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Sectional Design Standard for Flexible/Rigid-Flexible Printed Boards

Supersedes IPC-2223D

September 2016

An international standard developed by IPC

Association Connecting Electronics Industries



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IPC-2223E

Sectional Design Standard for Flexible/Rigid-Flexible Printed Boards

Developed by the Flexible Circuits Design Subcommittee (D-11) of the
Flexible Circuits Committee (D-10) of IPC

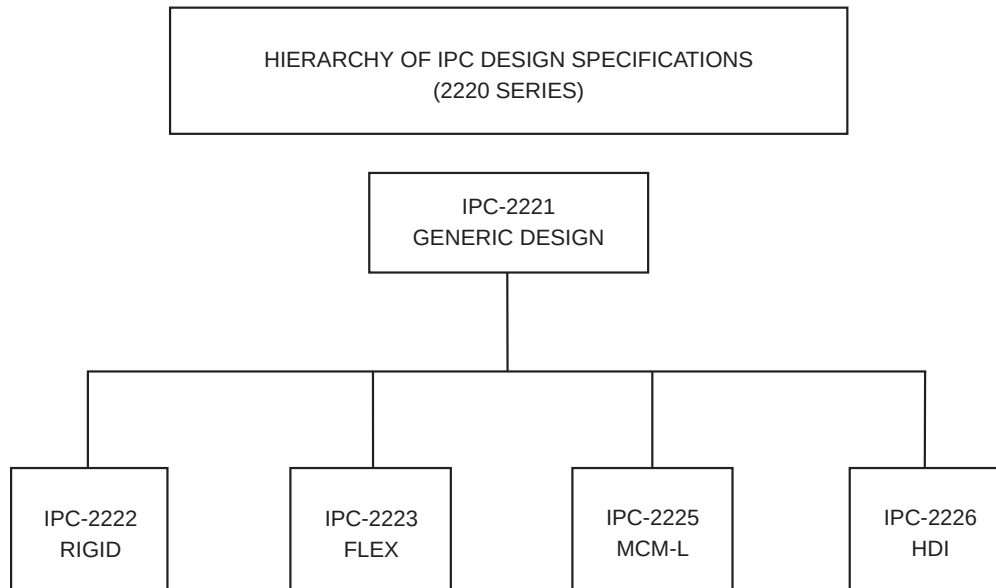
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Foreword

This standard is intended to provide information on the detailed requirements for flexible printed wiring design. All aspects and details of the design requirements are addressed in this sectional.

The information contained herein is intended to supplement generic design requirements identified in IPC-2221. This sectional standard, used in conjunction with IPC-2221, supersedes IPC-2223.

Benefits of Flex

Due to the thin films used in flexible circuitry, flex can save weight and space and conform to three-dimensional configurations.

Printed circuits in flex can be fanned out to allow the use of different connectors and folded to change orientation.

A number of flexible dielectrics are available (e.g., polyimide, polyester, polyetherimide), some of which can offer thermal stability, while others can be used in low cost applications.

The thermal stability of polyimide flexible circuits allows the use of through hole and or surface mount components. Polyester circuits can offer lower cost circuits with limited component usage. Polyester is typically used for low soldering temperature applications.

The flexibility of these circuits can allow movement for ease in installation and/or maintenance during use.

A combination of flexible circuitry and rigid PCB technology can be combined for improved packaging in confined spaces through interconnect elimination/simplification.

Acknowledgment

Any document involving a complex technology draws material from a vast number of sources across many continents. While the principal members of the Flexible Circuits Design Subcommittee (D-11) of the Flexible Circuits Committee (D-10) 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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Table of Contents

1 SCOPE	1	5 MECHANICAL AND PHYSICAL PROPERTIES	11
1.1 Purpose	1	5.1 Fabrication Requirements	11
1.2 Classification of Products	1	5.1.1 Bare Printed Board Fabrication	11
1.2.1 Printed Board Type	1	5.1.2 Roll to Roll Fabrication	11
1.2.2 Installation Uses	4	5.2 Product/Printed Board Configuration	12
1.3 Revision Level Changes	4	5.2.1 Circuit Profile (Outline)	12
2 APPLICABLE DOCUMENTS	4	5.2.2 Rigid Area Considerations	13
2.1 IPC	4	5.2.3 Flexible Areas	13
2.2 Joint Industry Standards	4	5.2.4 Preforming Bend	16
3 GENERAL REQUIREMENTS	5	5.2.5 Differential Lengths	17
3.1 Design Modeling	5	5.2.6 Shielding	21
3.2 Design Layout	5	5.2.7 Ground/Power Plane	21
3.2.1 Mechanical Layout Efficiency (Consider Final Panelization)	5	5.2.8 Stiffeners and Heat Sinks	21
3.2.2 Fabrication Drawing Recommendations	5	5.2.9 Strain Relief Fillet Guidelines for Flexible and Rigid-Flex Printed Boards	21
3.3 Schematic	5	5.3 Assembly Requirements	22
3.4 Test Requirement Considerations	6	5.3.1 Mechanical Considerations	22
3.4.1 Environmental	6	5.3.2 Array Sub-Pallets for Flexible and Rigid Printed Boards	22
3.4.2 Mechanical/Flexural	6	5.3.3 Single Part Sub-Pallets	22
4 MATERIALS	6	5.3.4 Non-Palletized Flexible and Rigid-Flex Printed Boards	22
4.1 Material Selection	6	5.3.5 Moisture	23
4.1.1 Material Options	7	5.3.6 Infrared Preheats and Reflow	23
4.2 Dielectric Materials (Including Prepreg and Adhesives)	7	5.3.7 Adhesive T _g	23
4.2.1 Preimpregnated Bonding Material (Prepreg)	7	5.4 Dimensioning	23
4.2.2 Adhesives (Liquid)	7	5.4.1 Datum Features	23
4.2.3 Flexible Adhesive Bonding Films (Cast Adhesive or Bondply)	7	6 ELECTRICAL PROPERTIES	23
4.2.4 Conductive Anisotropic Adhesives	7	6.1 Electrical Considerations	23
4.2.5 Cover Materials	8	6.2 Impedance and Capacitance Control	24
4.3 Conductive Materials (Surface Finishes)	9	6.2.1 Impedance Modeling Software	24
4.3.1 Electrolytic Copper Plating	9	6.2.2 Material Thickness and Stack Up	24
4.3.2 Nickel Plating	10	6.2.3 Conductor Pitch	24
4.3.3 Tin-Lead Plating	10	6.2.4 Narrow Conductors	24
4.3.4 Solder Coating	10	6.2.5 Differential Impedance	25
4.3.5 Other Metallic Coatings	11	6.2.6 Unbonded Flexible Impedance Controlled Layers ("Loose-leaf layers")	25
4.3.6 Electronic Component Materials (Buried Resistors and Capacitors)	11	6.2.7 Modifications to Shield Layers	26
4.3.7 Conductive Coatings for Shielding	11	6.2.8 Dielectric Constant Changes Over Frequency	27
4.4 Organic Protective Coatings	11	7 THERMAL MANAGEMENT	27
4.4.1 Solder Mask	11	8 COMPONENT AND ASSEMBLY ISSUES	27
4.4.2 Conformal Coating	11	8.1 General Placement Requirements	27
4.5 Marking and Legend	11	8.2 Standard Surface Mount Requirements	27

8.3	Lands for Surface Mounting	27	Figure 1-4	Type 2 Double-Sided Flexible Printed Board – Adhesiveless Substrate Construction	2
8.4	Constraints on Mounting to Flexible Sections ..	27	Figure 1-5	Type 3 Multilayer Flexible Printed Board – Adhesive Substrate Construction	2
8.5	Interfacial Connections	27	Figure 1-6	Type 3 Multilayer Flexible Printed Board – Adhesiveless Substrate Construction	2
8.6	Offset Lands	27	Figure 1-7	Type 4 Rigid-Flex Printed Board – Adhesive Substrate Construction	3
9	HOLES/INTERCONNECTIONS	28	Figure 1-8	Type 4 Rigid-Flex Printed Board – Adhesiveless Substrate Construction	3
9.1	General Requirements for Lands with Holes	28	Figure 1-9	Type 5 Flexible or Rigid-Flex Printed Board without PTHs – Adhesive Substrate Construction	3
9.1.1	Land Requirements	28	Figure 1-10	Type 5 Flexible or Rigid-Flex Printed Board without PTHs – Adhesiveless Substrate Construction	3
9.1.2	Annular Ring Requirements	28	Figure 3-1	Dimensional Modeling	5
9.1.3	Eyelet or Standoff Land Area Considerations ...	28	Figure 3-2	Final Panelization	5
9.1.4	Land Size for Non-Plated Component Holes ...	28	Figure 4-1	Flexible Cross-Sectional Construction Examples	6
9.1.5	Land Size for Plated-Through Component Holes	28	Figure 4-2	Unbonded Flex Cross-Sectional Construction of Rigid Flex	6
9.1.6	Thermal Relief in Conductor Planes	28	Figure 4-3	Plating for Adhesiveless Substrate Applications	10
9.1.7	Surface Mount Components	28	Figure 4-4	Selective Plating for Adhesive Substrate Applications	10
9.1.8	Nonfunctional Lands	28	Figure 5-1	Circuits Nested On a Panel	12
9.1.9	Land-to-Conductor Transition	29	Figure 5-2	Special Flexible Printed Board Features	12
9.1.10	Unsupported Edge Conductors/Fingers	29	Figure 5-3	Cutout with a Drilled Hole	12
9.2	Holes	36	Figure 5-4	Reinforcement Patch for Flex Area	12
9.2.1	Unsupported (Non-Plated) Component Holes ...	36	Figure 5-5	Slits and Slots	13
9.2.2	Plated Component Holes	36	Figure 5-6	Spacing of PTH from Rigid to Flex Interface	13
9.2.3	Copper Filled Vias	36	Figure 5-7	Reduced Bend Radii	14
9.2.4	Back-drilled Holes	36	Figure 5-8	Conductors in Bend Areas	14
9.3	Coverlay Access Openings	36	Figure 5-9	Bend/Crease Areas Center Lines	15
9.3.1	Coverlay Access, Unsupported Lands	36	Figure 5-10	Neutral Axis Ideal Construction	15
9.3.2	Coverlay Access, Holes	37	Figure 5-11	Definition of Bend Ratio	16
9.3.3	Coverlay Access Spacing	38	Figure 5-12	Irregular Folds	17
9.3.4	Land Access/Exposed Lands	38	Figure 5-13	Differential Printed Board Lengths	18
9.3.5	Type 1 Land Access, Opposite Sides	38	Figure 5-14	Differential Printed Board Lengths, Rigid-Flex	18
10	CONDUCTORS	38	Figure 5-15	Bookbinder	20
10.1	Conductor Characteristics	38	Figure 5-16	Staggered Flexible Layer Bands	20
10.1.1	Conductor Routing	38	Figure 5-17	Staggered Flexible Layer Bands	20
10.1.2	Conductor Edge Spacing	39	Figure 5-18	Typical Example of Copper Removal for Flexible Shielding	21
10.2	Land Characteristics	39	Figure 5-19	Stiffener Thickness Preferred in Order to Apply Strain Relief Fillet	21
10.3	Large Conductive Areas	39	Figure 5-20	Strain Relief	22
11	DOCUMENTATION	39	Figure 5-21	Rigid Rails for Single Part Sub-Pallets	22
12	QUALITY ASSURANCE	39	Figure 5-22	Establishing Datums	23
APPENDIX A	Design Tutorial	40	Figure 6-1	Adjustment to Dielectric Thickness between Rigid and Flexible Regions	23

Figures

Figure 1-1	Type 1 Single-Sided Flexible Printed Board – Adhesive Substrate Construction	1
Figure 1-2	Type 1 Single-Sided Flexible Printed Board – Adhesiveless Substrate Construction	1
Figure 1-3	Type 2 Double-Sided Flexible Printed Board – Adhesive Substrate Construction	2

Figure 6-2	Conductor Pitch for Differential Pairs	25	Figure 9-15	Bonding of Unsupported Fingers to Printed Board with Reinforcement	35
Figure 6-3	TDR Waveform for Type 2 Flexible Printed Board	25	Figure 9-16	Coverlay Access Openings and Exposed Unsupported Lands	37
Figure 6-4	Buckling of Unbonded Flexible Layers	26	Figure 9-17	Coverlay Access Opening for Unsupported Lands	37
Figure 6-5	Cross Hatching	26	Figure 9-18	Coverlay Access Openings and Exposed Supported Lands	38
Figure 9-1	Conductor to Land Transitions	28	Figure 10-1	Conductor Routing, Rigid-Flex Transition	38
Figure 9-2	Sculptured, Straight, Tapered Fingers	30	Figure A-1	Single Row ZIF Style Printed Board Contact Area	41
Figure 9-3	Sculptured, Formed for Surface Mount	30	Figure A-2	Dual Row ZIF Style Printed Board Contact Area	41
Figure 9-4	Sculptured, Formed for Through-Hole	30			
Figure 9-5	Straight Fingers for Lap Soldering to Printed Board	30			
Figure 9-6	Adhesive Squeeze Out Where Fingers Exit Insulation	33			
Figure 9-7	Laser Ablated Window	33			
Figure 9-8	Broken Fingers Resulting from Poor Handling	33			
Figure 9-9	Fingers Connected with a Foil Buss Bar	34			
Figure 9-10	Insulator Buss Bar with Notched Fingers	34			
Figure 9-11	Fingers Attached to a Support Bar	34			
Figure 9-12	Staggered Base/Coverlay Edges Used to Reduce Stress Points	34			
Figure 9-13	Sculptured Flex Showing the Foil Thickness Transition	35			
Figure 9-14	Fingers Brazed to Circuit Lands	35			

Tables

Table 4-1	Characteristics of Typical Flexible Dielectrics	8
Table 4-2	Minimum Average Copper Thickness, mm [in] ...	9
Table 9-1	Minimum Standard Fabrication Allowance for Interconnection Lands, mm [in]	28
Table 9-2	Nonfunctional Land Considerations	29
Table 9-3	Typical Foil Options for Designing for Flex Circuits with Unsupported Fingers	31
Table 9-3	Typical Foil Options for Designing for Flex Circuits with Unsupported Fingers (continued)	32
Table 9-4	Common Brazed Finger Options	35

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Sectional Design Standard for Flexible/ Rigid-Flexible Printed Boards

1 SCOPE

This standard establishes the specific requirements for the design of flexible and rigid-flexible printed board applications and its forms of component mounting and interconnecting structures. The flexible materials used in the structures are comprised of insulating films, reinforced and/or non-reinforced, dielectric in combination with metallic materials. These interconnecting boards may contain single, double, multilayer, or multiple conductive layers and can be comprised wholly of flex or a combination of both flex and rigid.

1.1 Purpose The requirements contained herein are intended to establish specific design details that **shall** be used in conjunction with IPC-2221 and may also be used in conjunction with IPC-2222 for the rigid sections of rigid-flex circuits.

1.2 Classification of Products Classification type and use of products **shall** be in accordance with IPC-2221 and as stated in 1.2.1 and 1.2.2.

1.2.1 Printed Board Type This standard provides design information for different flexible and rigid-flex printed board types. Printed board types are classified as:

Type 1 Single-sided flexible printed board containing one conductive layer, with or without stiffener, and constructed using an adhesive or adhesiveless substrate (see Figure 1-1 and Figure 1-2).

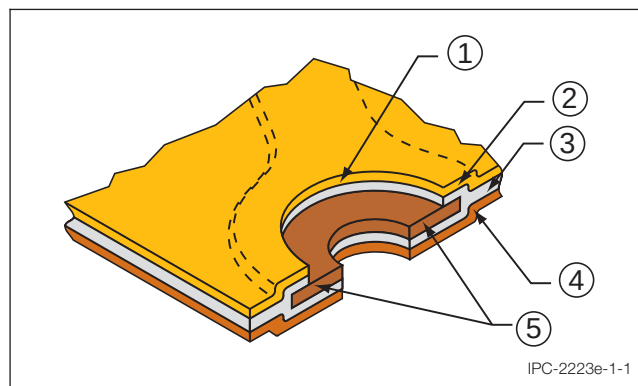


Figure 1-1 Type 1 Single-Sided Flexible Printed Board – Adhesive Substrate Construction

Note 1: Access Hole.

Note 2: Coverlay.

Note 3: Adhesive.

Note 4: Substrate.

Note 5: Copper Pad.

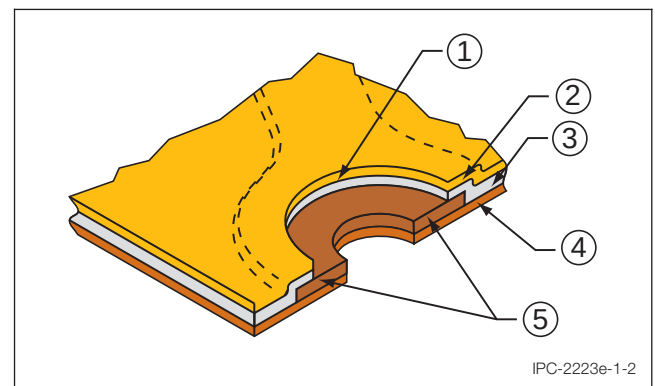


Figure 1-2 Type 1 Single-Sided Flexible Printed Board – Adhesiveless Substrate Construction

Note 1: Access Hole.

Note 2: Coverlay.

Note 3: Adhesive.

Note 4: Adhesiveless Substrate.

Note 5: Copper Pad.

Type 2 Double-sided flexible printed board containing two conductive layers with plated-through holes (PTHs), with or without stiffeners (see Figure 1-3 and Figure 1-4).

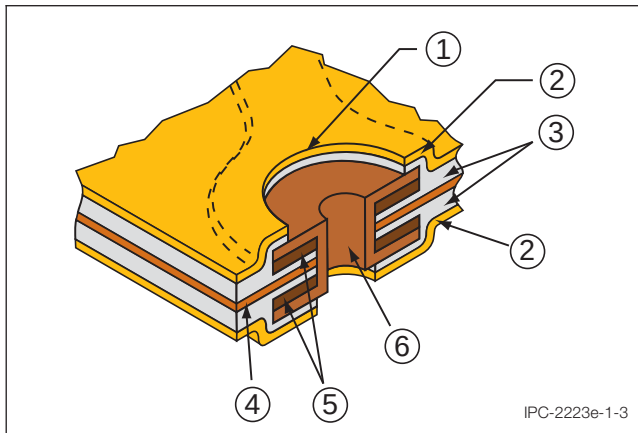


Figure 1-3 Type 2 Double-Sided Flexible Printed Board – Adhesive Substrate Construction

Note 1: Access Hole.

Note 2: Coverlay.

Note 3: Adhesive.

Note 4: Polyimide Substrate.

Note 5: Copper Pad.

Note 6: Copper PTH.

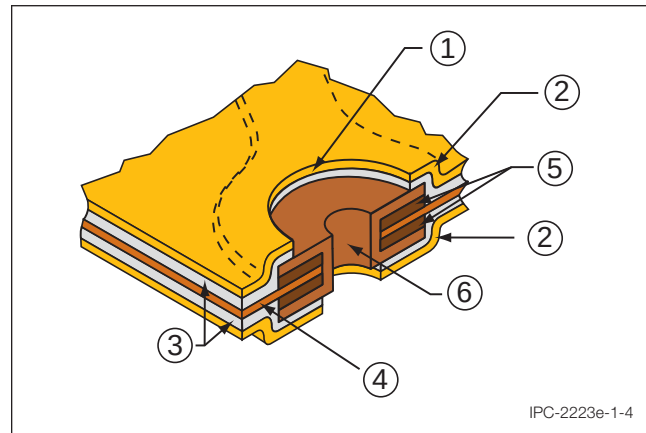


Figure 1-4 Type 2 Double-Sided Flexible Printed Board – Adhesiveless Substrate Construction

Note 1: Access Hole.

Note 2: Coverlay.

Note 3: Adhesive.

Note 4: Adhesiveless Substrate.

Note 5: Copper Pad.

Note 6: Copper PTH.

Type 3 Multilayer flexible printed board containing three or more conductive layers with PTHs, with or without stiffeners, and constructed using an adhesive or adhesiveless substrate (see Figure 1-5 and Figure 1-6).

Note: When using Type 3 constructions, the number of layers should be limited due to the high adhesive content of the flexible adhesive systems (see 4.2.4.1).

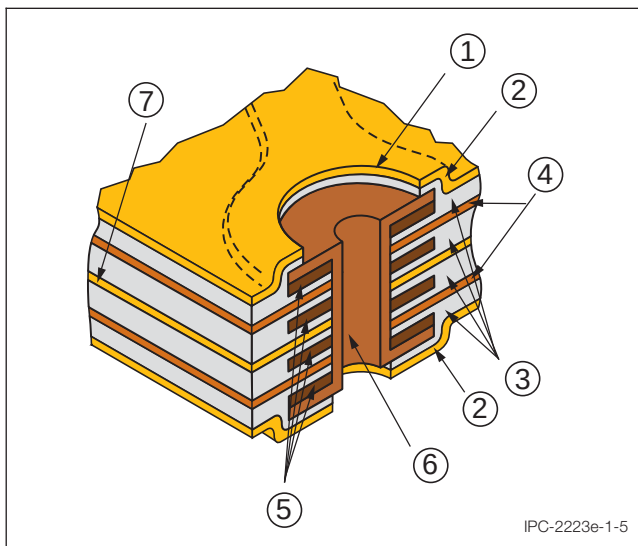


Figure 1-5 Type 3 Multilayer Flexible Printed Board – Adhesive Substrate Construction

Note 1: Access Hole.

Note 2: Coverlay.

Note 3: Adhesive.

Note 4: Polyimide Substrate.

Note 5: Copper Pad.

Note 6: Copper PTH.

Note 7: Bond Ply.

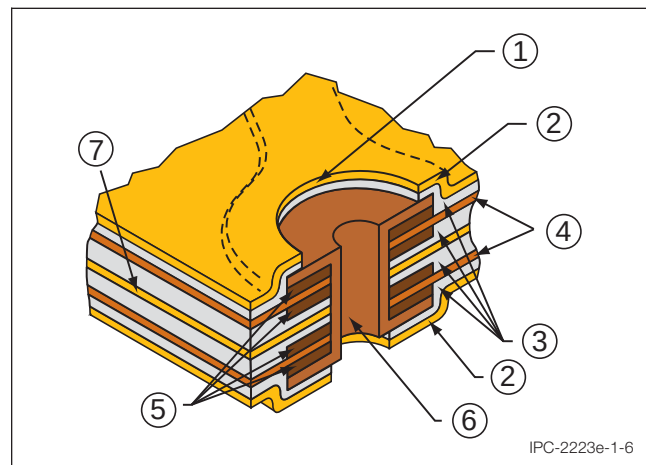


Figure 1-6 Type 3 Multilayer Flexible Printed Board – Adhesiveless Substrate Construction

Note 1: Access Hole.

Note 2: Coverlay.

Note 3: Adhesive.

Note 4: Adhesiveless Substrate.

Note 5: Copper Pad.

Note 6: Copper PTH.

Note 7: Bond Ply.

Type 4 Multilayer rigid and flexible material combinations containing three or more conductive layers with PTHs (see Figure 1-7 and Figure 1-8).

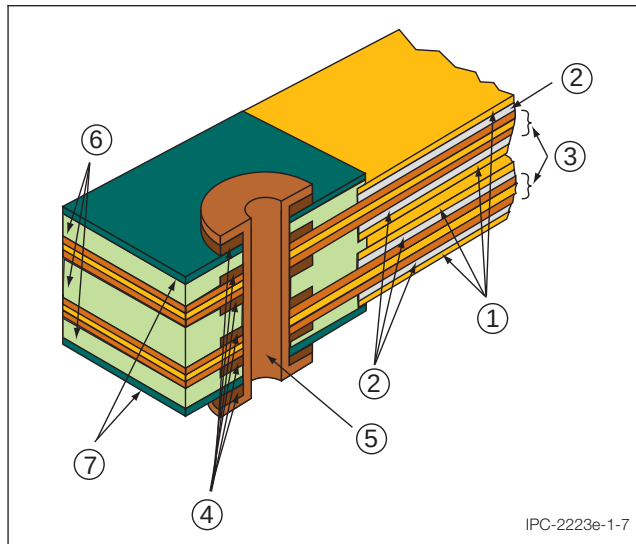


Figure 1-7 Type 4 Rigid-Flex Printed Board – Adhesive Substrate Construction

Note 1: Coverlay.

Note 2: Adhesive.

Note 3: Adhesive Based Substrate.

Note 4: Copper Pad.

Note 5: Copper PTH.

Note 6: Prepreg.

Note 7: Rigid Material.

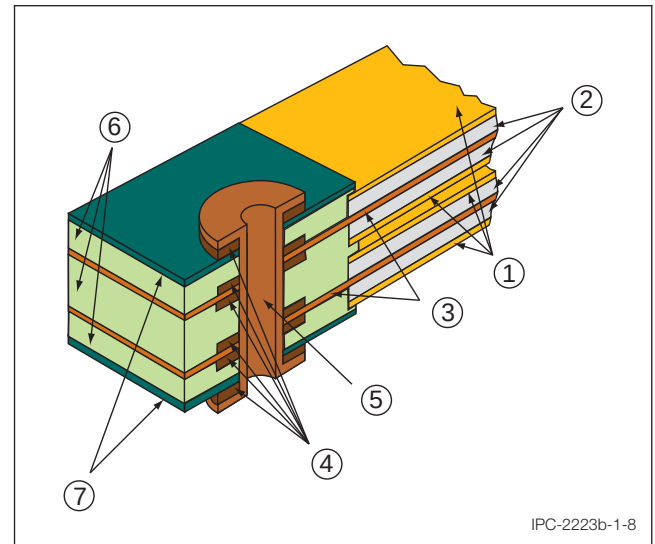


Figure 1-8 Type 4 Rigid-Flex Printed Board – Adhesiveless Substrate Construction

Note 1: Coverlay.

Note 2: Adhesive.

Note 3: Adhesiveless Substrate.

Note 4: Copper Pad.

Note 5: Copper PTH.

Note 6: Prepreg.

Note 7: Rigid Material.

Type 5 Flexible or rigid-flex printed board containing two or more conductive layers without PTHs (see Figure 1-9 and Figure 1-10)

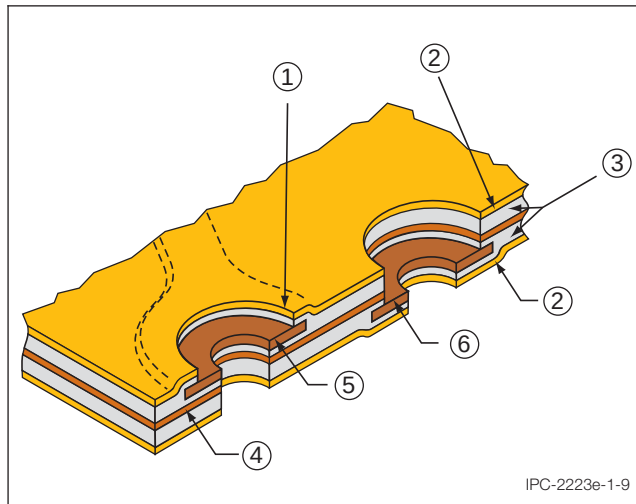


Figure 1-9 Type 5 Flexible or Rigid-Flex Printed Board without PTHs – Adhesive Substrate Construction

Note 1: Access Hole.

Note 2: Coverlay.

Note 3: Adhesive.

Note 4: Polyimide Substrate.

Note 5: Copper Pad (Layer #1).

Note 6: Copper Pad (Layer #2).

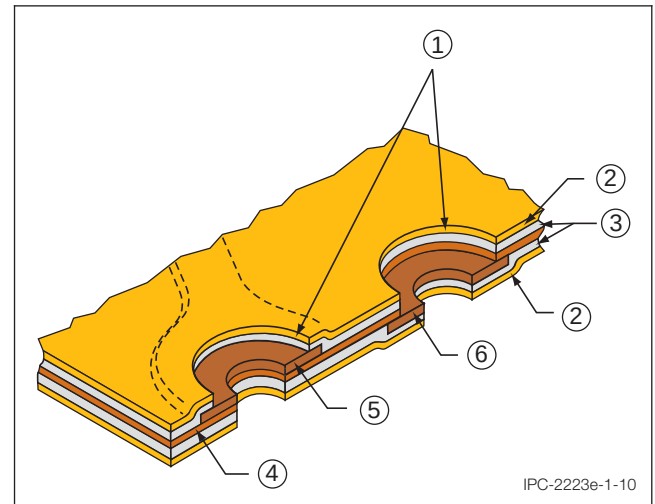


Figure 1-10 Type 5 Flexible or Rigid-Flex Printed Board without PTHs – Adhesiveless Substrate Construction

Note 1: Access Hole.

Note 2: Coverlay.

Note 3: Adhesive.

Note 4: Adhesiveless Substrate.

Note 5: Copper Pad (Layer #1).

Note 6: Copper Pad (Layer #2).

1.2.2 Installation Uses Flexible circuit designs are unique in each application; however; the following are some typical classes of use. It is recommended that the intended use be specified on the fabrication drawing. It may be necessary to define specific tests for design verification on the master drawing. These categories can be used individually or in a combination.

Use A Capable of withstanding flex during installation (flex-to-install). See 5.2.3.2

Use B Capable of withstanding continuous flexing for the number of cycles as specified on the master drawing (dynamic flex). See 5.2.3.2

Use C High temperature environment (over 105 °C [221 °F])

Use D UL recognition

1.3 Revision Level Changes Changes made to this revision of the IPC-2223 are indicated throughout by gray-shading of the relevant subsection(s). Changes to a figure or table are indicated by gray-shading of the figure or table header.

2 APPLICABLE DOCUMENTS

The following documents form a part of this standard to the extent specified herein. If a conflict of requirements exist between IPC-2223 and those listed in 2.1, IPC-2223 takes precedence. The revision of the document in effect at the time of solicitation **shall** take precedence.

2.1 IPC¹

IPC-TM-650 Test Methods Manual²

2.4.18.1 Tensile Strength and Elongation, In-House Plating

IPC-HDBK-840 Solder Mask Handbook

IPC-SM-840 Qualification and Performance Specification of Permanent Solder Mask and Flexible Cover Materials

IPC-2152 Standard for Determining Current Carrying Capacity in Printed Board Design

IPC-2221 Generic Standard on Printed Board Design

IPC-2222 Sectional Design Standard for Rigid Printed Boards

IPC-2226 Sectional Design Standard for High Density Interconnect (HDI) Printed Boards

IPC-2615 Printed Board Dimensions and Tolerances

IPC-4101 Specification for Base Materials for Rigid or Multilayer Printed Boards

IPC-4202 Flexible Bare Dielectrics for use in Flexible Printed Wiring

IPC-4203 Adhesive Coated Dielectric Films for Use as Cover Sheets for Flexible Printed Wiring and Flexible Bonding Films

IPC-4204 Metal Clad Flexible Dielectrics for Use in Fabrication of Flexible Printed Wiring

IPC-4562 Metal Foil for Printed Wiring Applications

IPC-7351 Generic Requirements for Surface Mount Design and Land Pattern Standard

2.2 Joint Industry Standards³

J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies

1. www.ipc.org.

2. Current and revised IPC Test Methods are available on the IPC Web site (www.ipc.org/html/testmethods.html).

3. www.ipc.org.

3 GENERAL REQUIREMENTS

General requirements **shall** be in accordance with IPC-2221 and as recommended in 3.1 through 3.4.2.

3.1 Design Modeling The design cycle should include full-sized three dimensional modeling of the design to ensure correct dimensioning and layout of flexible and rigid circuit areas (see Figure 3-1). It is recommended that physical mockups of the design be fabricated to evaluate stiffness, flexibility, fit or other properties before releasing the design for fabrication.

3.2 Design Layout The circuit layout depicts the physical size, flexible section, and location of all electronic and mechanical components, and incorporates the electrical schematic, and the electrical requirements (e.g., impedance, amperage, voltage) to allow preparation of documentation and artwork.

Design activity should work closely with manufacturer to optimize producibility as early in the design process as possible.

3.2.1 Mechanical Layout Efficiency (Consider Final Panelization) Because flex designs may take a variety of shapes, it is recommended that the designer consider the use of folding to accomplish efficient panelization (see Figure 3-2). Layout efficiency is important because of the benefits in reduced processing cost and material usage. However, these savings can be offset by the labor required for the folding in the final assembly. Each fold will change the coverlay access opening orientation of the single-sided flexible circuit.

To achieve panel efficiency, consideration should be given to alternative interconnections such as discrete wiring. In many cases, it is possible to eliminate costly or lengthy flex extensions by the simple attachment of wiring or cable.

3.2.2 Fabrication Drawing Recommendations Separate views showing an installed flex configuration should be added to the fabrication drawing. The intent is to provide the fabricator with the locations of the critical areas that are to be folded or flexed.

Application specific requirements not covered in this standard **shall** be specified on the procurement documentation. Drawings should contain a detailed list and description of the materials contained in the flex construction (e.g., materials stack-up, finished copper weight of each copper layer, reinforced/stiffened areas and critical thickness areas). A cross-sectional view is recommended. Critical thickness areas (and measurement location) should be clearly defined. Critical bend radius locations should be identified with reference dimensions.

3.3 Schematic Pin out considerations should be considered early in the design to avoid complicated and costly crossovers in the flex connectivity. Pin out considerations can reduce layers and therefore reduce cost.

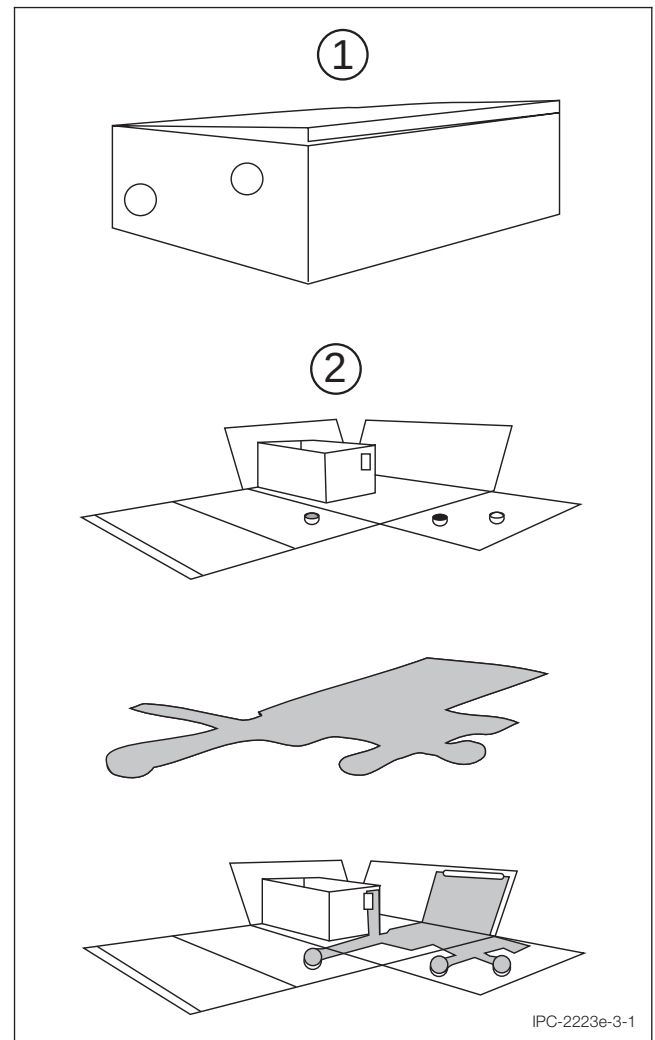


Figure 3-1 Dimensional Modeling

Note 1: Prepare a model of the package to be wired.

Note 2: Determine component layout.

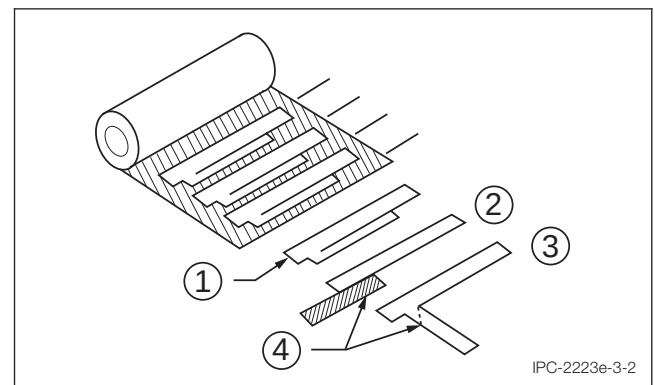


Figure 3-2 Final Panelization

Note 1: Cut out.

Note 2: First fold.

Note 3: Second fold (final configuration).

Note 4: Folded.

3.4 Test Requirement Considerations Electrical testing for flex circuits may include connectors and components. Specifications need to be given to the fabricator as to the electrical requirements of the end product. Design requirements for test considerations should be in accordance with IPC-2221.

Flex/Rigid-flex printed boards have some different/unique test considerations. Examples include:

- Fixturing – Because of the flexibility, tooling holes may be used to obtain stability during test
- Staying on grid is not a requirement
- Overlapping appendages – Areas of boards might be inaccessible by a bed of nails tester when folded
- Variable thicknesses among flex and rigid areas

Note: Flexible area thicknesses are often not specified.

3.4.1 Environmental The end use environment should be considered during design and material selection.

3.4.2 Mechanical/Flexural To evaluate flex life, it is recommended that flexural testing be done in a manner that reflects intended end product use.

Note: Materials with a high modulus have better dimensional stability than those with a lower modulus, though there is a trade-off in that the higher modulus materials have a relatively lower flex life.

4 MATERIALS

4.1 Material Selection Material type and construction is extremely important in designing flexible printed boards. Care should be taken in material selection to ensure compatibility with adjacent materials. All materials **shall** be specified on the master drawing. For clarification, it is suggested that cross-sectional views be used to highlight material selection. Examples of this are shown in Figure 4-1 and Figure 4-2.

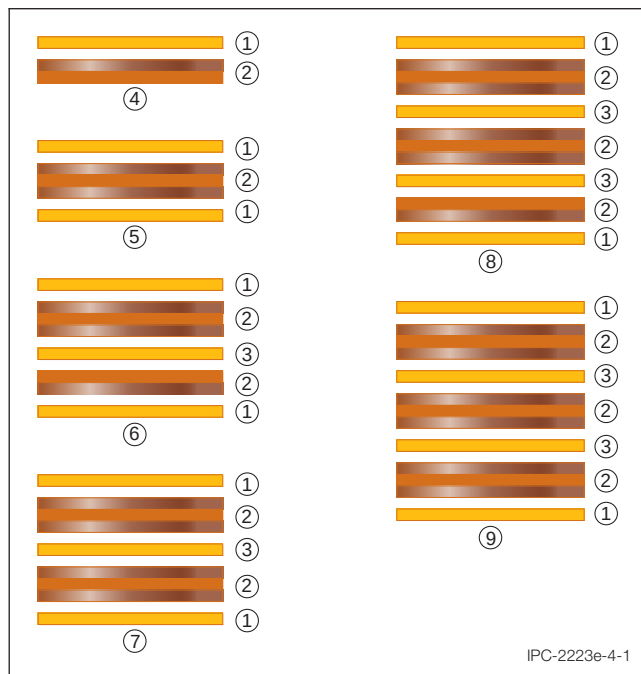


Figure 4-1 Flexible Cross-Sectional Construction Examples

Note 1: Coverlay.

Note 2: Flex laminate.

Note 3: Bond ply.

Note 4: Type 1, single-sided construction.

Note 5: Type 2, double-sided construction.

Note 6: Type 3, three layer construction.

Note 7: Type 3, four layer construction.

Note 8: Type 3, five layer construction.

Note 9: Type 3, six layer construction.

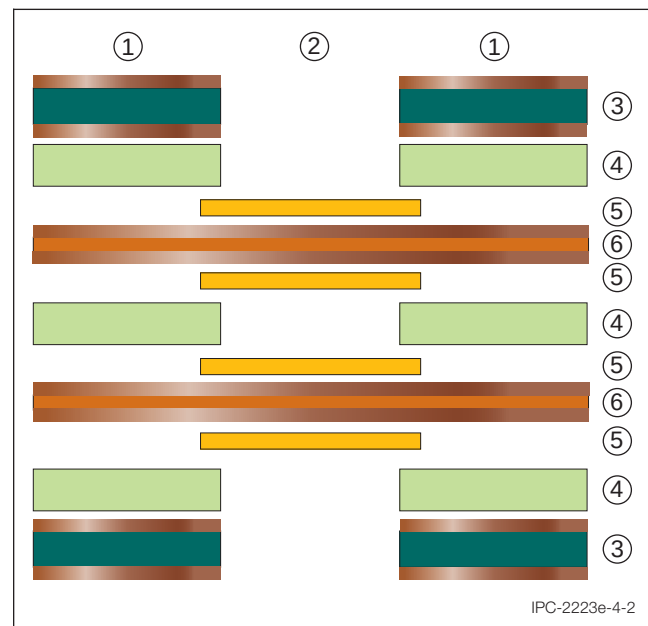


Figure 4-2 Unbonded Flex Cross-Sectional Construction of Rigid Flex

Note 1: Rigid area. Rigid areas should overlap the flexible polyimide coverlay within the flex area.

Note 2: Flex area.

Note 3: Rigid laminate.

Note 4: Pre-preg.

Note 5: Flexible polyimide coverlay.

Note 6: Adhesiveless flexible polyimide laminate. Adhesiveless constructions should be used to increase flexibility and decrease Z-axis problems within the rigid areas (see 5.2.2.2).

For Type 4 (rigid-flex) constructions, in the areas where prepreg is used to define the rigid areas, the use of rigid laminate is not necessary.

4.1.1 Material Options At the fabricator's option, flexible metal clad dielectrics and adhesive coated dielectric films may be manufactured using individual components per IPC-4562, IPC-4202, and IPC-4203. In addition, materials per IPC-4204 and IPC-4203 may be substituted where individual components are specified. These documents group materials into slash sheets that are generic in nature. This means that materials meeting the minimum requirements have widely different typical properties. It is important to research the various products to choose the one best meeting the design requirements. The attributes that should be considered are:

- Moisture absorption
- Fire retardancy
- Electrical properties
- Mechanical properties
- Thermal properties

Example: The dimensional stability of IPC-4204/1 states a maximum value of 0.20% for Method "B." Some manufacturers of IPC-4204/1 may produce material with a dimensional stability of 0.05% or better. Therefore it is recommended to consult the manufacturer if specific attributes are required that exceed the stated minimum or maximum value. Many attributes are also gauge (thickness) dependent. Where possible the slash sheets define a specific value for different gauges, i.e., Peel Strength.

The designer and fabricator should concurrently review material selection for cost, performance, and producibility.

4.2 Dielectric Materials (Including Prepreg and Adhesives)

4.2.1 Preimpregnated Bonding Material (Prepreg) Prepregs are used in the fabrication of rigid-flexible printed boards. "No-flow" and "low-flow" types are typically used in the bonding of the rigid sections. The higher glass transition temperature (T_g) materials used in these prepregs offer higher operating temperatures and lower Z-axis expansion coefficient, which directly affect PTH reliability for ≥ 8 layers (see 5.2.2.2). Disadvantages of using these materials include lower dielectric strength and reduced flexibility.

When preimpregnated bonding materials are used on flexible and rigid-flex printed boards, the material **shall** be in accordance with IPC-4101. The areas that require adhesive and those to be free of adhesive **shall** be defined on the master drawing.

4.2.2 Adhesives (Liquid) Adhesives such as flexible epoxy, acrylic, RTV silicone or polysulfide can be used to provide strain relief/fillet at rigid-flex transition areas or at the transition of Type 1, Type 2 and Type 3 printed boards with partial stiffeners (see 5.2.8). These materials may be a potential out-gassing issue for specific applications.

4.2.3 Flexible Adhesive Bonding Films (Cast Adhesive or Bondply) Flexible adhesive bonding films are typically used in bonding multiple flexible layers and attachments used for thermal management or structural support. These materials offer high bond strength to the flexible dielectric. These bonding films may be formulated from low T_g resins to enhance adhesion and flexibility. In rigid-flex designs, these materials should be minimized or removed from the rigid sections to eliminate the problem of excessive Z-axis expansion.

When flexible adhesive bonding films are used on flexible and rigid-flex printed boards, the material **shall** be in accordance with IPC-4203. The areas that require adhesive and those to be free of adhesive **shall** be defined on the master drawing.

4.2.4 Conductive Anisotropic Adhesives Adhesives of this type can be used to bond multiple layers/printed boards (rigid and flexible) and provide an electrical and mechanical connection between vertically adjacent pads. The lateral conductivity of these adhesives is low and can maintain electrical isolation of laterally adjacent pads. The products are supplied in film form.

4.2.4.1 Flexible Metal Clad Dielectrics (Flexible Substrate Materials) These materials are combinations of dielectric films and metallic foils. The foils can be attached to the dielectric by several means (i.e., adhesive resins or by direct deposition). The dielectric can be cast onto the metallic foil. The cast dielectric laminates and direct deposition materials

called adhesiveless substrates. The traditional laminate configuration is constructed via the use of adhesive resin to bond the dielectric film to the metal foil. The T_g of these adhesive resins is usually lower than the dielectric film. High layer rigid-flex designs are currently employing adhesiveless substrates to minimize the impact of the low T_g adhesives (see Table 4-1). As such it is recommended to avoid adhesive based substrates in all Type 4 constructions or high temperature applications (Use C), and also in Type 3 constructions where the layer count exceeds eight layers. Flexible metal clad substrates **shall** be in accordance with IPC-4204 or combinations of IPC-4562, IPC-4202, and IPC-4203.

Table 4-1 Characteristics of Typical Flexible Dielectrics¹

	Polyester (with Adhesive)	Polyimide (with Adhesive)	Polyimide (Adhesiveless)
MECHANICAL			
Flexing (R ~ 2.0 mm [0.079 i])	FAIR	GOOD	EXCELLENT
Thermal Forming	GOOD	GOOD	FAIR
Modulus	2800 – 5500 Mpa	2500 Mpa	4000 Mpa
Tear Strength	800 g	500 g	500 g
Peel Strength (Ambient)	1050 N/M	1750 N/M	1225 N/M
CHEMICAL/ENVIRONMENTAL			
Caustic (>20%)	EXCELLENT	POOR	GOOD
UV	POOR – PET FAIR – PEN	GOOD	EXCELLENT
UL Recognition/Maximum Operating Temperature	PET ² , 85 °C PEN ³ , 160 °C	85 – 160 °C	105 – 220 °C
Flame Retardancy	VTM-0 with FR Adhesive	VTM-0 with FR Adhesive	VTM-0
ELECTRICAL			
Dielectric Constant (1 MHz)	3.4	3.5	3.3
Dielectric Strength	4-5 Kv/25 µm	3-5 Kv/25 µm	5 Kv/25 µm
Insulation Resistance	10 ³ Ω-cm	10 ³ Ω-cm	10 ³ Ω-cm
THERMAL			
Solder Processing	5 sec @ 205 °C	5 sec @ 288 °C (Predry Req.)	10 sec @ 288 °C (No Predry)
ASSEMBLY			
Through Hole	LIMITED	EXCELLENT	EXCELLENT
Surface Mount (IR Reflow)	PEN, YES PET, NO	GOOD TO EXCELLENT	EXCELLENT
Wire Bonding	NO	SOME ADH. ARE OK	EXCELLENT
Chip (Direct Attach)	POOR	FAIR TO EXCELLENT	EXCELLENT

Note 1. The stated values are typical and will vary among different material suppliers. Consult the laminate manufacturer utilized by the fabricator for specific values.

Note 2. Polyethylene terephthalate.

Note 3. Polyethylene naphthalate.

4.2.4.2 Rigid Metal Clad Laminate Materials These laminate materials are combinations of metallic foils, resins, and woven or non-woven reinforcements. Resins used in these laminates offer a wide range of T_g (see IPC-2221 and IPC-4101).

4.2.5 Cover Materials Cover material is a generic term applied to thin dielectrics that are used to encapsulate circuitry, most commonly for flexible circuit applications. There are three types of cover materials, including coverlay, coverfilm and covercoat.

4.2.5.1 Coverlay The coverlay is a combination of applied film and integral adhesive made from separate layers of generically different chemistries that subsequently becomes a permanent flexible dielectric coating. The coverlay is used to insulate/isolate the conductor layers on the surface of a flexible printed board. The coverlay is constructed of materials that can be flexed or formed in the intended use. The coverlay has access holes/windows to expose lands, PTHs and mounting holes. See IPC-4202, IPC-4203 and IPC-4204 for additional guidance.