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Design Guide for Microwave Circuit Boards Utilizing Soft Substrates

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2215 Sanders Road
Northbrook, Illinois
60062-6135

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

Table of Contents

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

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

9.0 Quality Assurance 23
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

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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_o): 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_o, 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 (oz/ft^2). A copper foil weight of 1 oz/ft^2 corresponds to a nominal 34 μm 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 lowpass 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 δ) 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 δ, 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'_{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.