-4101 may be used as fillers in multilayer boards for dielectric spacing between layers.

When Underwriter’s Labs (UL) requirements are imposed, the material used must be approved by UL for use as fillers in multilayer boards for dielectric spacing between layers. Printed boards shall be fabricated from the laminate materials specified in Table 4-1 or UL 746E.

The board design shall be such that internal temperature rise due to current flow in the conductor, when added to all other sources of heat at the conductor/laminate interface, will not result in an operating temperature in excess of that specified for the laminate material. The values in Table 4-1 are based on long term thermal aging tests by UL and may be mandatory for designs to be used in UL approved products. Since heat dissipated by parts mounted on the boards will contribute local heating effects, the material selection shall take this factor, plus the equipment’s general internal rise temperature, plus the specified operating ambient temperature for the equipment into account. Hot spot temperatures shall not exceed the temperatures specified in Table 4-1 for the laminate material selected. Materials used (copper-clad, prepreg, copper foil, heat sink, etc.) shall be specified on the master drawing.

4.3.1 Measurement of Dielectric Thickness Dielectric thickness will vary across applications. Thickness by mechanical measurement is determined in accordance with IPC-TM-650, Method 2.1.6. Thickness by microsection (view shown in Figure 4-1) is determined in accordance with IPC-TM-650, Method 2.1.1. The dielectric thickness is measured in accordance with Figure 4-1 and taken at the closest point between metal claddings.
### Table 4-1  Clad Laminate Maximum Operating Temperatures

<table>
<thead>
<tr>
<th>Designation</th>
<th>Dielectric Thickness (mm)</th>
<th>Temperature (max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEMA FR-4</td>
<td>0.1 mm</td>
<td>120°C</td>
</tr>
<tr>
<td></td>
<td>0.4 mm</td>
<td>130°C</td>
</tr>
<tr>
<td></td>
<td>0.6 mm</td>
<td>140°C</td>
</tr>
<tr>
<td></td>
<td>1.4 mm</td>
<td>170°C</td>
</tr>
<tr>
<td>NEMA FR-5</td>
<td>0.1 mm</td>
<td>140°C</td>
</tr>
<tr>
<td></td>
<td>1.6 mm</td>
<td>170°C</td>
</tr>
<tr>
<td>NEMA GPY</td>
<td>0.1 mm</td>
<td>120°C</td>
</tr>
<tr>
<td></td>
<td>0.4 mm</td>
<td>130°C</td>
</tr>
<tr>
<td></td>
<td>0.6 mm</td>
<td>140°C</td>
</tr>
<tr>
<td></td>
<td>1.4 mm</td>
<td>170°C</td>
</tr>
<tr>
<td></td>
<td>0.1 mm</td>
<td>120°C</td>
</tr>
<tr>
<td></td>
<td>1.6 mm</td>
<td>170°C</td>
</tr>
<tr>
<td>NEMA 70/71</td>
<td>0.1 mm</td>
<td>140°C</td>
</tr>
<tr>
<td></td>
<td>0.4 mm</td>
<td>170°C</td>
</tr>
</tbody>
</table>

1. Ambient temperature plus the temperature rise caused by current in the conductors and components.
2. FR-4 laminates should not be combined in one board with GPY prepreg.
3. When GPY laminates are combined in one board with FR-4 prepreg, the temperature shall be that specified for the FR-4 materials.
4. A multilayer board shall be limited to a maximum operating temperature for the total dielectric thickness shown above.
5. For reinforcement/resin combinations not specifically shown above, the maximum operating temperature should be close to that of a listed combination with the same resin.
6. Other materials in the same classification with higher operating temperatures may be available.
7. Dielectric thickness smaller than those shown above may be temperature rated by UL for certain laminate manufacturers.

#### 4.3.2 Dielectric Thickness/Spacing

The minimum dielectric thickness/spacing shall be specified on the master drawing. If the minimum dielectric spacing and the number of reinforcing layers are not specified, the minimum dielectric spacing is 0.09 mm and the number of reinforcing layers may be selected by the supplier.

Note: Minimum dielectric spacing may be specified to be 0.03 mm; however, low-profile copper foils should be used and the voltages employed should be taken into consideration so as not to cause breakdown between layers. See IPC-2221 for more information on electrical conductor spacing.

![Dielectric layer thickness measurement](PC-2221-4-1)
4.3.3 Laminate Properties

4.3.3.1 Thickness Tolerance When specifying overall multilayer board thickness, and individual dielectric thickness between layers, it is important to recognize the effects of accumulated tolerances of individual dielectrics on the overall thickness of completed boards.

4.3.3.2 Resin Content Laminate materials shall be specified on the drawing, as shown in Figure 4-2, for a mapping of the recommended material selection process.

4.3.4 Prepreg

4.3.4.1 Epoxy Low T_g epoxies are the most common resin materials which are combined with glass cloth or other reinforcement. As laminate thicknesses increase, heavier glass cloths or reinforcements are used, and the percentages of resin (resin content) decrease. Lammates with higher resin content tend to have higher coefficients of thermal expansion and lower dimensional stability. However, if resin contents are too low, weave exposure and smearing may result. The glass to resin ratio of a laminate also has a direct effect on dielectric constant.

4.3.4.2 High-Temperature Prepregs High temperature prepregs include those made from resins such as Epoxy, Cyanate ester, Triazine blends and polyimide. High temperature prepregs may be used for specialized Class 1 multilayer printed board applications, but are more commonly used for Class 3 multilayer printed boards.

4.3.4.3 Glass Style A variety of glass cloth styles are available for prepregs. Glass cloth styles are available for prepregs (see IPC-EG-140). The glass cloth selection is dependent upon dielectric thickness and tolerance required, circuit filling needs, and electrical requirements of the dielectric.

4.3.4.4 Electrical Requirements For multilayer printed boards which have controlled impedance requirements, the dielectric constant of the laminated prepreg must be controlled. Because dielectric constant is a function of the resin/glass or other reinforcement ratio, prepreg styles should be chosen so that after lamination, the proper retained resin content is achieved in order to arrive at the specified dielectric constant.

4.3.5 Single-Clad Laminate Laminate with foil on one side may be used as an outer layer or internal layer of a multilayer printed board, as appropriate.

4.3.6 Double-Clad Laminate Laminites with foil on both sides may be used to provide either internal or external conductive layers. Double-clad laminate is specified in both industry and IPC specifications by the dielectric separation between the conductive layers as shown in Figure 4-1. Tables 4-2 through 4-6 provide information on the properties of finished bare laminates for different prepreg constructions. To establish final laminate thickness with copper, add 0.35 mm for each oz. of copper on the laminate.

4.3.7 Laminate Material Laminate materials shall be specified on the drawing. See Figure 4-2 for a mapping of the recommended material selection process.

Materials are generally purchased to meet the requirements of IPC-4101. A typical material code designation of a specific material would be L21 1500 C1/C1 A1A. When the finished product requires Underwriters Labs (UL) approval, material shall be ordered to meet UL specifications.

4.3.7.1 Typical Material Designation The first three characters of the code designate the type of material. “L” indicates laminate material. “P” indicates prepreg material.

• “L21” — Woven “E” glass fabric impregnated with flame resistant, epoxy resin of a type that is a majority of difunctional resin. Small amounts of multifunctional resin or novalac are sometimes added to enhance the physical properties. This is the standard NEMA FR-4 grade manufactured by most laminators since the 1950s. The glass transition temperature (T_g) is normally from 110 to 150°C but not specified.

• “L25” — Woven “E” glass fabric impregnated with flame resistant epoxy resin which is commonly a polyfunctional type resin. This resin may be modified with other epoxies to increase the high temperature physical properties. This material may be used where repeated soldering operations to replace components are anticipated. The T_g is specified to be from 150 to 200°C.

• “L26” — This grade is similar to L25 except that the epoxy resin is modified with non-epoxy resins such as cyanate esters and/or bismaleimides. The uses are similar but where higher temperatures may be anticipated. The T_g is specified to be from 170 to 220°C.

• “L40” — Woven “E” glass fabric impregnated with polyimide resin. Introduced in the 1960s for high temperature operating environments such as missile engine controls, the resin has been supplied primarily from one European source. The natural color is opaque brown. The T_g is normally from 200 to 250°C but not specified.

• “L42” — This grade is similar to L40 except that the polyimide resin may be modified with nonpolyimide resins. The primary purpose of the modifications are to improve the producibility of the printed board. The applications are similar. The T_g is specified as from 200 to 250°C.
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Legend:
- ◆: Better
- □: Blank
- ◆: Worse
### Slash Sheet 2

#### High Tg FR-4 Copper Clad Laminate Construction Selection

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<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 12</td>
<td>0.21mm</td>
<td>2113/2116</td>
<td>49</td>
<td>4.37</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 13</td>
<td>0.21mm</td>
<td>2x2116</td>
<td>45</td>
<td>4.48</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 14</td>
<td>0.25mm</td>
<td>2x2116</td>
<td>54</td>
<td>4.33</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 15</td>
<td>0.28mm</td>
<td>7628/1080</td>
<td>42</td>
<td>4.42</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 16</td>
<td>0.28mm</td>
<td>2x1080/2116</td>
<td>56</td>
<td>4.18</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 17</td>
<td>0.31mm</td>
<td>2x1060/7628</td>
<td>47</td>
<td>4.43</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 18</td>
<td>0.32mm</td>
<td>7628/2116</td>
<td>46</td>
<td>4.45</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 19</td>
<td>0.37mm</td>
<td>2x7628</td>
<td>39</td>
<td>4.66</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 20</td>
<td>0.37mm</td>
<td>2x2113/7628</td>
<td>45</td>
<td>4.48</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 21</td>
<td>0.43mm</td>
<td>2x2116/7628</td>
<td>45</td>
<td>4.18</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 22</td>
<td>0.43mm</td>
<td>2x7628/1080</td>
<td>41</td>
<td>4.60</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 23</td>
<td>0.48mm</td>
<td>2x7628/2116</td>
<td>40</td>
<td>4.63</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 24</td>
<td>0.51mm</td>
<td>2x1080/2x7628</td>
<td>42</td>
<td>4.57</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 25</td>
<td>0.53mm</td>
<td>3x7628</td>
<td>39</td>
<td>4.66</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 26</td>
<td>0.54mm</td>
<td>2x2116/2x7628</td>
<td>45</td>
<td>4.48</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 27</td>
<td>0.51mm</td>
<td>3x7628/1080</td>
<td>42</td>
<td>4.57</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 28</td>
<td>0.74mm</td>
<td>4x7628</td>
<td>39</td>
<td>4.66</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 29</td>
<td>0.74mm</td>
<td>2x2113/3x7628</td>
<td>42</td>
<td>4.57</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 30</td>
<td>0.75mm</td>
<td>4x7628/1080</td>
<td>40</td>
<td>4.63</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>POLY 31</td>
<td>1.52mm</td>
<td>8x7628</td>
<td>41</td>
<td>4.60</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- Better +
- Blank
- Worse
Figure 4-2  Designer / end user materials selection map
• "L41" — This grade is similar to L40 except that the resin chemistry may be altered. The applications are similar but higher operating temperature limits are possible. The $T_f$ is specified as above 250°C.

• "L30" — Woven "E" glass fabric impregnated with BT resin. This resin is a mixture of bismaleimides and triazine. Its uses are similar to these for L25. The $T_f$ is normally from 165 to 180°C. Hot strength retention should not be confused with flame resistance. Hot strength retention allows the board to operate at higher temperatures without losing electrical and mechanical properties. Flame resistance implies self-extinguishing properties.

4.3.7.2 Dielectric Thickness The next four numbers of the code (1500) designates the nominal dielectric thickness.

The nominal base thickness is identified by four digits that indicate the thickness of the base material in thousands of a millimeter (i.e., 1500 represents a nominal base thickness of 1.5 mm). When English units are specified, the four digits indicate thickness in ten-thousandths of an inch [i.e., 0.0590 = 0.059 in]. The overall nominal thickness does not include the metal cladding. The nominal thickness (i.e., 1500) stands alone with no tolerance. The drawing title block tolerance of three decimal places does not apply. Later in the code is a designation that applies a tolerance to the nominal thickness per industry standards. Whatever nominal thickness (typically 1.5 mm) is required, the corresponding number is inserted.

4.3.7.3 Copper Foil Designation The type and nominal weight of the copper foil cladding is identified by the next five characters of the code (i.e., C1/C1). The first and fourth characters of this designator will consist of the following letters to indicate the type of copper foil cladding.

A — Copper, rolled, wrought (IPC-MF-150, Class 5).

B — Copper, rolled (treated).

C — Copper, drum side out, electrodeposited (IPC-MF-150, Class 1).

D — Copper, drum side out, (double treated) electrodeposited.

G — Copper, high ductility electrodeposited (IPC-MF-150, Class 2).

H — Copper, high temperature elongation (IPC-MF-150, Class 3).

J — Copper, annealed electrodeposited (IPC-MF-150, Class 4).

K — Copper, light cold rolled-wrought (IPC-MF-150, Class 6).

L — Copper, annealed-wrought (IPC-MF-150, Class 7).

O — Unclad

M — Copper, as rolled-wrought-low temperature (IPC-MF-150, Class 8).

N — Nickel

U — Aluminum

V — Copper-Invar-Copper (IPC-CF-152)

Type C or H copper foil claddings are most often used.

The second and the fifth characters of this designator will indicate the nominal copper foil weight in ounces per square foot (oz/ft²). The two indicators, which are separated by a slash (third character), will use the actual numbers for copper foil 1 oz/ft² or over, and the following letters for copper foil under 1 oz/ft².

E — 0.125 oz/ft²

Q — 0.25 oz/ft²

T — 0.375 oz/ft²

H — 0.50 oz/ft²

M — 0.75 oz/ft²

O — Unclad

X — For any weight or thickness not expressed (e.g., 10 oz. copper foil) by a single digit designator. For example, "C1/C1" designates 1 oz/ft² copper, drum side out, on one side and 1 oz/ft² copper drum side out, on the other side. The slash should be considered to be the base laminate.

Base materials that are unclad on both sides would be designated 00/00.

This designation does not mean the total amount of copper that should be on the surface after processing (see IPC-2221).

Copper foils can be specified in foil weights from 0.125 to 7 oz/ft².

"CX/00" is the requirement for single-sided boards.

"CX/CX" is the requirement for double-sided boards.

4.3.7.4 Pit Designation The thirteenth character ("A") in the material specification code denotes the class of pits and dents allowed in the copper foil. Class of foil indentations is determined by the total amount and individual length of the pits and dents. A "pit" is a disruption or void in the surface of the copper, and must be within the limitations allowed by the applicable procurement document. A "dent" is a depression in the surface of the base laminate, and under pressure during lamination, the dent is transferred to the surface of the copper. There are five allowable designations: "A", "B", "C", "D", and "X" (see IPC-4101).

• "A" designation [29 points per 300 mm x 300 mm area] is adequate down to 0.25 mm conductors and spaces.

• "B" designation [5 points per 300 mm x 300 mm area] should be considered below 0.25 mm conductors and spaces.
Typical maximum fabrication panel size limits for board processing equipment are summarized in Table 5-1.

5.2 Product/Board Configuration Product/board configuration shall be in accordance with the generic standard IPC-2221 and as follows:

5.2.1 Board Geometries The following are considerations to be taken into account during the design of a printed board.

5.2.1.1 Borders and Spacing Borders and margins are commonly employed by the printed board fabricator to provide room for tooling features and other process control features (see Figure 5-1).

The size of such borders is usually in the range of 10 to 40 mm. This is determined by also taking into account an optimum number of boards per panel, obtaining optimum plating across the panel (especially important for high-density/fine line boards), etc.

When the printed boards are made using a print-and-etch procedure the border size may depend on the type of printed board being made, i.e., double-sided printed boards tend to have smaller borders; multilayer printed boards tend to have wider borders. Also, the size of the borders need not be the same on all four sides of the panel.

The margins between boards on a panel also have to accommodate the panel/board shearing, blanking and routing operations. Thus, their size is commonly chosen to be either 4.8, 5.0 and 6.5 mm or the nearest dimension suitable to maintain the board features on the basic processing grid.

5.2.1.2 Dimensional Aspect Ratio Board length to width relationships should be kept as similar as possible. Long narrow boards or unusually-shaped boards lead to excessive bowing/twisting. Dimensional instability, and associated problems at all stages of fabrication, assembly, test and system fixturing become factors in determining final board size.

5.2.2 Support Adequate mechanical support should be provided typically for at least two opposite edges of a printed wiring assembly. The location and method of support shall be such as to minimize shock and/or vibration to a level that will protect against fracturing or loosening of conductor foil, or breaking of the components or component leads as a result of flexing the printed board assembly within the tolerance of the applicable specification.

5.3 Assembly Requirements Assembly requirements shall be in accordance with the generic standard IPC-2221 and as follows:
Table 5-1  Panel Size to Manufacturing Operation Relationships

<table>
<thead>
<tr>
<th>Operation</th>
<th>Typical Maximum Panel Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drill</td>
<td>460 mm x 610 mm</td>
</tr>
<tr>
<td>Scrub, deburr, and most conveyorized finishing equipment</td>
<td>610 mm x open</td>
</tr>
<tr>
<td>Plating equipment</td>
<td>Custom sized, check with fabricator</td>
</tr>
<tr>
<td>Exposure equipment</td>
<td>610 mm x 610 mm</td>
</tr>
<tr>
<td>Routing equipment</td>
<td>460 mm x 610 mm</td>
</tr>
<tr>
<td>Screening equipment</td>
<td>510 mm x 760 mm</td>
</tr>
<tr>
<td>Bare board test</td>
<td>460 mm x 460 mm</td>
</tr>
<tr>
<td>Laminating press size (based on 610 mm x 760 mm press with 50 mm open area on plased edges)</td>
<td>510 mm x 660 mm</td>
</tr>
<tr>
<td>Solder coating</td>
<td>460 mm x 610 mm</td>
</tr>
</tbody>
</table>

Figure 5-1  Panel borders

5.3.1 Assembly and Test  Palletization of parts is a standard process in many instances for both test and assembly. This can be achieved using a number of different techniques. These include simple scoring, a combination of routing and scoring, and a combination of routing plus breakaway.

Scoring is the machining of a shallow, precise V-groove into the top and bottom surfaces of the laminate. It is generally accomplished using CNC equipment. As scoring allows the removal of rails and individual parts from a pallet, positional accuracy is critical. See Table 5-2 and Figure 5-2 for some standard scoring parameters.

Figure 5-2  Scoring parameters

Table 5-2  Standard Scoring Parameters

<table>
<thead>
<tr>
<th>Detail Letter</th>
<th>Title</th>
<th>Definition</th>
<th>Attainable Tolerances</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Web</td>
<td>The material remaining between the two (2) ‘V’ scores on a plane perpendicular to the printed board surface</td>
<td>± 80 μm</td>
</tr>
<tr>
<td>B</td>
<td>Centrality</td>
<td>The distance the center of a web is offset from true center within the printed board.</td>
<td>± 80 μm</td>
</tr>
<tr>
<td>C</td>
<td>Blade offset</td>
<td>The distance the top and bottom scoring blades are offset from one another.</td>
<td>± 80 μm</td>
</tr>
<tr>
<td>D</td>
<td>Score width</td>
<td>The width of a score line at the surface of the printed board</td>
<td>± 80 μm</td>
</tr>
<tr>
<td>E</td>
<td>Cutter angle</td>
<td>The total angle of a scoring blade.</td>
<td>± 2°</td>
</tr>
<tr>
<td>F</td>
<td>Keep out area</td>
<td>The area, expressed from nominal score line placement, that no features should be placed within.</td>
<td>D/2 + All registration</td>
</tr>
<tr>
<td>G</td>
<td>Printed board thickness</td>
<td>Overall printed board thickness to be scored.</td>
<td>Per IPC standards</td>
</tr>
<tr>
<td>H</td>
<td>Trueness/ Position</td>
<td>The tolerance of two or more score lines on one side of the printed board. Measured from nominal, squareness and actual position.</td>
<td>± 80 μm cumulative</td>
</tr>
</tbody>
</table>
Routing is the process of profiling a pallet or printed board to the correct dimension using a cutting bit. This can be performed either by the use of a pin router and template, or a CNC routing machine.

Frequently a combination of routing and scoring is used, where both pallet and printed board are routed, leaving a small connection bridge. This bridge is then scored to facilitate removal following test and assembly.

The final method involves the use of routing and drilled breakaway tabs. Instead of scoring, a series of holes are drilled in the tab to facilitate removal. (See Figure 5-3.)

Grid systems are always basic and have no tolerance, and therefore all features located on a grid shall be tolerated elsewhere on the master drawing. Grid systems shall be located with respect to a minimum of two printed board datums.

The grid increment shall be specified on the master drawing. The choice of grid increment is based on the component terminal location for through-hole components, and on the component center for surface mount components.

Typical grid increments are multiples of 0.13 mm for through-hole components, and 0.05 mm for surface mount components.

5.4 Dimensioning Systems Dimensioning systems shall be in accordance with the generic standard IPC-2221 and as follows:

5.4.1 Grid Systems When manually designing printed boards, grid systems are used to locate components, plated-through holes, conductor patterns, and other features of the printed board and its assembly so they need not be individually dimensioned. When printed board features are required to be off a grid, they shall be individually dimensioned and tolerated on the master drawing.

### Table 5-3 Tolerance of Profiles, Cutouts, Notches, and Keying Slots, as Machined, mm

<table>
<thead>
<tr>
<th>Tolerances to be applied to profile of a surface:</th>
<th>Level A</th>
<th>Level B</th>
<th>Level C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profile feature</td>
<td>0.25</td>
<td>0.20</td>
<td>0.15</td>
</tr>
<tr>
<td>Location where greatest basic location dimension is less than 300.0</td>
<td>0.30</td>
<td>0.25</td>
<td>0.20</td>
</tr>
<tr>
<td>Location where greatest basic location dimension is greater than 300.0</td>
<td>0.35</td>
<td>0.30</td>
<td>0.25</td>
</tr>
</tbody>
</table>

1For definition of productivity level, see IPC-2221.
6.0 ELECTRICAL PROPERTIES
Electrical properties shall be in accordance with the generic standard IPC-2221.

7.0 THERMAL MANAGEMENT
Thermal management shall be in accordance with the generic standard IPC-2221.

8.0 COMPONENT AND ASSEMBLY ISSUES
Component assembly issues shall be in accordance with the generic standard IPC-2221 and as follows:

8.1 General Attachment Requirements In addition to the general attachment requirements outlined in the generic standard IPC-2221, the following shall apply:

8.1.1 Attachment of Wires/Leads to Terminals For cases in which more than one wire is attached to a terminal, the largest diameter wire should be mounted to the bottom-most post for ease of removal and repair. In general, no more than three attachments should be made to each section of a turret or bifurcated terminal. As an exception, bus bar terminals may hold more than three wires or leads per section when specifically designed to hold more.

8.1.2 Board Extractors Board extractors or handles are used to provide a convenient means of extracting the printed board from its mating connector. They are generally used where the amount of force makes it difficult to safely remove the board without damage to the electrical components or to the person removing the board.

Board extractors are commercially available and come in a variety of shapes and sizes.

Extractors are usually of the camming type and are mounted to the corners of the board. They provide a mechanical advantage for disengaging the connectors and a convenient place to grasp the board during removal.

Board extractors may be incorporated into the design of the board, or may require separate conditions in the printed board assembly. When board extractors are a part of the design, adequate reinforcement shall be used to properly allow the extracting action to remove the board from its connected assembly in the backplane (see Figure 8-1).

When board extractors are not a part of the printed board assembly, an extractor of the gripping variety may be used (see Figure 8-2). They grip the board in a particular area, which shall be kept free of components and circuitry. If a hook-type board extractor is used, where a hook passes through holes in the printed board, and then pulls the board out, special grommets should be used to reinforce the hole structure to avoid board crazing or cracking.

9.0 HOLE/INTERCONNECTIONS

9.1 General Requirements for Lands with Holes General requirements for lands with holes shall be in accordance with the generic standard IPC-2221 and as follows:

9.1.1 Land Requirements When eyelets or standoff terminals are used, the lands on external layers shall be so designed as to have a minimum diameter of at least 0.5 mm greater than the maximum diameter of the projection of the eyelet or solder terminal flange.

9.1.2 Thermal Relief in Conductor Planes The relationship between the hole size, land and web area is critical. Typically, divide 60% of the minimum land area diameter by the number of webs desired to obtain the width of each web in accordance with the following example:
A. Land Size Calculation

Maximum hole size = 1.0 mm
Annular ring = 2 x 0.05 mm
= 0.10 mm
Fabrication allowance = 0.25 mm
Minimum land size = 1.0 mm + 0.10 mm + 0.25 mm
= 1.35 mm diameter

B. Thermal Relief Calculation

Total thermal width = 60% of land size
= 0.6 x 1.35 mm
= 0.80 mm

C. Original Web Size Calculation

2-web width = 1/2 of total thermal width
= 0.50 x 0.80 mm
= 0.40 mm

3-web width = 1/3 of total thermal width
= 0.33 x 0.80 mm
= 0.27 mm

4-web width = 1/4 of total thermal width
= 0.25 x 0.80 mm
= 0.20 mm

If the actual land diameter chosen is greater than the minimum value calculated, the percentage difference between the land diameters must be subtracted from the total web width calculation, i.e.:

Minimum land diameter = 1.35 mm
Actual land diameter = 1.70 mm
Percent difference = (1.70 - 1.35 mm)/1.35 mm
= 25%

New total web width = total web width
percent difference
= 0.80 mm - 25% (0.80 mm)
= 0.60 mm

D. Adjusted Web Size Calculation

2-web width = 1/2 of new total web width
= 0.50 x 0.60 mm
= 0.30 mm

3-web width = 1/3 of new total web width
= 0.33 x 0.60 mm
= 0.20 mm

4-web width = 1/4 of new total web width
= 0.25 x 0.60 mm
= 0.15 mm

Total cumulative copper web for all layers in any plated-through hole should not exceed 4.0 mm for 1 oz copper or 2.0 mm for 2 oz copper.

The total of the thermal relief cross-sectional area divided by the number of planes connected to the plated-through hole shall not violate current carrying capacity requirements for a given hole.

If the individual web width violates the intended minimum conductor width it shall be specified on the master drawing.

9.1.3 Clearance Area in Planes Clearance area in planes shall be provided in accordance with Figure 9-1.

9.1.3.1 Small Pitch Clearance Area in Planes A special precaution must be observed when routing high speed circuits and/or very small pitch devices. When routing small pitch devices and/or vias routed on small grids, designers must remain aware of factors relating to power/ground plane clearance areas. When the pitch is very small, designers must remain cognizant of the narrow foil web between clearance openings (see Figure 9-2). As the clearance area (diameter) is made larger, the foil web between clearance areas becomes smaller. Designs having very small foil webs are less desirable because of their reduced current carrying capability, potential for increased voltage drop, higher EMI emissions, and reduced thermal dissipating characteristics. It is highly desirable for heat generating devices to be “heatsinked” down through via holes and dissipated across the surface of inner planes. For these reasons the foil web should be as large as possible and overlapping clearance areas in planes should be avoided. Use the following formula when dealing with small pitch devices and/or via holes, when routing on very small grids.
Typical example:
Determine the desired width of foil web.
Ex: 0.20 mm Web

Total available area = pitch - foil web
= 1.25 - 0.20 mm
= 1.05 mm

B = 0.25 mm min. fabrication allowance per Table 9-1 of IPC-2221.
Clearance area (diameter) = hole diameter (max.) + 2B
= 0.35 mm + 2 (0.25 mm)
= 0.35 mm + 0.50 mm
= 0.85 mm

Note: Maximum clearance area (diameter) in the plane is calculated by using the formula above and must not exceed the total available area.

9.1.4 Nonfunctional Lands Nonfunctional lands should be included on internal layers for all plated-through holes. Nonfunctional lands need not be used where electrical clearance requirements do not permit, such as ground planes, voltage planes and thermal planes. For high layer count boards, greater than 10 layers, it is recommended to remove some of the nonfunctional lands in the vertical stack. Plated-through holes passing through internal conductive planes (ground, voltage, etc.) and thermal planes shall meet the same minimum spacing requirements as conductors on internal layers, and should meet the minimum spacing requirements of Figure 9-2.

9.1.5 Conductive Pattern Feature Location Tolerance
The presentation in Table 9-1 is for the tolerance to be applied to the nominal dimension chosen for the location of the lands connector contacts and conductors in relation to the datum. This tolerance includes tolerances for master pattern accuracy, material movement, layer registration and fixturing.

Table 9-1 Feature Location Tolerances (Lands, Conductor Pattern, etc.) (Diameter True Position)

<table>
<thead>
<tr>
<th>Greatest Board/ X, Y Dimension</th>
<th>Level A</th>
<th>Level B</th>
<th>Level C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 300 mm</td>
<td>0.30 mm</td>
<td>0.20 mm</td>
<td>0.10 mm</td>
</tr>
<tr>
<td>Up to 450 mm</td>
<td>0.35 mm</td>
<td>0.25 mm</td>
<td>0.15 mm</td>
</tr>
<tr>
<td>Up to 600 mm</td>
<td>0.40 mm</td>
<td>0.30 mm</td>
<td>0.20 mm</td>
</tr>
</tbody>
</table>

Note: Conductor pattern registration may be expressed in terms of minimum annular ring violations, which establishes manufacturing registration allowances.

9.2 Holes Holes shall be in accordance with the generic standard IPC-2221 and as follows:

9.2.1 Unsupported Holes

9.2.1.1 Diameter of Unsupported Holes When using the basic dimensioning system, holes shall be expressed in terms of maximum material (MMC) and least material condition (LMC) limits. The diameter of an unsupported component hole shall be such that the MMC of the lead subtracted from the MMC of the hole provides a clearance between a minimum of 0.15 mm and a maximum of 0.5 mm. The number of different hole sizes shall be kept to a minimum. When flat ribbon leads are mounted through unsupported holes, the difference between the nominal diagonal of the lead and the inside diameter of the unsupported hole shall not exceed 0.5 mm and shall be not less than 0.15 mm.

9.2.1.2 Unsupported Hole Tolerance When using the basic dimensioning system, holes shall be expressed in terms of maximum material condition (MMC) and least material condition (LMC) limits. The bilateral tolerances shown in Table 9-2 are used to determine the MMC-LMC limit for the appropriate hole diameter; thus, a hole 1.0 ± 0.05 mm would be expressed as 0.95-1.05 mm.

Table 9-2 Minimum Unsupported Holes Tolerance Range (Difference between high and low hole size limits)

<table>
<thead>
<tr>
<th>Hole Diameter</th>
<th>Level A</th>
<th>Level B</th>
<th>Level C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 - 0.8 mm</td>
<td>0.15 mm</td>
<td>0.10 mm</td>
<td>0.05 mm</td>
</tr>
<tr>
<td>0.81 - 1.6 mm</td>
<td>0.20 mm</td>
<td>0.15 mm</td>
<td>0.10 mm</td>
</tr>
<tr>
<td>1.61 - 5.0 mm</td>
<td>0.30 mm</td>
<td>0.20 mm</td>
<td>0.15 mm</td>
</tr>
</tbody>
</table>

9.2.1.3 Eyelet Hole Diameter When eyelets are used, the diameter of holes in which eyelets are inserted shall not exceed the outside diameter of the barrel of the eyelet by
more than 0.15 mm. The relationships between maximum and minimum barrel diameters and wire diameters shall be as shown in Table 9-3.

9.2.2 Plated-Through Holes The maximum and minimum plated-through hole diameters used to attach component leads or pins to the printed board shall be evaluated in accordance with Table 9-3. Both minimum and maximum leads shall be taken into consideration in evaluating the finished plated-through hole requirements. If the lead is a ribbon lead, the minimum and maximum diagonal of a flat ribbon lead shall be considered. Table 9-3 shows the limits of the plated-through hole.

These limits shall be optimized so that manufacturability is enhanced to provide the most liberal tolerances allowable (see Figure 9-3).

Figure 9-3 Lead-to-hole clearance

Unless otherwise specified, the hole size shall be the finished plated size after solder coating or final plating and fusing, if required. The hole size shall be specified on the master drawing. Plated-through holes used for functional interfacial connections shall not be used for the mounting of devices which put the plated-through hole in compression. Plated-through holes used for functional interfacial connections shall not be used for the mounting of eyelets, solder terminals, or rivets. Plated-through holes shall be used for all interfacial connections on multilayer boards Type 3 through Type 6 (inclusive). Platings and coatings shall be in accordance with IPC-2221.

9.2.2.1 Aspect Ratio The aspect ratio of plated-through holes plays an important part in the ability of the manufacturer to provide sufficient plating within the plated-through hole, as well as in the reliability of the PTH/PTV structure (see IPC-D-279). Table 9-4 provides information on the producibility of aspect ratios for various levels of complexity.

9.2.2.2 Plated-Through Hole Tolerances When using the basic dimensioning system, plated-through holes used to attach component leads or pins to the printed board should be expressed in terms of MMC and LMC limits. The bilateral tolerances shown in Table 9-5 are used to determine the MMC-LMC limit for the appropriate finished hole diameter. Thus, a hole 1.0 ± 0.05 mm would be expressed as 0.95-1.05 mm. When hole size is less than one-fourth the basic board thickness, the tolerance shall be increased by 0.05 mm.

9.2.2.3 Minimum Hole Sizes for Plated-Through Hole Vias In order to meet the performance requirements of the various classes of equipments, the plated-through hole size to board thickness aspect ratio for plated-through hole vias shall be in accordance with Table 9-4. Table 9-6 provides information on the minimum drilled hole to be used in conjunction with various board thicknesses. The table reflects the three classes of equipment assuming that each class requires a slightly more severe environment, thus having to meet more stringent thermal cycling conditions (see IPC-D-279).

If a particular class requires more stringent cycling than shown in the table, the user may invoke the requirements of a larger drilled hole size.

Solder may fill the through hole or via if processed with fused tin-lead plate or solder coating. Partial filling at assembly can create stress concentrations affecting reliability. For drilled hole diameters 0.35 mm or less and aspect ratios of 4:1 or larger, the fabricator should mask or plug by a suitable method the plated through vias to prevent entry of solder.

The drilled hole size used for through hole vias shall be represented on the master drawing as the maximum plated-through hole dimension that assumes that the hole contains a minimum plating thickness. No minimum plated-through hole dimension should be specified since the through-hole via contains no component lead or pin and could theoretically be plated shut. Thus, a master drawing call out of 0.0-0.2 mm diameter reflects drilling a 0.25 mm hole that can contain a minimum plating of 0.025 mm to a maximum plating of 0.125 mm copper per side.

In addition, Table 9-6 contains a letter code in each of the boxes. This letter code reflects the producibility level of complexity in each of the particular hole size to aspect ratios.

9.2.3 Etchback Etchback, when required, will reduce the annular ring support on internal layers of the board. Therefore, this should be taken into account when specifying plated-through hole land size. However, the maximum
etchback allowed on the master drawing shall not be greater than the minimum design annular ring.

9.3 Drill Size Recommendations for Printed Boards
Drill sizes as related to maximum board thickness are shown in Table 9-7. These drills may be used to drill unsupported or plated-through holes in rigid printed boards.

Although the designer rarely specifies the drilled hole size, these dimensions may be used in determining minimum annular ring calculations, or minimum land sizes.

Also shown in Table 9-7 are the maximum board thicknesses to which the various drill sizes should be applied. (Note: These dimensions are maximums. Thinner boards may be used to accommodate all drills shown within a drill set category.) Designers are encouraged to limit the number of drill selections to approximately 10 drill sizes per each printed board. Where possible a lesser number should be used, recognizing that the manufacturer needs certain drill sizes for tooling hole and other configurations. It is recommended that the designer select no more than one drill size from any given row in order to optimize drill size operation. The information in Table 9-7 is a suggested guideline based on the availability of existing manufacturing drills.

10.0 GENERAL CIRCUIT FEATURE REQUIREMENTS

10.1 Conductor Characteristics  Conductor characteristics shall be in accordance with the generic standard IPC-2221 and as follows:

10.1.1 Edge Spacing  Except for edge-board contacts, the minimum distance between conductive surfaces and the edge of the finished board, or a non-plated through hole, shall not be less than the minimum spacing specified in Table 6-1 of IPC-2221 plus 0.4 mm. Printed boards that slide into guides shall have a minimum external conductor to guide distance of 1.25 mm or minimum electrical clearance (see Table 6-1 of IPC-2221), whichever is greater. Special design applications in areas such as high voltage, surface mount, and radio frequency (RF) technology may require variances to these requirements. Ground and heat sink planes may extend to the edge when required by design.

![Table 9-3 Plated-Through Hole Diameter to Lead Diameter Relationships](image)

<table>
<thead>
<tr>
<th>Lead Diameter</th>
<th>Level A</th>
<th>Level B</th>
<th>Level C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum hole to minimum lead diameter</td>
<td>No greater than 0.7 mm over minimum lead diameter</td>
<td>No greater than 0.7 mm over minimum lead diameter</td>
<td>No greater than 0.6 mm over minimum lead diameter</td>
</tr>
<tr>
<td>Minimum hole to maximum lead diameter</td>
<td>No less than 0.25 mm over maximum lead diameter</td>
<td>No less than 0.20 mm over maximum lead diameter</td>
<td>No less than 0.15 mm over maximum lead diameter</td>
</tr>
</tbody>
</table>

![Table 9-4 Plated-Through Hole Aspect Ratio](image)

<table>
<thead>
<tr>
<th>Aspect Ratios</th>
<th>Level A</th>
<th>Level B</th>
<th>Level C</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤5:1</td>
<td>6:1 to 8:1</td>
<td>9:1 and up</td>
<td></td>
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</tbody>
</table>

![Table 9-5 Minimum Plated-Through Hole Diameter Tolerance Range, mm](image)

<table>
<thead>
<tr>
<th>Hole Diameter</th>
<th>Level A</th>
<th>Level B</th>
<th>Level C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 to 0.8</td>
<td>0.20</td>
<td>0.15</td>
<td>0.10</td>
</tr>
<tr>
<td>&gt;0.8 to 1.6</td>
<td>0.30</td>
<td>0.20</td>
<td>0.10</td>
</tr>
<tr>
<td>&gt;1.6 to 5.0</td>
<td>0.40</td>
<td>0.30</td>
<td>0.20</td>
</tr>
</tbody>
</table>

![Table 9-7 Drill Size Recommendations Related to Maximum Board Thickness](image)

<table>
<thead>
<tr>
<th>Drill size (mm)</th>
<th>Maximum Board Thickness (mm), as drilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤0.10</td>
<td>≤0.25</td>
</tr>
<tr>
<td>0.15-0.25</td>
<td>≤1.0</td>
</tr>
<tr>
<td>0.30-0.45</td>
<td>≤1.6</td>
</tr>
<tr>
<td>0.50-0.85</td>
<td>≤3.2</td>
</tr>
<tr>
<td>0.90-1.05</td>
<td>≤4.8</td>
</tr>
<tr>
<td>≤1.10</td>
<td>≤6.4</td>
</tr>
</tbody>
</table>

![Table 9-6 Minimum Drilled Hole Size for Plated-Through Hole Vias](image)

<table>
<thead>
<tr>
<th>Board Thickness</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1.0 mm</td>
<td>Level C 0.15 mm</td>
<td>Level C 0.2 mm</td>
<td>Level C 0.25 mm</td>
</tr>
<tr>
<td>1.0 mm to 1.6 mm</td>
<td>Level C 0.2 mm</td>
<td>Level C 0.25 mm</td>
<td>Level B 0.3 mm</td>
</tr>
<tr>
<td>1.6 mm to 2.0 mm</td>
<td>Level C 0.3 mm</td>
<td>Level B 0.4 mm</td>
<td>Level B 0.5 mm</td>
</tr>
<tr>
<td>&gt;2.0 mm</td>
<td>Level B 0.4 mm</td>
<td>Level A 0.5 mm</td>
<td>Level A 0.6 mm</td>
</tr>
</tbody>
</table>

Note: If copper plating thickness in hole is greater than 0.03 mm, hole size can be reduced by one class.
10.1.2 Balanced Conductors Whenever possible, to reduce bow and twist and to increase dimensional stability, conductors should be balanced within an individual layer. Conductor routing density should be spread throughout the board wherever possible, to avoid the need for special etching or plating thieves.

Plating thieves are added metallic areas which are nonfunctional within the finished board profile but allow uniform plating density, giving uniform plating thickness over the board surface.

The multilayer printed board structure should also be as balanced as possible providing equal layers of signal conductors and planes to either side of the center of the multilayer construction.

10.1.3 Flush Conductors for Rotating or Sliding Contacts When flush circuits are required for application as mating contact surfaces, the degree of flushness shall meet the requirements of Table 10-1. Figure 10-1 (A and B) shows a typical flush circuit design.

Note: The level of flushness required is normally a function of factors related to the mating contact, such as contact size, shape, load, rotational force, surface friction, etc. It is recommended that the designer fully understand the dynamics of the mating contact system before establishing surface flushness requirements.

<table>
<thead>
<tr>
<th>Table 10-1 Surface Flushness Requirements</th>
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<tbody>
<tr>
<td>Level A</td>
</tr>
<tr>
<td>As agreed between user and supplier</td>
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</tbody>
</table>

Figure 10-1A Typical flush circuit

10.1.4 Metallic Finishes for Flush Conductors Metallic finishes for flush conductor contacts should be gold over nickel, or other suitable corrosion resistant, low contact resistance finish.

10.2 Land Characteristics Land characteristics shall be in accordance with the generic standard IPC-2221 and as follows:

10.2.1 Lands for Interfacial Connection Vias Lands for interfacial connections shall meet the requirements of 10.1.

10.2.2 Offset Lands Lands, when used in conjunction with clinched leads, may be located adjacent to (not surrounding) the lead termination hole. The land shall be a sufficient distance from the hole to allow clipping of the part lead prior to unsoldering the part lead from the land.

10.2.3 Conductive Pattern Feature Location Tolerance The presentation in Table 9-1 is for the tolerance to be applied to the nominal dimension chosen for the location of the lands connector contacts and conductors in relation to the datum. This tolerance includes tolerances for master pattern accuracy, material movement, layer registration and fixturing. (See IPC-SM-782.)

10.2.4 Nonfunctional Lands See 9.1.4.

10.3 Large Conductive Areas Large conductive areas (Planes 3 mm wide or larger conductors) increase the likelihood for blistering, warping, or heat shielding during wave or reflow soldering.

Large areas that cover more than a 25.0 mm diameter may be broken up into a cross-hatched or similarly patterned area (see Figure 10-2). Modifications to large conductive areas shall not adversely impact the electrical characteristics or performance of the board. Large conductive areas should not be on the solder side of the board unless solder resist or similar is used.

External conductors that extend beyond a 25.0 mm diameter circle should contain etched areas that break up the large conductive area, but retain the continuity and functionality of the conductor. If etched areas are not provided, other methods should be used to minimize blistering or bowing.

Large conductive areas should, if possible, be on the primary side of the board. If solder resist is employed over meltable metals, conductive areas wider than 1.3 mm shall not be employed under the solder resist coatings.

When a conductive area that extends beyond a 25.0 mm diameter is used on a internal layer, the conductive area
Surface Flushness for Level A, B, or C can result in the following conditions:

A. Resin is flush with metal contact surfaces.

B. Resin is below contact surface.

C. Resin is above contact surface.

11.0 DOCUMENTATION

Documentation shall be in accordance with the generic standard IPC-2221 and as follows:

11.1 Filled Holes  Via holes designated to be filled by the design requirements shall be identified on the drawing.

11.2 Nonfunctional Holes  Electrically nonfunctional supported holes should be identified as such on the fabrication or assembly drawing and do not need to meet the electrical connection requirement.

12.0 QUALITY ASSURANCE

Quality Assurance shall be in accordance with the generic standard IPC-2221.

should be placed as near to the center or the board as possible, and should contain etched areas that will break up the large conductive area, but will retain the continuity and functionality of the conductor. When UL requirements are imposed, the area shall be within the limits approved by UL for the printed board manufacturer.
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☐ This is a CHANGE to an existing definition.

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Committees affected by this term:

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Subject:
Message: signoff DesignerCouncil

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IPC conducts local educational workshops and national conferences to help you better understand conventional and emerging technologies. Members receive discounts on registration fees. Visit www.ipc.org to see what programs are coming to your area.

IPC Certification Programs
IPC provides world-class training and certification programs based on several widely-used IPC standards, including the IPC-A-610, the J-STD-001, and the IPC-A-600. IPC-sponsored certification gives your company a competitive advantage and your workforce valuable recognition.
For more information on programs, contact Alexandra Curtis
tel 847/790-5377   fax 847/509-9798
e-mail: curta@ipc.org   www.ipc.org

IPC Video Tapes and CD-ROMs
IPC video tapes and CD-ROMs can increase your industry know-how and on-the-job effectiveness. Members receive discounts on purchases.
For more information on IPC Video/CD Training, contact Mark Pritchard
tel 505/758-7937 ext. 202   fax 505/758-7938
e-mail: markp@ipcvideo.org   www.ipc.org

IPC Printed Circuits Expo®
IPC Printed Circuits Expo is the largest trade exhibition in North America devoted to the PWB manufacturing industry. Over 90 technical presentations make up this superior technical conference. Visit www.ipcprintedcircuitsexpo.org for upcoming dates and information.
Exhibitor Information:
Contact: Mary MacKinnon
Sales Manager
tel 847/790-5386
e-mail: MaryMacKinnon@ipc.org

Registration Information:
Alicia Balonek
Exhibits Manager
tel 847/790-5398
e-mail: AliciaBalonek@ipc.org

APEX® / IPC SMEMA Council Electronics Assembly Process Exhibition & Conference
APEX is the premier technical conference and exhibition dedicated entirely to the electronics assembly industry. Visit www.goAPEX.org for upcoming dates and more information.
Exhibitor Information:
Contact: Mary MacKinnon
tel 847/790-5386
e-mail: MaryMacKinnon@ipc.org

Registration Information:
tel 847/790-5369
e-mail: goAPEX@ipc.org

How to Get Involved
The first step is to join IPC. An application for membership can be found in the back of this publication. Once you become a member, the opportunities to enhance your competitiveness are vast. Join a technical committee and learn from our industry's best while you help develop the standards for our industry. Participate in market research programs which forecast the future of our industry. Participate in Capitol Hill Day and lobby your Congressmen and Senators for better industry support. Pick from a wide variety of educational opportunities: workshops, tutorials, and conferences. More up-to-date details on IPC opportunities can be found on our web page: www.ipc.org.
For information on how to get involved, contact:
Jeanette Ferlman, Membership Director
tel 847/790-5309   fax 847/509-9798
e-mail: JeanetteFerlman@ipc.org   www.ipc.org
Application for Site Membership

Thank you for your decision to join IPC members on the “Intelligent Path to Competitiveness”! 
IPC Membership is site specific, which means that IPC member benefits are available to all individuals employed at the site designated on the other side of this application.

To help IPC serve your member site in the most efficient manner possible, please tell us what your facility does by choosing the most appropriate member category. (Check one box only.)

☐ Independent Printed Board Manufacturers

This facility manufactures and sells to other companies, printed wiring boards (PWBs) or other electronic interconnection products on the merchant market. What products do you make for sale?

☐ One-sided and two-sided rigid printed boards
☐ Multilayer printed boards
☐ Other interconnections
☐ Flexible printed boards

Name of Chief Executive Officer/President
________________________________________________________________________

☐ Independent Electronic Assembly EMSI Companies

This facility assembles printed wiring boards, on a contract basis, and may offer other electronic interconnection products for sale.

Name of Chief Executive Officer/President
________________________________________________________________________

☐ OEM—Manufacturers of any end product using PCB/PCAs or Captive Manufacturers of PCBs/PCAs

This facility purchases, uses and/or manufactures printed wiring boards or other interconnection products for use in a final product, which we manufacture and sell.

What is your company’s primary product line?
________________________________________________________________________

☐ Industry Suppliers

This facility supplies raw materials, machinery, equipment or services used in the manufacture or assembly of electronic interconnection products.

What products do you supply?
________________________________________________________________________

☐ Government Agencies/Academic Technical Liaisons

We are representatives of a government agency, university, college, technical institute who are directly concerned with design, research, and utilization of electronic interconnection devices. (Must be a non-profit or not-for-profit organization.)