



---

*The Institute for  
Interconnecting  
and Packaging  
Electronic Circuits*

# IPC-D-316

## Design Guide for Microwave Circuit Boards Utilizing Soft Substrates

### **IPC-D-316**

Original Publication  
June 1995

A standard developed by the Institute for Interconnecting  
and Packaging Electronic Circuits

---

2215 Sanders Road  
Northbrook, Illinois  
60062-6135

Tel 847 509.9700  
Fax 847 509.9798  
URL: <http://www.ipc.org>

# Table of Contents

<b>1.0 General</b> .....	1	5.3.2.8 Immersion Tin .....	10
1.1 Purpose .....	1	5.3.2.9 Electroplated Tin .....	10
1.2 Scope .....	1	5.3.3 Galvanic Corrosion .....	10
1.3 Terms and Definitions .....	1	5.3.4 Chromate Conversion Coating .....	10
1.4 Interpretation .....	3	5.4 Conformal Coating .....	10
<b>2.0 Applicable/Reference Documents</b> .....	3	5.4.1 General Caution .....	10
2.1 IPC .....	3	<b>6.0 Electrical Characteristics</b> .....	10
2.2 ANSI .....	3 2	6.1 Stripline .....	11
2.3 Military Standards & Specifications .....	3 3	6.1.1 Narrow traces .....	11
2.5 Reference Information .....	3	6.1.2 Wide traces .....	11
<b>3.0 Design Considerations</b> .....	3	6.1.3 Asymmetric Stripline .....	11
3.1 Initial Input .....	3	6.2 Microstrip .....	11
3.2 Design Options .....	3	<b>7.0 Detailed Board Requirements</b> .....	14
3.3 Line Type, Materials, and Components .....	3	7.1 Machined Features .....	14
3.4 Electrical Design .....	3	7.1.1 Dimensioning and Tolerancing .....	14
3.5 Mechanical Design .....	5	7.1.2 Plated-Through Holes .....	15
3.6 Preliminary Design Review .....	5	7.1.2.1 Pinning/Ground Connections .....	15
3.7 Brassboard .....	5	7.1.3 Unplated Holes .....	16
3.8 Prototype .....	5	7.1.4 Depth Pockets and Slots .....	16
3.9 Documentation .....	5	7.1.5 Inner-Layer Access Machining .....	16
3.10 Final Design Review .....	5	7.1.6 Periphery .....	16
<b>4.0 Documentation Requirements</b> .....	5	7.1.7 NC Tapes .....	16
4.1 Design Features Printed .....	5	7.1.8 Dimensional Inspection .....	17
4.2 Master Drawing .....	5	7.2 Imaging .....	17
4.3 Master Pattern .....	6	7.2.1 Artwork .....	17
<b>5.0 Materials</b> .....	6	7.2.2 Photoresist .....	17
5.1 Microwave Printed Circuit Board Materials .....	6	7.2.3 Annular Rings .....	17
5.1.1 Substrate Selection .....	6	7.3 PTFE Activation .....	18
5.1.1.1 Relative Permittivity .....	6	7.4 Metallization .....	18
5.1.1.2 Loss Tangent .....	6	7.4.1 Plated Edge Designs .....	18
5.1.1.3 Thickness .....	6	7.4.2 Copper Plating .....	18
5.1.1.4 Environment .....	7	7.5 Etching .....	18
5.1.1.5 Cost .....	7	7.6 Bonding .....	19
5.1.1.6 Supplier .....	8	7.7 Testing .....	19
5.2 Bonding Films .....	8	<b>8.0 Device Attachments and Packaging</b> .....	19
5.2.1 Thermoplastic Bonding Films .....	8	8.1.1 Mechanical Mounting .....	19
5.2.2 Thermoset Bonding Films .....	8	8.1.2 Epoxies (both conductive and non conductive) .....	19
5.2.3 Bonding Considerations .....	8	8.1.3 Thermoplastic Films .....	20
5.3 Metals .....	8	8.1.4 Soldering .....	20
5.3.1 Cladding .....	8	8.1.5 Direct Bonding .....	20
5.3.1.1 Thin Cladding Considerations .....	8	8.2 Connector Attachment .....	20
5.3.1.2 Heavy Cladding Considerations .....	9	8.3 Device Attachment .....	21
5.3.2 Metal Plating .....	9	8.3.1 Welded Bonds .....	22
5.3.2.1 Electroless Copper .....	9	8.3.1.1 Resistance Welding .....	22
5.3.2.2 Electrodeposited Copper .....	9	8.3.1.2 Parallel Gap Welding .....	22
5.3.2.3 Nickel .....	9	8.3.1.3 Percussive Arc Welding .....	22
5.3.2.4 Gold .....	9	8.3.1.4 Laser Welding .....	22
5.3.2.5 Silver .....	9	8.3.1.5 Soldering .....	22
5.3.2.6 Tin-lead .....	9	8.3.2 Diffusion Bonding .....	22
5.3.2.7 Solder Coating .....	9		

8.3.2.1	Ultrasonic Welding .....	22
8.3.2.2	Thermal Compression Bonding .....	22
8.3.2.3	Thermosonic Bonding .....	22
8.3.3	Device Attachment .....	23
8.3.3.1	Ultrasonic Wire Bonding .....	23
8.3.3.2	Thermosonic (Ball) Bonding .....	23
8.3.3.3	Parallel Gap Welding .....	23
8.3.3.4	Thermal Compression Bonding .....	23
8.3.3.5	Solder Reflow .....	23
<b>9.0</b>	<b>Quality Assurance</b> .....	<b>23</b>
9.1	Quality Conformance Evaluations .....	24
9.2	Reliability .....	25

### **Figures**

Figure 1	Microwave Circuit Design Flowchart .....	4
Figure 6.1-1	Stripline .....	12
Figure 6.1-2	Cutaway View of Stripline .....	12
Figure 6.2-1	Cross-sectional view of microstrip line without metal cover .....	12
Figure 6.2-2	Cross-sectional view of microstrip line with metal cover .....	13
Figure 7-1	Comparison of Bilateral and True Position Tolerancing Methods .....	15
Figure 7-2	Straight Headless Pin (Solid) .....	16
Figure 7-3	Straight Headed Pin (Solid) .....	16
Figure 7-4	Roll Pin .....	16
Figure 8-1	Mounting a Surface Connector to a Buried Land .....	21
Figure 8-2	Alternative Mounting Method .....	22
Figure 9-1	Coupon Placement Recommendations .....	24
Figure 9-2	Test Coupons A and B .....	25
Figure 9-3	Test Coupon C, External Layers Only .....	25
Figure 9-4	Coupon E (Dielectric Withstanding Voltage, Moisture Assistance and Insulation Assistance) ..	26
Figure 9-5	Coupon F (Registration) .....	26

### **Tables**

Table 1	Typical Microwave Materials .....	6
Table 2	Typical Characteristics of Thermoplastic Bonding Films .....	8
Table 3	Characteristics of Thermoset Bonding Films .....	8
Table 4	Most Common Thin Copper Foils .....	9
Table 5	Thick metal Claddings .....	9
Table 6	Coupon Frequency Requirements .....	24

# Design Guide for Microwave Circuit Boards Utilizing Soft Substrates

## 1.0 General

**1.1 Purpose** The purpose of this document is to aid in the design of microwave circuit boards. This document is not intended to include information relating to the detailed electrical design of microwave circuits. Rather, it is intended to include information from which practical, functional, and cost-effective circuit boards may be designed once the design engineer has determined the circuit requirements. This design aid is to be used by microwave circuit design engineers, packaging engineers, and drafters. It is restricted to microwave circuit boards using substrates specified in IPC-L-125 (See section 5.0).

**1.2 Scope** This document addresses microwave circuitry. For the purpose of this document microwaves apply to radio waves in the frequency range of 100 MHz and to 30 GHz. The document also applies to operations in the region where distributed constant circuits enclosed by conducting boundaries are used instead of conventional lumped-constant circuit elements.

## 1.3 Terms and Definitions

**Anisotropy:** The condition for a substance having differing values for properties, such as permittivity, depending on the direction within the material. Isotropy describes the case where a property is the same in all directions. Isotropy may exist in non-crystalline homogeneous (single phase) substances. In a microwave laminate based on a polymer composite, anisotropy of the dielectric layer exists.

**Characteristic impedance ( $Z_0$ ):** For a uniform transmission line of any length, the ratio of inductance per unit length to capacitance per unit length. A 50 ohm characteristic impedance is often used because it matches that of most test instrumentation. When a signal propagating along a transmission line encounters a change in  $Z_0$ , scattering of the signal will occur, that is, some of the signal will be reflected backwards along the line.

**Coaxial Cable (coax):** A transmission line having a center conductor coaxial with an outside shield conductor of inside diameter larger than the center conductor and separated from it by dielectric.

**Coefficient of Thermal Expansion (CTE):** The ratio of dimensional change of a material to the dimension per degree of temperature change. Typically CTE values refer to linear dimensions in a particular direction such as the X, Y, Z

orthogonal axes where Z refers to the thickness direction and X to the planar direction of greatest orientation of a composite structure.

**Copper Weight:** The mass of copper per unit area for a foil. The copper foil industry typically expresses weight in ounces per square foot ( $\text{oz}/\text{ft}^2$ ). A copper foil weight of  $1 \text{ oz}/\text{ft}^2$  corresponds to a nominal  $34 \mu\text{m}$  thickness.

**Copper Thickness:** The thickness dimension of the copper cladding on a laminate.

**Cut-off Frequency:** Frequency of a transmission line at which modes other than TEM are generated. Also, in a low-pass or highpass filter it is the frequency where the response falls off by 3 dB.

**Dielectric:** An electrically insulating or non-conducting material. The properties of permittivity (dielectric constant) and loss tangent (loss factor or  $\tan \delta$ ) for such a material determine how it will alter an electromagnetic wave as it propagates through the material.

**Dielectric Thickness:** Dimension of the laminate excluding the thickness of the copper cladding.

**Directional coupler:** A device or structure which causes some of the energy propagating along one transmission line to be transferred to a second transmission line so that most of the transferred energy propagates in a specific direction along the second line. The other direction is considered isolated. At lower frequencies this function can be accomplished in a design with lumped capacitive and inductive elements while at microwave frequencies two stripline or microstrip traces that run parallel to each other for a certain distance can serve the purpose. One use for such devices is to sample amplitude or phase of a signal traveling in a specific direction.

**Directivity:** The difference between the isolation and the coupling values of a directional coupler.

**Dissipation Factor:** Also referred to as  $\tan \delta$ , the ratio of the energy dissipated in a material to the energy stored.

**Distributed Component:** A component whose parameters are distributed over an area of copper on a microwave laminate.

**Effective Permittivity (effective dielectric constant or  $K'_{\text{eff}}$ ):** The permittivity of a single dielectric medium, such as in coaxial line or stripline, that has the equivalent propagation velocity of a mixed media configuration, such as air and solid dielectric in microstrip.